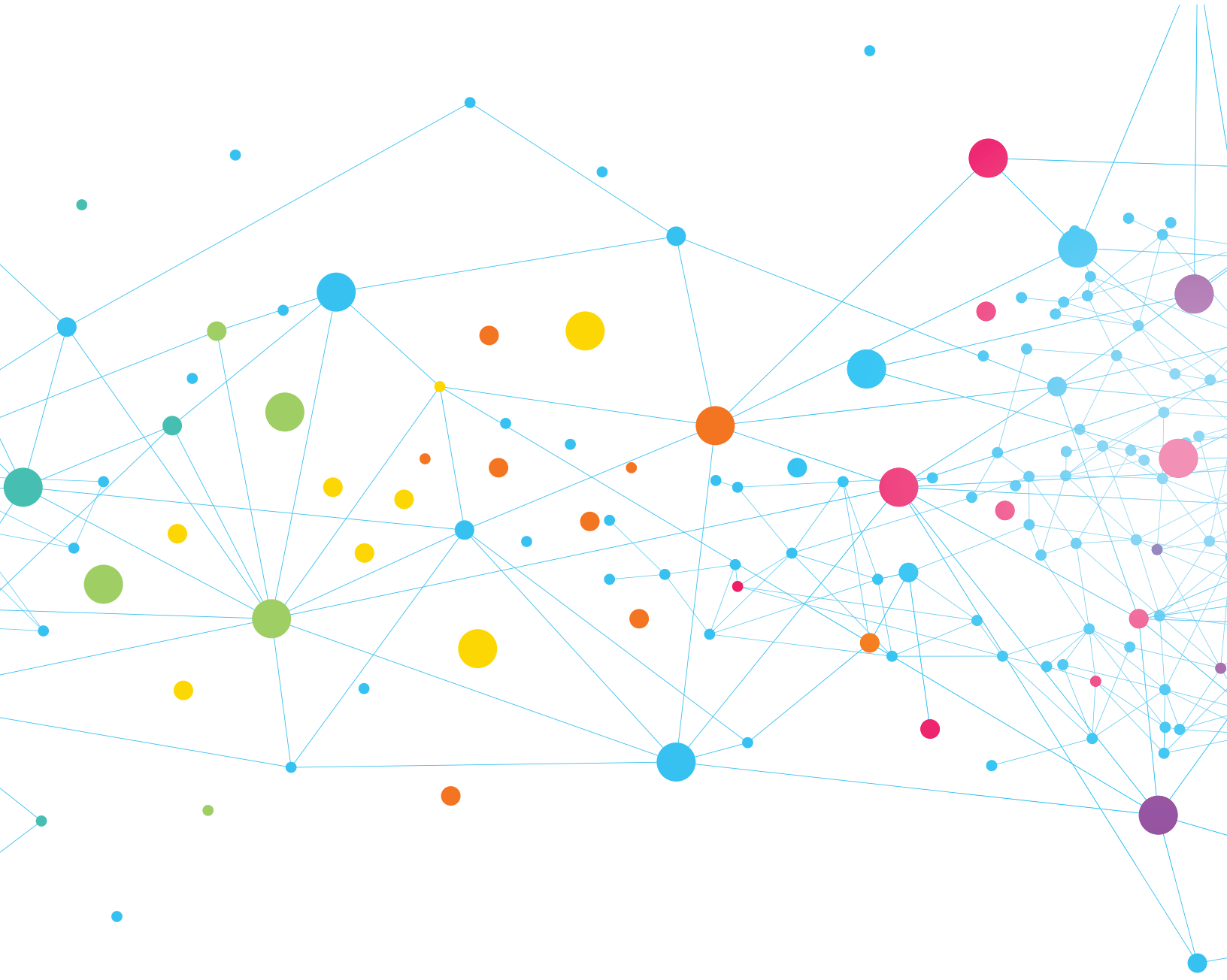
DEFINING DIGITAL DENTISTRY

A Survey of Recent Literature

ACP
AMERICAN COLLEGE OF PROSTHODONTISTS



Journal of Prosthodontics
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IJP The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Journal of Dentistry

Introduction & Acknowledgements

AMERICAN COLLEGE OF PROSTHODONTISTS

The American College of Prosthodontists (ACP) has embraced the task of building the core foundational knowledge for digital dentistry. This effort grew from surveys of our membership, professional news, and industry discussions. With the generous support of Henry Schein, the ACP Education Foundation (ACPEF) has powered this effort with tireless effort of a volunteer taskforce including our Digital Curriculum Content Committee that made this update possible. Along the way to building a digital curriculum that can serve the broader discipline of prosthodontics and dentistry in general, we have assimilated much of the emerging information about digital dentistry. One source of our information is the peer-reviewed literature. Here, we have compiled a representative sampling of this literature in published abstract form with links to the publishing journal. With the generous support of the respective editors, these abstracts cover an intentionally broad range of topics that include investigations of intraoral and extraoral scanning accuracy, CBCT technology, the CAD/CAM milling of restorations, guided implant surgery, complete denture methodologies, removable partial denture techniques, and applications to maxillofacial prosthetics. This collection, while not intended to be complete, offers the reader the opportunity to view the spectrum of digital technologies influencing prosthodontics in 2019. This compilation is not a complete collection of published literature; however, is a peer-reviewed selection of abstracts. Mid-course along our path to delivering a curriculum for digital dentistry to the prosthodontic specialty and more broadly to the profession, please join our task force in taking a moment to absorb the outstanding science representing the latest in the exponentially evolving field of digital dentistry. On behalf of the ACPEF Digital Dentistry Curriculum Development Team of 49 individuals from 29 academic institutions, including general dentists and prosthodontists from around the country, we are pleased to present this unique compilation as a timely reference.

ACP Digital Dentistry Curriculum Development Task Force

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Thank you to the ACP Digital Dentistry Curriculum Content Committee for its efforts to ensure the latest updates are included in the Survey of Recent Literature.

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Thank you to the leadership of Henry Schein for an unrestricted grant to support the efforts of the ACPEF.

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Computer-aided technology for fabricating complete dentures: systematic review of historical background, current status, and future perspectives

Bidra AS, Taylor TD, Agar JR
J Prosthet Dent 2013;109:361-366

Computer-aided technology is an emerging method for fabricating complete dentures. Consolidated information about historical background, current status, and scope for the future is lacking.

The purpose of this systematic review was to analyze the existing literature on computer-aided technology for fabricating complete dentures and provide the reader with a historical background, current status, and future perspectives on this emerging technology.

An electronic search of the English language literature between the periods of January 1957 and June 2012 was performed by using PubMed/MEDLINE with the following specific search terms: CAD-CAM complete dentures, digital complete dentures, computer dentures, designed dentures, machined dentures, manufactured dentures, milled dentures, and rapid prototyping dentures. Additionally, the search terms were used on the Google search engine to identify current commercial manufacturers and their protocols.

A total of 1584 English language titles were obtained from the electronic database, and the systematic application of exclusion criteria resulted in the identification of 8 articles pertaining to computer-aided technology for complete dentures. Since the first published report in 1994, multiple authors have described different theoretical models and protocols for fabricating complete dentures with computer-aided technology. Although no clinical trials or clinical reports were identified in the scientific literature, the Google search engine identified 2 commercial manufacturers in the United States currently fabricating complete dentures with computer-aided design and computer-aided manufacturing (CAD/CAM) technology for clinicians world-wide. These manufacturers have definitive protocols in place and offer exclusive dental materials, techniques, and laboratory support. Their protocols contrast with conventional paradigms for fabricating complete dentures and allow the fabrication of complete dentures in 2 clinical appointments.

A body of scientific literature related to computer-aided technology for complete dentures is emerging. Significant advancements in this technology have now resulted in their commercial availability with shorter clinical protocols. However, prospective clinical trials with true clinical endpoints are necessary to validate this technology. This could affect dental education, patient care, research, and public health worldwide.

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Marginal adaptation of ceramic crowns: a systematic review

Contrepois M, Soenen A, Bartala M, Laviole O
J Prosthet Dent 2013;110:447-454.e10

STATEMENT OF PROBLEM: After the development of a variety of ceramic restorative systems over the past 20 years, the fabrication of fixed dental prostheses has undergone considerable change. Esthetics and resistance to fracture are two of the main determinants of the success of a restoration; the third is marginal adaptation. Therefore, a systematic review of the literature dedicated to the marginal accuracy of ceramic systems is indicated.

PURPOSE: This study reviewed the current scientific literature that pertains to the marginal fit of ceramic crowns fabricated with different systems and investigated the factors that influence marginal adaptation.

MATERIAL AND METHODS: An electronic search was completed by using the PubMed and Scopus databases with the following combination of key words: (discrepancy or fit or gaps or adaptation) and (disilicate or ceramic) and (copings or crowns). The search was limited to English-language peer-reviewed articles published before April 15, 2012. Titles and abstracts were read to identify articles that fulfilled the inclusion criteria designed for this review.

RESULTS: Of 469 studies identified, 54 satisfied the selection criteria and were included in this review. All were published between 1994 and 2012. A total of 17 ceramic systems were tested in 48 in vitro and 6 in vivo studies. Of all the marginal gaps measured, 94.9% were in the range of clinical acceptability. Study heterogeneity made it impossible to conduct a proper meta-analysis of research findings and to compare and rank the various systems in terms of marginal fit. Four parameters were found to influence marginal adaptation: finish line configuration, value of the predefined cementing space, veneering process, and cementation.

CONCLUSIONS: The systems evaluated in the selected articles generally provide a clinically acceptable marginal fit. The current state of research does not allow for a proper comparison of the various systems in terms of marginal fit. The use of computer x-ray microtomography is recommended for further research on marginal adaptation.

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Intraoral digital impression technique: A review

Ting-Shu S, Jian S
J Prosthodont 2015 Jun;24 :313-321. PMID: 25220390

With the techniques of computer-aided design and computer-aided manufacturing (CAD/CAM) being applied in the field of prosthodontics, a concept of intraoral digital impressions was put forward in the early 1980s. It has drawn comprehensive attention from dentists and has been used for dental prosthesis fabrication in a number of cases. This new digital impression technique is expected to bring about absolute digitization to the mode of prosthodontics. A few published articles have indicated that dental prostheses fabricated from intraoral digital impressions have exhibited remarkable advantages over those from conventional impressions in several respects. The present review discusses intraoral digital impression techniques in terms of the following aspects: categories and principles of intraoral digital impression devices currently available; operating characteristics of the devices; and comparison of the manipulation, accuracy, and repeatability between intraoral digital impression and conventional impression.

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Digital versus conventional impressions for fixed prosthodontics: A systematic review and meta-analysis

Chochlidakis K, Papaspyridakos P, Geminiani A, Chen C, Feng I, Ercoli C
J Prosthet Dent 2016;116:184-190

STATEMENT OF PROBLEM: Limited evidence is available for the marginal and internal fit of fixed dental restorations fabricated with digital impressions compared with those fabricated with conventional impressions.

PURPOSE: The purpose of this systematic review was to compare marginal and internal fit of fixed dental restorations fabricated with digital techniques to those fabricated using conventional impression techniques and to determine the effect of different variables on the accuracy of fit.

MATERIAL AND METHODS: Medline, Cochrane, and EMBASE databases were electronically searched and enriched by hand searches. Studies evaluating the fit of fixed dental restorations fabricated with digital and conventional impression techniques were identified. Pooled data were statistically analyzed, and factors affecting the accuracy of fit were identified, and their impact on accuracy of fit outcomes were assessed.

RESULTS: Dental restorations fabricated with digital impression techniques exhibited similar marginal misfit to those fabricated with conventional impression techniques ($P>.05$). Both marginal and internal discrepancies were greater for stone die casts, whereas digital dies produced restorations with the smallest discrepancies ($P<.05$). When a digital impression was used to generate stereolithographic (SLA)/polyurethane dies, misfit values were intermediate. The fabrication technique, the type of restoration, and the impression material had no effect on misfit values ($P>.05$), whereas die and restoration materials were statistically associated ($P<.05$).

CONCLUSIONS: Although conclusions were based mainly on in vitro studies, the digital impression technique provided better marginal and internal fit of fixed restorations than conventional techniques did.

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Evaluation of the marginal fit of single-unit, complete-coverage ceramic restorations fabricated after digital and conventional impressions: A systematic review and meta-analysis

Tsirogiannis P, Reissmann D, Heydecke G
J Prosthet Dent 2016;116:328-335

STATEMENT OF PROBLEM: In existing published reports, some studies indicate the superiority of digital impression systems in terms of the marginal accuracy of ceramic restorations, whereas others show that the conventional method provides restorations with better marginal fit than fully digital fabrication. Which impression method provides the lowest mean values for marginal adaptation is inconclusive. The findings from those studies cannot be easily generalized, and in vivo studies that could provide valid and meaningful information are limited in the existing publications.

PURPOSE: The purpose of this study was to systematically review existing reports and evaluate the marginal fit of ceramic single-tooth restorations after either digital or conventional impression methods by combining the available evidence in a meta-analysis.

MATERIAL AND METHODS: The search strategy for this systematic review of the publications was based on a Population, Intervention, Comparison, and Outcome (PICO) framework. For the statistical analysis, the mean marginal fit values of each study were extracted and categorized according to the impression method to calculate the mean value, together with the 95% confidence intervals (CI) of each category, and to evaluate the impact of each impression method on the marginal adaptation by comparing digital and conventional techniques separately for in vitro and in vivo studies.

RESULTS: Twelve studies were included in the meta-analysis from the 63 identified records after database searching. For the in vitro studies, where ceramic restorations were fabricated after conventional impressions, the mean value of the marginal fit was 58.9 mm (95% CI: 41.1-76.7 mm), whereas after digital impressions, it was 63.3 mm (95% CI: 50.5-76.0 mm). In the in vivo studies, the mean marginal discrepancy of the restorations after digital impressions was 56.1 mm (95% CI: 46.3-65.8 mm), whereas after conventional impressions, it was 79.2 mm (95% CI: 59.6-98.9 mm)

CONCLUSION: No significant difference was observed regarding the marginal discrepancy of single-unit ceramic restorations fabricated after digital or conventional impressions.

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An update on computer-engineered complete dentures: A systematic review on clinical outcomes

Kattadiyil MT, AlHelal A
J Prosthet Dent 2017;117:478-485

STATEMENT OF PROBLEM: Reports on computer-engineered complete dentures (CECDs) continue to increase. Systematic reviews on clinical outcomes and applications associated with CECDs are lacking in the literature.

PURPOSE: The purpose of this systematic review was to determine the clinical outcomes and applications of CECDs.

MATERIAL AND METHODS: Electronic searches of the English literature from January 1984 to May 2016 were performed in MEDLINE and Cochrane databases, with the results enriched by hand searches and citation mining to address 2 relevant population intervention comparison outcome (PICO) questions: What are the clinical outcomes associated with CECDs? Are there specific applications and significant advantages for CECDs?

RESULTS: A review of the selected articles on CECDs revealed significantly better retention and reduced clinical time for the milled CECDs compared with conventional complete dentures. An advantage associated with CECDs is the possibility of electronically archiving data using digital technology for rapid fabrication. Applications reported in the literature with CECDs were also identified.

CONCLUSIONS: A positive trend was seen in the outcomes with CECDs, although patient selection might have also contributed to favorable outcomes. Significantly reduced clinical time, improved retention, and digital archiving were the main advantages associated with CECDs.

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Additive manufacturing techniques in prosthodontics: Where do we currently stand? A critical review

Alharbi N, Wismeijer D, Osman RB
Int J Prosthodont. 2017;30:474-484

PURPOSE: The aim of this article was to critically review the current application of additive manufacturing (AM)/3D-printing techniques in prosthodontics and to highlight the influence of various technical factors involved in different AM technologies.

MATERIALS AND METHODS: A standard approach of searching MEDLINE, EMBASE, and Google Scholar databases was followed. The following search terms were used: (Prosth* OR Restoration) AND (Prototype OR Additive Manufacture* OR Compute* OR 3D-print* OR CAD/CAM) AND (Dentistry OR Dental). Hand searching the reference lists of the included articles and personal connections revealed additional relevant articles. Selection criteria were any article written in English and reporting on the application of AM in prosthodontics from 1990 to February 2016.

RESULTS: From a total of 4,290 articles identified, 33 were seen as relevant. Of these, 3 were narrative reviews, 18 were in vitro studies, and 12 were clinical in vivo studies. Different AM technologies are applied in prosthodontics, directly and indirectly for the fabrication of fixed metal copings, metal frameworks for removable partial dentures, and plastic mock-ups and resin patterns for further conventional metal castings. Technical factors involved in different AM techniques influence the overall quality, the mechanical properties of the printed parts, and the total cost and manufacturing time.

CONCLUSION: AM is promising and offers new possibilities in the field of prosthodontics, though its application is still limited. An understanding of these limitations and of developments in material science is crucial prior to considering AM as an acceptable method for the fabrication of dental prostheses.

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Digital versus conventional impressions in fixed prosthodontics: A review

Ahlholm P, Sipilä K, Vallittu P, Jakonen M, Kotiranta U
J Prosthodont. 2018 ;27(1):35-41. doi: 10.1111/jopr.12527

PURPOSE: To conduct a systematic review to evaluate the evidence of possible benefits and accuracy of digital impression techniques vs. conventional impression techniques.

MATERIAL AND METHODS: Reports of digital impression techniques versus conventional impression techniques were systematically searched for in the following databases: Cochrane Central Register of Controlled Trials, PubMed, and Web of Science. A combination of controlled vocabulary, free-text words, and well-defined inclusion and exclusion criteria guided the search.

RESULTS: Digital impression accuracy is at the same level as conventional impression methods in fabrication of crowns and short fixed dental prostheses (FDPs). For fabrication of implant-supported crowns and FDPs, digital impression accuracy is clinically acceptable. In full-arch impressions, conventional impression methods resulted in better accuracy compared to digital impressions.

CONCLUSIONS: Digital impression techniques are a clinically acceptable alternative to conventional impression methods in fabrication of crowns and short FDPs. For fabrication of implant-supported crowns and FDPs, digital impression systems also result in clinically acceptable fit. Digital impression techniques are faster and can shorten the operation time. Based on this study, the conventional impression technique is still recommended for full-arch impressions.

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Marginal adaptation and CAD-CAM technology: A systematic review of restorative material and fabrication techniques

Papadiochou S, Pissiotis AL
J Prosthet Dent 2018;119:545-551

STATEMENT OF PROBLEM: The comparative assessment of computer-aided design and computer-aided manufacturing (CAD-CAM) technology and other fabrication techniques pertaining to marginal adaptation should be documented. Limited evidence exists on the effect of restorative material on the performance of a CAD-CAM system relative to marginal adaptation.

PURPOSE: The purpose of this systematic review was to investigate whether the marginal adaptation of CAD-CAM single crowns, fixed dental prostheses, and implant-retained fixed dental prostheses or their infrastructures differs from that obtained by other fabrication techniques using a similar restorative material and whether it depends on the type of restorative material.

MATERIAL AND METHODS: An electronic search of English-language literature published between January 1, 2000, and June 30, 2016, was conducted of the Medline/PubMed database.

RESULTS: Of the 55 included comparative studies, 28 compared CAD-CAM technology with conventional fabrication techniques, 12 contrasted CAD-CAM technology and copy milling, 4 compared CAD-CAM milling with direct metal laser sintering (DMLS), and 22 investigated the performance of a CAD-CAM system regarding marginal adaptation in restorations/infrastructures produced with different restorative materials.

CONCLUSIONS: Most of the CAD-CAM restorations/infrastructures were within the clinically acceptable marginal discrepancy (MD) range. The performance of a CAD-CAM system relative to marginal adaptation is influenced by the restorative material. Compared with CAD-CAM, most of the heat-pressed lithium disilicate crowns displayed equal or smaller MD values. Slip-casting crowns exhibited similar or better marginal accuracy than those fabricated with CAD-CAM. Cobalt-chromium and titanium implant infrastructures produced using a CAD-CAM system elicited smaller MD values than zirconia. The majority of cobalt-chromium restorations/infrastructures produced by DMLS displayed better marginal accuracy than those fabricated with the casting technique. Compared with copy milling, the majority of zirconia restorations/infrastructures produced by CAD-CAM milling exhibited better marginal adaptation. No clear conclusions can be drawn about the superiority of CAD-CAM milling over the casting technique and DMLS regarding marginal adaptation.

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Intraoral scan bodies in implant dentistry: A systematic review

Mizumoto RM, Yilmaz B
J Prosthet Dent 2018;120:343-352

STATEMENT OF PROBLEM: Intraoral scan body (ISB) design is highly variable and its role in the digital workflow and accuracy of digital scans is not well understood.

PURPOSE: The purpose of this systematic review was to determine the relevant reports pertaining to ISBs with regard to design and accuracy and to describe their evolution and role in the digital dentistry workflow. Special attention was placed on their key features in relation to intraoral scanning technology and the digitization process.

MATERIALS AND METHODS: A MEDLINE/PubMed search was performed to identify relevant reports pertaining to ISB usage in dentistry. This search included but was not limited to scan body features and design, scan body accuracy, and scan body techniques and the role of ISBs in computer-aided design and computer-aided manufacturing (CAD-CAM) processes. Commercially available scanbodies were examined, and a patient situation was shown highlighting the use of ISBs in the digital workflow.

RESULTS: Deficiencies in the reports were found regarding various scan body topics, including ISB features/design, accuracy, and the role of ISBs in CAD-CAM processes.

CONCLUSIONS: ISBs are complex implant-positioning-transfer devices that play an essential role in the digital workflow and fabrication of accurately fitting implant-supported restorations. With scanner technology rapidly evolving and becoming more widespread, future studies are needed and should be directed toward all parts of the digital workflow when using ISBs. By understanding the basic components of ISBs and how they relate to digital scanning and CAD-CAM technology, more emphasis may be placed on their importance and usage in the digital workflow to ensure accurate transfer of implant position to the virtual and analog definitive cast. Efforts should be made by clinicians to identify an optimal ISB design in relation to the specific intraoral scanning technology being used.

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Patient outcomes and procedure working time for digital versus conventional impressions: A systematic review

Gallardo YR, Bohner L, Tortamano P, Pigozzo MN, Laganá DC, Sesma N
J Prosthet Dent 2018;119:214-219

STATEMENT OF PROBLEM: Limited evidence is available comparing digital versus conventional impressions from the point of view of patient preference.

PURPOSE: The purpose of this systematic review was to identify and summarize the available literature related to patient-centered outcomes for digital versus conventional impression techniques.

MATERIAL AND METHODS: The databases Medline, Cochrane, Science Direct, Scopus, and Embase were electronically searched and complemented by hand searches. All published papers available on the databases from 1955 to July 2016 were considered for title and abstract analysis.

RESULTS: A total of 2943 articles were initially identified through database searches, of which only 5 met the inclusion criteria for qualitative analysis. Four studies comparing patient-reported outcome measures (PROMs) between conventional and digital impressions revealed that the digital technique was more comfortable and caused less anxiety and sensation of nausea. Only 1 study reported no difference between the techniques regardless of patient comfort. Two studies reported a shorter procedure for the conventional technique, whereas 3 studies reported a shorter procedure for the digital technique.

CONCLUSIONS: A lack of clinical studies addressing patient outcomes regarding digital prosthodontic treatments was observed among the included articles. However, current evidence suggests that patients are more likely to prefer the digital workflow than the conventional techniques.

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J Prosthodont. 2018;27:35-41.

PURPOSE: To conduct a systematic review to evaluate the evidence of possible benefits and accuracy of digital impression techniques vs. conventional impression techniques.

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CONCLUSIONS: Digital impression techniques are a clinically acceptable alternative to conventional impression methods in fabrication of crowns and short FDPs. For fabrication of implant-supported crowns and FDPs, digital impression systems also result in clinically acceptable fit. Digital impression techniques are faster and can shorten the operation time. Based on this study, the conventional impression technique is still recommended for full-arch impressions.

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Digital versus conventional impressions for full-coverage restorations: A systematic review and meta-analysis

Nagarkar SR, Perdigão J, Seong WJ, Theis-Mahon N
J Am Dent Assoc 2018;149:139-147

BACKGROUND: The primary objective of this systematic review was to investigate the survival of full-coverage restorations fabricated by using digital impressions (DIs) versus that of those fabricated by using conventional impressions. The authors also compared secondary outcomes of marginal and internal fit and occlusal and interproximal contacts.

TYPES OF STUDIES REVIEWED: The authors conducted a systematic literature search in multiple databases to identify clinical trials with no restrictions by publication type, date, or language. The authors assessed study-level risk of bias and outcome-level strength of evidence. The authors performed a meta-analysis by using a random-effects model.

RESULTS: Ten studies met the inclusion criteria. The authors identified no studies in which the investigators compared the impression techniques with respect to survival of full-coverage restorations. Mean differences for marginal gap and internal gap were -9.0 micrometers (95% confidence interval, -18.9 to 0.9) and -15.6 ·m (95% confidence interval, -42.6 to 11.4), respectively. Studies assessing internal gap were substantially heterogeneous (I2 = 72%; P = .003).

CONCLUSIONS AND PRACTICAL IMPLICATIONS: Research is lacking to draw robust conclusions about the relative benefits of DIs in terms of restoration survival. Low-quality evidence for marginal fit and internal fit suggested similar performance for both techniques. Evidence quality for interproximal contact and occlusal contact was very low and insufficient to draw any conclusions regarding how the impression techniques compared. Given the uncertainty of the evidence, results should be interpreted with caution. With increasing popularity and adoption of digital scanners by dentists, pragmatic practice-based trials involving standardized, patient-centered outcomes may improve confidence in the comparative effectiveness of DIs.

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Marginal and internal fit of CAD-CAM inlay/onlay restorations: A systematic review of in vitro studies

Goujat A, Abouelleil H, Colon P, Jeannin C, Pradelle N, Seux D, Grosgogeat B
J Prosthet Dent 2019;121:590-597

STATEMENT OF PROBLEM: Different parameters can influence the adaptation of computer-assisted design and computer-assisted manufacturing (CAD-CAM) inlay/onlay restorations. However, systematic reviews to identify and discuss these parameters are lacking.

PURPOSE: The purpose of this systematic review was to summarize the scientific literature investigating all parameters that can influence both the marginal and internal adaptation of CAD-CAM inlay/onlay restorations.

MATERIAL AND METHODS: An electronic search was conducted by 2 independent reviewers for studies published in English between January 1, 2007 and September 20, 2017 on the PubMed/MEDLINE, Scopus, and Web of Science databases and in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. Factors investigated in the selected articles included the type of CAD-CAM system, virtual space parameters, version of the software, type of block, luting procedure, type of restoration, sample size and aging procedure, evaluation method, and number of measurement points per specimen.

RESULTS: A total of 162 articles were identified, of which 23 articles met the inclusion criteria. Nine studies investigated adaptation with different restorative materials, 2 evaluated adaptation according to the type of preparation design, 9 compared adaptation before/after thermomechanical loading, and 2 before/after cementation, 1 study investigated marginal adaptation based on whether the optical scan was made intraorally or extraorally, 1 compared adaptation with 5 and 3 axis CAM systems, and 1 assessed adaptation with 4 different intraoral scanners. The risk of bias was high for 7, medium for 15, and low for 1 of the studies reviewed. The high level of heterogeneity across the studies excluded meta-analysis.

CONCLUSIONS: Most of the studies reported clinically acceptable values for marginal adaptation. The performance of a CAD-CAMsystem is influenced by the type of restorative material. A nonretentive cavity preparation exhibited better adaptation than a retentive preparation. Most studies showed that thermomechanical loading affected the quality of marginal adaptation. Cementation increased marginal discrepancies. No statistically significant difference was found for marginal fit of onlays between intraoral and extraoral optical scans using a stone die. The number of milling axes, the type of digital camera, and the region measured were statistically significant in relation to marginal/internal adaptation. Values of adaptation recorded failed to reproduce the preestablished spacer parameters in the software. Clarification is needed concerning adaptation according to the type of preparation design, the type of material, the choice of intrinsic parameters for the CAD process, the type and shape of milling instruments, and the behavior of the material during milling. Adaptation of CAD-CAM inlay/onlays should be evaluated under clinical conditions.

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Marginal adaptation of CAD/CAM all-ceramic crowns made by different impression methods: A literature review

Memari Y, Mohajerfar M, Armin A, Kamalian F, Rezayani V, Beyabanaki E
J Prosthodont. 2019;28:e536-e544

All-ceramic crowns for teeth are widely used for restoring teeth. Stone casts have been made from conventional impression methods; however, newer techniques have made this process easier and faster for both the patient and the practitioner. Laboratory CAD/CAM technology mainly involves scanning the die stone, while other systems permit impression or intraoral scanning; however, one major concern remaining is the marginal fit of the restorations made using different methods for recording the prepared teeth. This study aims to review studies evaluating the marginal fit of all-ceramic crowns manufactured by CAD/CAM systems using different extra- and intra-oral scanners compared to conventional impressions.

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CAD/CAM vs conventional technique for fabrication of implant-supported frameworks: A systematic review and meta-analysis of in vitro studies

Mello CC, Lemos CAA, de Luna Gomes JM, Verri FR, Pellizzer EP
Int J Prosthodont 2019;32:182-192

PURPOSE: To compare the marginal vertical misfit between implant-supported frameworks fabricated using CAD/CAM systems and the conventional technique (lost-wax casting).

MATERIALS AND METHODS: This review was performed according to PRISMA criteria and registered on PROSPERO (CRD42017055685). An electronic search was performed independently by two examiners in the MEDLINE (Pubmed), Embase, Web of Science, and Cochrane Library databases to find studies published up to April 2018.

RESULTS: The database search yielded 507 references. After removing duplicate references, 384 studies remained. Eleven in vitro studies were selected according to the eligibility criteria (inter-reader κ = 0.88). Nine different CAD/CAM systems were used to fabricate 172 frameworks of different materials, including zirconia, monolithic lithium disilicate, and metallic alloys. Subgroup analyses were performed for different types and retention systems of the frameworks. In the general analysis, marginal misfit observed with the CAD/CAM systems was lower than with the conventional method ($P = .003$), as was observed in the subgroup analysis for single-unit frameworks ($P < .00001$). For fixed ($P = .89$), cemented ($P = .60$), and screwed ($P = .18$) frameworks, no significant difference was observed between the evaluated techniques.

CONCLUSIONS: The CAD/CAM systems showed improved marginal fit over the conventional lost-wax casting technique for fabricating single-unit frameworks; however, in the subgroup analyses, no difference was observed for the fixed implant-supported type or for the retention systems evaluated.

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Evaluation of the absolute marginal discrepancy of zirconia-based ceramic copings

Martínez-Rus F, Suárez MJ, Rivera B, Pradíes G
J Prosthet Dent 2011;105:108-114

STATEMENT OF PROBLEM: Marginal fit is an important factor for the long-term success of ceramic restorations; however, it is difficult to compare results from studies on marginal accuracy of zirconium oxide-based restorations that used various computer-assisted systems, because different methods were used to obtain the data.

PURPOSE: The purpose of this study was to analyze the effect of different manufacturing techniques on the marginal adaptation of zirconia ceramic copings.

MATERIAL AND METHODS: An extracted mandibular first premolar was prepared for a complete coverage restoration and subsequently duplicated 40 times in a liquid crystal polymer (LCP). Ceramic copings (n=10) were fabricated on the LCP models using the following systems: glass-infiltrated zirconia-toughened alumina (In-Ceram Zirconia) and yttrium cation-doped tetragonal zirconia polycrystals (In-Ceram YZ, Cercon, and Procera Zirconia). The absolute marginal discrepancy of the cores was assessed by using an image analysis system. The data were analyzed using 1-way ANOVA and Scheffé's test (a=.05).

RESULTS: The mean marginal openings were 29.98 ± 3.97 μm for the In-Ceram Zirconia group, 12.24 ± 3.08 μm for the In-Ceram YZ group, 13.15 ± 3.01 μm for the Cercon group, and 8.67 ± 3.96 μm for the Procera group. Significant differences were found among the 4 systems (P<.05).

CONCLUSIONS: The marginal accuracy achieved for the 4 zirconia-based ceramic crown systems analyzed was within the range of clinical acceptance (120μm).

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Fit of single tooth zirconia copings: comparison between various manufacturing processes

Grenade C, Mainjot A, Vanheusden A
J Prosthet Dent 2011;105:249-255

STATEMENT OF PROBLEM: Various CAD/CAM processes are commercially available to manufacture zirconia copings. Comparative data on their performance in terms of fit are needed.

PURPOSE: The purpose of this in vitro study was to compare the internal and marginal fit of single tooth zirconia copings manufactured with a CAD/CAM process (Procera; Nobel Biocare) and a mechanized manufacturing process (Ceramill; Amann Girrbach).

MATERIAL AND METHODS: Abutments (n=20) prepared in vivo for ceramic crowns served as a template for manufacturing both Procera and Ceramill zirconia copings. Copings were manufactured and cemented (Clearfil Esthetic Cement; Kuraray) on epoxy replicas of stone cast abutments. Specimens were sectioned. Nine measurements were performed for each coping. Over- and under-extended margins were evaluated. Comparisons between the 2 processes were performed with a generalized linear mixed model (α=.05).

RESULTS: Internal gap values between Procera and Ceramill groups were not significantly different (P=.13). The mean marginal gap (SD) for Procera copings (51(50) µm) was significantly smaller than for Ceramill (81(66) µm) (P<.005). The percentages of over- and under-extended margins were 43% and 57% for Procera respectively, and 71% and 29% for Ceramill.

CONCLUSIONS: Within the limitations of this in vitro study, the marginal fit of Procera copings was significantly better than that of Ceramill copings. Furthermore, Procera copings showed a smaller percentage of over-extended margins than did Ceramill copings.

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Predicting marginal fit of CAD/CAM crowns based on the presence or absence of common preparation errors

Renne W, McGill ST, Forshee KV, DeFee MR, Mennito AS
J Prosthet Dent 2012;108:310-315

STATEMENT OF PROBLEM: Confusion exists as to what constitutes an ideal ceramic crown preparation and whether certain deviations from the ideal can affect the marginal fit of the milled restoration.

PURPOSE: This study evaluated the marginal gap of E4D crowns fabricated on preparations completed by clinicians with varying levels of expertise to identify whether common errors affect marginal fit.

MATERIAL AND METHODS: The fit of 75 crowns fabricated with the E4D system on preparations of varying quality were examined for marginal fit by using the replica technique. These same preparations were then visually examined for common criteria for ceramic restorations and placed in one of 3 categories: excellent, fair, or poor. These visual examinations sought the presence of common preparation errors, particularly those involving the finish line. The average marginal gap values and standard deviations were calculated for each category, and the Kruskal-Wallis test was used to determine significance.

RESULTS: The results showed a statistically significant correlation between the marginal fit of a CAD/CAM fabricated crown and the quality of the preparation. The mean marginal gap of the crowns fabricated on ideal preparations was 38.5 μm, those considered fair had a mean marginal gap of 58.3 μm, while those categorized as poor averaged 90.1 μm. The fit differences among all 3 groups were statistically significant (P<.05).

CONCLUSIONS: Within the limitations of this in vitro study, it can be concluded that preparation quality has a significant impact on marginal gap on crowns fabricated with a CAD/CAM system.

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Accuracy of ceramic restorations made with two CAD/CAM systems

Hamza TA, Ezzat HA, El-Hossary MM, Katamish HA, Shokry TE, Rosenstiel SF
J Prosthet Dent 2013;109:83-87

STATEMENT OF PROBLEM: Different types of CAD/CAM systems are currently available, but information regarding which system produces the best marginal fit is lacking.

PURPOSE: The purpose of this study was to evaluate the effect of 2 different CAD/CAM systems (Cerec inLab, Kavo Everest) on the marginal fit of 2 types of zirconia-based and lithium disilicate crowns.

MATERIAL AND METHODS: Forty zirconia-based and lithium disilicate crowns, 20 each, were fabricated with the Cerec inLab and Everest CAD/CAM systems on a specially designed stainless steel die to ensure the standardization of specimen shape and dimensions. The vertical marginal fit for all tested crowns was evaluated by using a digital microscope at ·100 magnification, and the data were tabulated and statistically analyzed with 2-way ANOVA, followed by the Tukey honestly significant difference (HSD) test with a confidence level of .05 to determine the mean differences.

RESULTS: The results showed that the CAD/CAM technique, ceramic type, and their interaction had a statistically significant effect on the mean marginal fit of both ceramic types tested.

CONCLUSIONS: Better marginal fit values were exhibited by the Everest CAD/CAM technique for both ceramic types tested.

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Accuracy of complete-arch dental impressions: a new method of measuring trueness and precision

Ender A, Mehl A
J Prosthet Dent 2013;109:121-128

STATEMENT OF PROBLEM: A new approach to both 3-dimensional (3D) trueness and precision is necessary to assess the accuracy of intraoral digital impressions and compare them to conventionally acquired impressions.

PURPOSE: The purpose of this in vitro study was to evaluate whether a new reference scanner is capable of measuring conventional and digital intraoral complete-arch impressions for 3D accuracy.

MATERIAL AND METHODS: A steel reference dentate model was fabricated and measured with a reference scanner (digital reference model). Conventional impressions were made from the reference model, poured with Type IV dental stone, scanned with the reference scanner, and exported as digital models. Additionally, digital impressions of the reference model were made and the digital models were exported. Precision was measured by superimposing the digital models within each group. Superimposing the digital models on the digital reference model assessed the trueness of each impression method. Statistical significance was assessed with an independent sample t test (a=.05).

RESULTS: The reference scanner delivered high accuracy over the entire dental arch with a precision of 1.6 ±0.6 μm and a trueness of 5.3 ±1.1 μm. Conventional impressions showed significantly higher precision (12.5 ±2.5 μm) and trueness values (20.4 ±2.2 μm) with small deviations in the second molar region (P<.001). Digital impressions were significantly less accurate with a precision of 32.4 ±9.6 μm and a trueness of 58.6 ±15.8μm (P<.001). More systematic deviations of the digital models were visible across the entire dental arch.

CONCLUSIONS: The new reference scanner is capable of measuring the precision and trueness of both digital and conventional complete-arch impressions. The digital impression is less accurate and shows a different pattern of deviation than the conventional impression.

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Accuracy of dies captured by an intraoral digital impression system using parallel confocal imaging

Kim S, Kim M, Han J, Yeo I, Lim Y, Kwon H
Int J Prosthodont 2013;161-163

The purpose of this investigation was to measure the accuracy of digital impressions (DIs) compared to conventional impressions (CIs). Using the iTero system, a master cast was scanned to produce stereolithography dies. As a control group, silicone impressions were taken and poured using stone. The resulting stereolithography and stone dies were scanned and overlayed on the scanned reference image of the master cast. The mean (± standard deviation) dimensional difference to the master cast was 23.9 (± 17.6) μm for DIs and 17.6 (± 45.6) μm for CIs. The results indicate that DIs also provides enough accuracy for clinical application.

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Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Dimensional and occlusal accuracy of a novel three-dimensional digital model of articulated dental arches

Tanaka Y, Hattori Y
Int J Prosthodont 2013;26:282-287

PURPOSE: To develop a method for capturing the three-dimensional (3D) shapes of dental arches in a position relative to that of maximum intercuspation and to evaluate its dimensional and occlusal accuracy.

MATERIAL AND METHODS: The conventional custom-tray impression technique was used to capture detailed and dimensionally accurate impressions of individual teeth, and a modified bite-registration technique was used to register the relative positions of the maxillary and mandibular teeth in maximum intercuspation. It was hypothesized that this procedure may help to eliminate the occlusal inaccuracy caused by mouth opening-induced mandibular flexion. Two types of rigid frames (buccal and palatal) were used to prevent deformation of the interocclusal record. Their effects were tested on an articulated full-arch master cast and compared in terms of dimensional accuracy. In addition, the procedure was applied to a healthy volunteer to visually evaluate occlusal accuracy based on the form and distribution of the occlusal contacts.

RESULTS: The mean decrements of the dental arch width were 0.037 ± 0.017 mm and 0.269 ± 0.114 mm when using the palatal and buccal frames, respectively. The dimensional accuracy of the palatal frame was comparable to that of the custom-tray impression technique. The form and distribution of the occlusal contacts between the 3D dental arches were similar to those observed in the transilluminated image of the interocclusal record, indicating the occlusal accuracy of this method.

CONCLUSION: The dimensional and occlusal accuracy of the method proposed here is suitable for clinical application when used in combination with the palatal frame.

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Assessing the feasibility and accuracy of digitizing edentulous jaws

Patzelt SB, Vonau S, Stampf S, Att W
J Am Dent Assoc 2013;144:914-920

BACKGROUND: Despite the accuracy of intraoral scanners (IOSs) in producing single-unit scans and the possibility of generating complete dentures digitally, little is known about their feasibility and accuracy in digitizing edentulous jaws. The purpose of this in vitro investigation was to evaluate the feasibility and accuracy of digitizing edentulous jaw models with IOSs.

METHODS: The authors used an industrial laser scanner (reference scanner) and four IOSs to digitize two representative edentulous jaw models. They loaded the data sets obtained into three-dimensional evaluation software, superimposed the data sets and compared them for accuracy. The authors used a one-way analysis of variance to compute differences within groups (precision), as well as to compare values with those of the reference scanner (trueness) (statistical significance, $P < .05$).

RESULTS: Mean trueness values ranged from 44.1 to 591.8 micrometers. Data analysis yielded statistically significant differences in trueness between all scanners ($P < .05$). Mean precision values ranged from 21.6 to 698.0 µm. The study results showed statistically significant differences in precision between all scanners ($P < .05$), except for the CEREC AC Bluecam (Sirona, Bensheim, Germany) and the Zfx IntraScan (manufactured by MHT Italy, Negrar, Italy/ MHT Optic Research, Niederhasli, Switzerland; distributed by Zfx, Dachau, Germany) ($P > .05$).

CONCLUSIONS: Digitizing edentulous jaw models with the use of IOSs appears to be feasible, although the accuracy of the scanners differs significantly. The results of this study showed that only one scanner was sufficiently accurate to warrant further intraoral investigations. Further enhancements are necessary to recommend these IOSs for this particular indication. Practical Implications. On the basis of the results of this study, the authors cannot recommend these four IOSs for digitization of edentulous jaws in vivo.

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Clinical evaluation of CAD/CAM metal-ceramic posterior crowns fabricated from intraoral digital impressions

Tamim H, Skjerven H, Ekfeldt A, Odont, Rønold HJ
Int J Prosthodont 2014;27:331–337. doi: 10.11607/ijp.3607

PURPOSE: The aim of this in vivo study was to evaluate the accuracy of metal-ceramic crowns fabricated using computer-aided design/computer-assisted manufacturing (CAD/CAM) in conjunction with intraoral digital impressions.

MATERIAL AND METHODS: Fifty patients in a general practice participated in the study. Patients were provided with crowns fabricated from digital impressions taken with an intraoral chairside scanner. Prior to crown insertion, the marginal integrity, esthetics, and occlusal and articulation contacts were evaluated using California Dental Association (CDA) criteria. The precementation space of the crowns was evaluated with the replica technique.

RESULTS: No adjustments were needed for any of the interproximal contact points. Adjustments of occlusion and articulation contacts were needed in 20% of the restorations. Clinical evaluation of the marginal integrity showed satisfactory results according to the CDA criteria. The 50 silicone replicas showed a median precementation space of 46 µm at the marginal measurement location, 94 µm at the midaxial location, and 185 µm at the centro-occlusal location.

CONCLUSIONS: The precementation spaces of the crowns were within the acceptable range for CAD/CAM restorations.

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A comparison of the marginal fit of crowns fabricated with digital and conventional methods

Ng J, Ruse D, Wyatt C
J Prosthet Dent 2014;112:555-260

STATEMENT OF PROBLEM: Little evidence is available with regard to the marginal fit of crowns fabricated with digital impressions and computer-aided design/computer-aided manufacturing technology in comparison with crowns fabricated from conventional techniques.

PURPOSE: The purpose of this study was to determine and compare the marginal fit of crowns fabricated with digital and conventional methods.

MATERIAL AND METHODS: The maxillary right second premolar was prepared for a ceramic crown in a typodont. The typodont was then digitized with a laboratory scanner, and the digital file was used to mill a replica of the maxillary arch from a monolithic block of yttria-stabilized zirconia to serve as the master model. Digital impressions of the prepared maxillary right second premolar were recorded with a scanning unit. Scan files were exported as .STL files and sent by e-mail to a dental laboratory. The files were input into a digital design workflow for digital articulation, digital waxing, and design of the definitive crown. Fifteen crowns were produced by milling computer-aided designed lithium disilicate glass ceramic blocks with a 5-axis milling. Fifteen lithium disilicate glass ceramic crowns were produced with a conventional impression and a laboratory fabrication method. The original zirconia die was removed from the zirconia master model to evaluate the crown margins. Circumferential marginal gap measurements were made at 8 measurement locations: mescal, distal, buccal, palatal and associated line angles (mesiobuccal, mesiolingual, distobuccal, and distolingual). Measurements were made to determine the vertical component of the marginal gap according to the definition of marginal fit.

RESULTS: Results: A total of 240 images (2 groups, 15 crowns per group, 8 sites per crown) were recorded and measured. The overall mean ±SD vertical gap measurement for the digitally made crowns was 48 ±25 μm, which was significantly smaller than that for the conventionally made crowns (74 ±47 μm).

CONCLUSIONS: The fully digital fabrication method provided better margin fit than the conventional method.

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Accuracy of computer-aided design/ computer-aided manufacturing-generated dental casts based on intraoral scanner data

Patzelt SB, Bishti S, Stampf S, Att W
J Am Dent Assoc 2014 Nov;145:1133-1140. doi: 10.14219/jada.2014.87

BACKGROUND: Little is known about the accuracy of physical dental casts that are based on three-dimensional (3D) data from an intraoral scanner (IOS). Thus, the authors conducted a study to evaluate the accuracy of full-arch stereolithographic (SLA) and milled casts obtained from scans of three IOSs.

METHODS: The authors digitized a polyurethane model using a laboratory reference scanner and three IOSs. They sent the scans (n = five scans per IOS) to the manufacturers to produce five physical dental casts and scanned the casts with the reference scanner. Using 3D evaluation software, the authors superimposed the data sets and compared them.

RESULTS: The mean trueness values of Lava Chairside Oral Scanner C.O.S. (3M ESPE, St. Paul, Minn.), CEREC AC with Bluecam (Sirona, Bensheim, Germany) and iTero (Align Technology, San Jose, Calif.) casts were 67.50 micrometers (95 percent confidence interval [CI], 63.43-71.56), 75.80 µm (95 percent CI, 71.74-79.87) and 98.23 µm (95 percent CI, 94.17-102.30), respectively, with a statistically significant difference among all of the scanners (P < .05). The mean precision values were 13.77 µm (95 percent CI, 2.76-24.79), 21.62 µm (95 percent CI, 10.60-32.63) and 48.83 µm (95 percent CI, 37.82-59.85), respectively, with statistically significant differences between CEREC AC with Bluecam and iTero casts, as well as between Lava Chairside Oral Scanner C.O.S. and iTero casts (P < .05).

CONCLUSION: All of the casts showed an acceptable level of accuracy; however, the SLA-based casts (CEREC AC with Bluecam and Lava Chairside Oral Scanner C.O.S.) seemed to be more accurate than milled casts (iTero).

PRACTICAL IMPLICATIONS: On the basis of the results of this investigation, the authors suggested that SLA technology was superior for the fabrication of dental casts. Nevertheless, all of the investigated casts showed clinically acceptable accuracy. Clinicians should keep in mind that the highest deviations might occur in the distal areas of the casts.

Journal of Dentistry

Impact of digital impression techniques on the adaption of ceramic partial crowns in vitro

Schaefer O, Decker M, Wittstock F, Kuepper H, Guentsch A
J Dent 2014;42:677-683

OBJECTIVES: To investigate the effects, digital impression procedures can have on the three-dimensional fit of ceramic partial crowns in vitro.

METHODS: An acrylic model of a mandibular first molar was prepared to receive a partial coverage all-ceramic crown (mesio-occlusal-distal inlay preparation with reduction of all cusps and rounded shoulder finish line of buccal wall). Digital impressions were taken using iTero (ITE), cara TRIOS (TRI), CEREC AC with Bluecam (CBC), and Lava COS (COS) systems, before restorations were designed and machined from lithium disilicate blanks. Both the preparation and the restorations were digitised using an optical reference-scanner. Data were entered into quality inspection software, which superimposed the records (best-fit-algorithm), calculated fit-discrepancies for every pixel, and colour-coded the results to aid visualisation. Furthermore, mean quadratic deviations (RMS) were computed and analysed statistically with a one-way ANOVA. Scheffé's procedure was applied for multiple comparisons ($n = 5$, $\alpha = 0.05$).

RESULTS: Mean marginal (internal) discrepancies were: ITE 90 (92) ·m, TRI 128 (106) ·m, CBC 146 (84) ·m, and COS 109 (93) ·m. Differences among impression systems were statistically significant at $p < 0.001$ ($p = 0.039$). Qualitatively, partial crowns were undersized especially around cusp tips or the occluso-approximal isthmus. By contrast, potential high-spots could be detected along the preparation finishline and at central occlusal boxes.

CONCLUSIONS: Marginal and internal fit of milled lithium disilicate partial crowns depended on the employed digital impression technique.

CLINICAL SIGNIFICANCE: The investigated digital impression procedures demonstrated significant fit discrepancies. However, all fabricated restorations showed acceptable marginal and internal gap sizes, when considering clinically relevant thresholds reported in the literature.

Journal of Dentistry

Digital evaluation of the accuracy of impression techniques and materials in angulated implants

Kurtulmus-Yilmaz S, Ozan O, Ozcelik TB, Yagiz A
J Dent 2014;42:1551-1559

OBJECTIVES: The aim of this study was to investigate the accuracy of 2 different impression techniques and 3 different impression materials in models simulating parallel and angulated implants.

METHODS: Three master models simulating partial edentulous mandible with 2 implants at the sites of second premolars (parallel) and second molars with different angulations (parallel, 10° or 20° angulated) were fabricated. Two different impression techniques [splinted direct (D), indirect (I)] and 3 different monophase impression materials [polyether (PE), vinyl polysiloxane (VPS), vinyl polyether silicone (VPES)] were used for each master model and a total of 180 impressions were made (n = 10). Master model and casts were scanned by a modified laser scanner and data were transferred to VRMesh software. Master model and duplicate cast scans were digitally aligned observing the superposition of anatomic markers. Angular and coronal deviations between master and duplicated copings were calculated and data were statistically analyzed.

RESULTS: Mean angular and coronal deviations were in a range of 0.205–0.359° and 22.56-33.33 μm, respectively. Statistical analysis revealed that the angulation of implant affected both coronal and angular deviations of the impression copings ($P < 0.05$). According to statistical analyses, for parallel implants, the accuracy of impression materials and techniques were ranging as VPS-D = PE-D > VPS-I = PE-I > VPES-D > VPES-I from most accurate to the least. For 10° and 20° angulated implants the most accurate material and technique was VPS-D whereas the least accurate combination was VPES-I ($P < 0.05$).

CONCLUSION: Angulation, impression technique and material were found to be effective on the accuracy of implant impressions.

CLINICAL SIGNIFICANCE: Clinicians may prefer VPS impression material and splinted direct technique for impressions of both parallel and up to 20° angulated implants.

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3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impression

Anadioti E, Aquilino SA, Gratton DG, Holloway JA, Denry I, Thomas GW, Qian F
J Prosthodont 2014 Dec;23:610-617. doi: 10.1111/jopr.12180

PURPOSE: This in vitro study evaluated the 3D and 2D marginal fit of pressed and computer-aided-designed/computer-aided-manufactured (CAD/CAM) all-ceramic crowns made from digital and conventional impressions.

MATERIAL AND METHODS: A dentoform tooth (#30) was prepared for an all-ceramic crown (master die). Thirty type IV definitive casts were made from 30 polyvinyl siloxane (PVS) impressions. Thirty resin models were produced from thirty Lava Chairside Oral Scanner impressions. Thirty crowns were pressed in lithium disilicate (IPS e.max Press; 15/impression technique). Thirty crowns were milled from lithium disilicate blocks (IPS e.max CAD; 15/impression technique) using the E4D scanner and milling engine. The master die and the intaglio of the crowns were digitized using a 3D laser coordinate measurement machine with accuracy of ±0.00898 mm. For each specimen a separate data set was created for the Qualify 2012 software. The digital master die and the digital intaglio of each crown were merged using best-fitting alignment. An area above the margin with 0.75 mm occlusal-gingival width circumferentially was defined. The 3D marginal fit of each specimen was an average of all 3D gap values on that area. For the 2D measurements, the marginal gap was measured at two standardized points (on the margin and at 0.75 mm above the margin), from standardized facial-lingual and mesial-distal digitized sections. One-way ANOVA with post hoc Tukey's honestly significant difference and two-way ANOVA tests were used, separately, for statistical analysis of the 3D and 2D marginal data (alpha = 0.05).

RESULTS: One-way ANOVA revealed that both 3D and 2D mean marginal gap for group A: PVS impression/IPS e.max Press (0.048 mm ± 0.009 and 0.040 mm ± 0.009) were significantly smaller than those obtained from the other three groups ($p < 0.0001$), while no significant differences were found among groups B: PVS impression/IPS e.max CAD (0.088 mm ± 0.024 and 0.076 mm ± 0.023), C: digital impression/IPS e.max Press (0.089 mm ± 0.020 and 0.075 mm ± 0.015) and D: digital impression/IPS e.max CAD (0.084 mm ± 0.021 and 0.074 mm ± 0.026). The results of two-way ANOVA revealed a significant interaction between impression techniques and crown fabrication methods for both 3D and 2D measurements.

CONCLUSIONS: The combination of PVS impression method and press fabrication technique produced the most accurate 3D and 2D marginal fits.

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Clinical marginal and internal fit of crowns fabricated using different CAD/CAM technologies

Huang Z, Zhang L, Zhu J, Zhao Y, Zhang X
J Prosthodont. 2015 Jun;24(4):291-5. doi: 10.1111/jopr.12209.

PURPOSE: The aims of this in vivo investigation were to compare the marginal and internal fit of single-unit crowns fabricated using a selective laser melting (SLM) procedure with two CAD/CAM grinding procedures, and to evaluate the influence of tooth type on the parameters measured.

MATERIAL AND METHODS: A total of 270 crowns were evaluated, including 90 SLM metal-ceramic crowns (group B), 90 zirconium-oxide-based ceramic crowns (group L), and 90 lithium disilicate ceramic crowns (group C). The marginal and internal gaps of the crowns were recorded using a replica technique with a silicone indicator paste stabilized with a light-body silicone. The gap replica specimen were sectioned buccolingually and mesiodistally and then examined using a stereomicroscope at 30Å~ magnification. Ten reference points were measured on each anterior and premolar specimen, and 20 reference points were measured on each molar specimen. Two-way ANOVA was performed to identify the significant differences between the groups.

RESULTS: The mean marginal fit of group B was significantly better than those of group C and group L ($p < 0.005$), but a significant difference was not found between group C and group L ($p > 0.05$). The mean axial gap of group B was significantly smaller than those of group C and group L ($p < 0.01$), while group C was not different from group L ($p > 0.05$). The mean occlusal gap of group B was significantly higher than those of group C and group L ($p < 0.05$), and no difference was found between group C and group L ($p > 0.05$). The marginal and internal gaps of crowns varying according to tooth type were not significantly different ($p > 0.05$).

CONCLUSION: The SLM system demonstrated better marginal and internal fit compared to the two CAD/CAM grinding systems examined. Tooth type did not significantly influence the marginal or internal fit.

Journal of Dentistry

Clinical evaluation comparing the fit of all-ceramic crowns obtained from silicone and digital intraoral impressions based on wavefront sampling technology

Pradíes G, Zarauz C, Valverde A, Ferreiroa A, Martínez-Rus F
J Dent 2015;43:201-208

OBJECTIVE: The aim of this study was to compare the fit of ceramic crowns fabricated from conventional silicone impressions with the fit of ceramic crowns fabricated from intraoral digital impressions.

METHODS: Twenty-five participants with 30 posterior teeth with a prosthetic demand were selected for the study. Two crowns were made for each preparation. One crown was fabricated from an intraoral digital impression system (IDI group) and the other crown was fabricated from a conventional two-step silicone impression (CI group). To replicate the interface between the crown and the preparation, each crown was cemented on its corresponding clinical preparation with ultra-flow silicone. Each crown was embedded in acrylic resin to stabilise the registered interface and then cut in 2 mm thick slices in a buco-lingual orientation. The internal gap was determined as the vertical distance from the internal surface of the crown to the prepared tooth surface at four points (marginal gap, axial gap, crest gap, and occlusal fossa gap) using stereomicroscopy with a magnification of 40·. Data was analysed by using Wilcoxon signed rank test (α = 0.05).

RESULTS: Internal adaptation values were significantly affected by the impression technique (p = 0.001). Mean marginal gap was 76.33 ffl 65.32 μm for the crowns of the IDI group and 91.46 ffl 72.17 μm for the CI group.

CONCLUSION: All-ceramic crowns fabricated from intraoral digital impressions with wavefront sampling technology demonstrated better internal fit than crowns manufactured from silicone impressions.

CLINICAL SIGNIFICANCE: Impressions obtained from an intraoral digital scanner based on wavefront sampling technology can be used for manufacturing ceramic crowns in the normal clinical practice with better results than conventional impressions with elastomers.

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Randomized controlled trial comparing direct intraoral digitization and extraoral digitization after impression taking

Quaas S, Loos R, Rudolph H, Luthardt RG
Int J Prosthodont 2015;28:30-32.doi: 10.11607/ijp.3455. PMID: 25588169

This study aimed to evaluate the correspondence of intraoral digitization (ID) with extraoral digitization (ED) after impression taking. One-stage putty-and wash impressions and ID were carried out in a randomized order for 10 subjects. The impressions were used to make casts, which were then subjected to ED. ID datasets were aligned to create computer-aided design reference models. Deviations between ID and ED were calculated. The mean positive and negative deviations were 37.7 and -48.4 µm, respectively, for one quadrant. The results showed that the ID system is well suited for the acquisition of single-tooth restorations and is of limited suitability for the acquisition of small multiple unit restorations.

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Effect of imaging powder and CAD/CAM stone types on the marginal gap of zirconia crowns

Alghazzawi TF, Al-Samadani KH, Lemons J, Liu PR, Essig ME, Bartolucci AA, Janowski GM.
J Am Dent Assoc 2015 Feb;146:111-120. doi: 10.1016/j.adaj.2014.10.006.

OBJECTIVE: To compare the marginal gap using different types of die stones and titanium dies with and without powders for imaging.

METHODS: A melamine tooth was prepared and scanned using a laboratory 3-shape scanner to mill a polyurethane die, which was duplicated into different stones (Jade, Lean, CEREC) and titanium. Each die was sprayed with imaging powders (NP, IPS, Optispray, Vita) to form 15 groups. Ten of each combination of stone/titanium and imaging powders were used to mill crowns. A light-bodied impression material was injected into the intaglio surface of each crown and placed on the corresponding die. Each crown was removed, and the monophase material was injected to form a monophase die, which was cut into 8 sections. Digital images were captured using a stereomicroscope to measure marginal gap. Scanning electron microscopy was used to determine the particle size and shape of imaging powders and stones.

RESULTS: Marginal gaps ranged from mean (standard deviation) 49.32 to 1.20 micrometers (3.97-42.41 µm). There was no statistical difference ($P > .05$) in the marginal gap by any combination of stone/titanium and imaging powders. All of the imaging powders had a similar size and rounded shape, whereas the surface of the stones showed different structures.

CONCLUSIONS: When a laboratory 3-shape scanner is used, all imaging powders performed the same for scanning titanium abutments. However, there was no added value related to the use of imaging powder on die stone. It is recommended that the selection of stone for a master cast be based on the hysical properties.

PRACTICAL IMPLICATIONS: When a laboratory 3-shape scanner is used, the imaging powder is not required for scanning die stone. Whenever scanning titanium implant abutments, select the least expensive imaging powder.

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Comparison of accuracy and reproducibility of casts made by digital and conventional methods

Cho S, Schaefer O, Thompson GA, Guentsch A
J Prosthet Dent 2015;113:310-315

STATEMENT OF PROBLEM: Little peer-reviewed information is available regarding the accuracy and reproducibility of digitally fabricated casts compared to conventional nondigital methods.

PURPOSE: The purpose of this in vitro study was to compare the accuracy and reproducibility of a digital impression and cast fabrication with a conventional impression and cast fabrication.

MATERIAL AND METHODS: Conventional impressions were made via a 1-step single viscosity technique with vinyl siloxanether material of a typodont master model, and conventional casts were cast from dental stone. Digital impressions were obtained with a digital scanner, and digital stereolithographic models were printed. The typodont and fabricated casts were digitized with a structured light scanner and saved in surface tessellation language (STL) format. All STL records were superimposed via a best-fit method. The digital impression and cast fabrication method was compared with the conventional impression and cast fabrication method for discrepancy, accuracy, and reproducibility. The Levene test was used to determine equality of variances, and a 1-way ANOVA was conducted to assess the overall statistical significance of differences among the groups (n=5, α=.05).

RESULTS: No significant statistical difference was found between the digital cast and conventional casts in the internal area or finish line area ($P>.05$). In addition, there was no statistically significant difference between these 2 techniques for a fixed dental prosthesis or single crown ($P>.05$). However, statistically significant differences were observed for overall areas of the casts in terms of accuracy ($P<.01$) and reproducibility ($P<.001$). Digital impression and cast fabrication were less accurate and reproducible than conventional impression and cast fabrication methods.

CONCLUSIONS: No statistically significant difference was found between the digital cast and conventional cast groups in the internal and finish line areas. However, in terms of the reproducibility and accuracy of the entire cast area, the conventional cast was significantly better than the digital cast.

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Internal fit of pressed and computer-aided design/computer-aided manufacturing ceramic crowns made from digital and conventional impressions

Anadioti E, Aquilino SA, Gratton DE, Holloway JA, Denry IL, Thomas GW, Qian F
J Prosthet Dent 2015;113:304-309

STATEMENT OF PROBLEM: No studies have evaluated the internal adaptation of pressed and milled ceramic crowns made from digital impressions.

PURPOSE: The purpose of this in vitro study was to evaluate the internal fit of pressed and milled ceramic crowns made from digital and conventional impressions.

MATERIAL AND METHODS: Thirty polyvinyl siloxane (PVS) impressions and 30 Lava COS impressionsmade of a prepared dentoform tooth (master die) were fabricated. Thirty crowns were pressed in lithium disilicate (IPS e.max Press), and 30 crowns were milled from lithium disilicate blocks (IPS e.max CAD) (15/impression technique) with the E4D scanner and milling engine. The master die and the intaglio of the crowns were digitized with a 3-dimensional laser coordinate measurement machine. The digital master die and intaglio of each crown were merged. The distance between the die and the intaglio surface of the crown was measured at 3 standardized points. One-way ANOVA was used for statistical analysis (a=.05).

RESULTS: One-way ANOVA revealed that the internal gap obtained from the Lava/press group (0.211 mm, ±SD 0.041) was significantly greater than that obtained from the other groups (P<.001), while no significant differences were found among PVS/press (0.111 mm ±SD 0.047), PVS/CAD/CAM (0.116 mm ±SD 0.02), and Lava/CAD/CAM (0.145 mm ±SD 0.024).

CONCLUSIONS: The combination of the digital impression and pressed crown produced the least accurate internal fit.

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Comparison of the marginal fit of lithium disilicate crowns fabricated with CAD/CAM technology by using conventional impressions and two intraoral digital scanners

Abdel-Azim T, Rogers K, Elathamna E, Zandinejad A, Metz M, Morton D
J Prosthet Dent 2015;114:554-559

STATEMENT OF PROBLEM: Conventional impression materials and techniques have been used successfully to fabricate fixed restorations. Recently, digital pathways have been developed, but insufficient data are available regarding their marginal accuracy.

PURPOSE: The purpose of this in vitro study was to compare the marginal gap discrepancy of lithium disilicate single crowns fabricated with computer-aided design and computer-aided manufacturing (CAD/CAM) technology by using both conventional and 2 digital impression techniques.

MATERIAL AND METHODS: One typodont maxillary right central incisor was prepared for a ceramic crown. Ten impressions were made by using each method: conventional with polyvinyl siloxane impression material, Lava COS (3M ESPE), and iTero (Cadent) intraoral scanning devices. Lithium disilicate (e.max CAD) crowns were fabricated with CAD/CAM technology, and the marginal gap was measured for each specimen at 4 points under magnification with a stereomicroscope. The mean measurement for each location and overall mean gap size by group were calculated. Statistically significant differences among the impression techniques were tested with F and t tests (α=.05).

RESULTS: The average (±SD) gap for the conventional impression group was 112.3 (±35.3) mm. The digital impression groups had similar average gap sizes; the Lava group was 89.8 (±25.4) mm, and the iTero group was 89.6 (±30.1) mm. No statistically significant difference was found in the effects among impression techniques ($P=.185$)

CONCLUSIONS: Within the limitations of this study, digital and conventional impressions were found to produce crowns with similar marginal accuracy.

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Three-dimensional evaluation of the repeatability of scanned conventional impressions of prepared teeth generated with white- and blue-light scanners

Jeon J, Choi B, Kim C, Kim J, Kim H, Kim W
J Prosthet Dent 2015;114:549-553

STATEMENT OF PROBLEM: Digital scanning is increasingly used in prosthodontics. Three-dimensional (3D) evaluations that compare the repeatability of the blue-light scanner with that of the white-light scanner are required.

PURPOSE: The purpose of this in vitro study was to evaluate the repeatability of conventional impressions of abutment teeth digitized with white- and blue-light scanners and compare the findings for different types of abutment teeth.

MATERIAL AND METHODS: Impressions of the canine, premolar, and molar abutment teeth were made and repeatedly scanned with each scanner type to obtain 5 sets of 3D data for each tooth. Point clouds were compared, and error sizes per tooth and scanner type were measured (n=10). One-way ANOVA with Tukey honest significant differences multiple comparison and independent t tests were performed to evaluate repeatability (α=.05).

RESULTS: Repeatability (mean ±SD) of the white- and blue-light scanners for canine, premolar, and molar teeth was statistically significant (means: P=.001, P<.001, P<.001; ±SD: P<.001, P<.001, P=.003). Means of discrepancies with the white-light scanner (P<.001) were 5.8 mm for the canine, 5.9 mm for the premolar, and 8.6 mm for the molar teeth and 4.4 mm, 2.9 mm, and 3.2 mm, respectively, with the blue-light scanner (P<.001). Corresponding SDs of discrepancies with the white-light scanner (P<.001) were 15.9 mm for the canine, 23.2 mm for the premolar, and 14.6 mm for the molar teeth and 9.8 mm, 10.6 mm, and 11.2 mm, respectively, with the blue-light scanner (P=.73).

CONCLUSIONS: On evaluation of the digitized abutment tooth impressions, the blue-light scanner exhibited greater repeatability than the white-light scanner.

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Intraoral digital impression technique compared to conventional impression technique. A randomized clinical trial

Gjelvold B, Chrcanovic BR, Korduner EK, Collin-Bagewitz I, Kisch J
J Prosthodont 2016;25:282-287. PMID: 26618259

PURPOSE: To compare digital and conventional impression techniques in a randomized clinical trial; specifically, procedure times, patient-centered outcomes, and clinical evaluation of the restorations.

MATERIALS AND METHODS: Forty-two patients in need of tooth-supported single crowns and/or fixed partial prostheses up to six units were randomly allocated to one of the impression techniques. The procedure times, dentists' and patients' assessments using a visual analog scale (VAS), and clinical evaluation of the restorations were compared between the two groups.

RESULTS: The mean total procedure times for digital and conventional impression technique were 14:33 ± 5:27 and 20:42 ± 5:42, respectively ($p < 0.0001$). Mean impression times were 7:33 ± 3.37 and 11:33 ± 1.56, respectively ($p < 0.0001$). Mean VAS scores for the dentist's assessment of difficulty (0 to 100; very difficult = 100) were 24.00 ± 18.02 and 48.02 ± 21.21, respectively ($p < 0.0001$). Mean VAS scores for the patients' assessment of discomfort (0 to 100; very discomforting = 100) was 6.50 ± 5.87 and 44.86 ± 27.13, respectively ($p < 0.0001$). Occlusal contacts showed a better result for the digital technique.

CONCLUSION: The results of this study demonstrated that the digital technique was more efficient and convenient than the conventional impression technique.

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In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions

Ender A, Attin T, Mehl A
J Prosthet Dent 2016;115:313-320

Digital impression systems have undergone significant development in recent years, but few studies have investigated the accuracy of the technique in vivo, particularly compared with conventional impression techniques.

The purpose of this in vivo study was to investigate the precision of conventional and digital methods for complete-arch impressions.

MATERIAL AND METHODS: Complete-arch impressions were obtained using 5 conventional (polyether, POE; vinylsiloxanether, VSE; direct scannable vinylsiloxanether, VSES; digitized scannable vinylsiloxanether, VSES-D; and irreversible hydrocolloid, ALG) and 7 digital (CEREC Bluecam, CER; CEREC Omnicam, OC; Cadent iTero, ITE; Lava COS, LAV; Lava True Definition Scanner, T-Def; 3Shape Trios, TRI; and 3Shape Trios Color, TRC) techniques. Impressions were made 3 times each in 5 participants (N=15). The impressions were then compared within and between the test groups. The cast surfaces were measured point-to-point using the signed nearest neighbor method. Precision was calculated from the (90%-10%)/2 percentile value.

RESULTS: The precision ranged from 12.3 mm (VSE) to 167.2 mm (ALG), with the highest precision in the VSE and VSES groups. The deviation pattern varied distinctly according to the impression method. Conventional impressions showed the highest accuracy across the complete dental arch in all groups, except for the ALG group.

CONCLUSIONS: Conventional and digital impression methods differ significantly in the completearch accuracy. Digital impression systems had higher local deviations within the complete arch cast; however, they achieve equal and higher precision than some conventional impression materials.

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Comparison of marginal and internal fit of 3-unit ceramic fixed dental prostheses made with either a conventional or digital impression

Su TS, Sun J
J Prosthet Dent 2016;116:362-367

STATEMENT OF PROBLEM: For 20 years, the intraoral digital impression technique has been applied to the fabrication of computer aided design and computer aided manufacturing (CAD-CAM) fixed dental prostheses (FDPs). Clinical fit is one of the main determinants of the success of an FDP. Studies of the clinical fit of 3-unit ceramic FDPs made by means of a conventional impression versus a digital impression technology are limited.

PURPOSE: The purpose of this in vitro study was to evaluate and compare the internal fit and marginal fit of CAD-CAM, 3-unit ceramic FDP frameworks fabricated from an intraoral digital impression and a conventional impression.

MATERIAL AND METHODS: A standard model was designed for a prepared maxillary left canine and second premolar and missing first premolar. The model was scanned with an intraoral digital scanner, exporting stereolithography (STL) files as the experimental group (digital group). The model was used to fabricate 10 stone casts that were scanned with an extraoral scanner, exporting STL files to a computer connected to the scanner as the control group (conventional group). The STL files were used to produce zirconia FDP frameworks with CAD-CAM. These frameworks were seated on the standard model and evaluated for marginal and internal fit. Each framework was segmented into 4 sections per abutment teeth, resulting in 8 sections per framework, and was observed using optical microscopy with ·50 magnification. Four measurement points were selected on each section as marginal discrepancy (P1), mid-axial wall (P2), axio-occusal edge (P3), and central-occlusal point (P4).

RESULTS: Mean marginal fit values of the digital group (64 ffl16 ·m) were significantly smaller than those of the conventional group (76 ffl18 ·m) (P<.05). The mean internal fit values of the digital group (111 ffl34 ·m) were significantly smaller than those of the conventional group (132 ffl44 ·m) (P<.05).

CONCLUSIONS: CAD-CAM 3-unit zirconia FDP frameworks fabricated from intraoral digital and conventional impressions showed clinically acceptable marginal and internal fit. The marginal and internal fit of frameworks fabricated from the intraoral digital impression system were better than those fabricated from conventional impressions.

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Precision of dental implant digitization using intraoral scanners

Flügge T, Att W, Metzger MC, Nelson K
Int J Prosthodont 2016;29:277-283doi: 10.11607/ijp.4417 PMID: 27148990

PURPOSE: The digitization of scanbodies on dental implants is required to use computer-aided design/computer-assisted manufacture processes for implant prosthetics. Little is known about the accuracy of scanbody digitization with intraoral scanners and dental lab scanners. This study aimed to examine the precision of different intraoral digital impression systems as well as a dental lab scanner using commercially available implant scanbodies.

MATERIAL AND METHODS: Two study models with a different number and distribution of dental implant scanbodies were produced from conventional implant impressions. The study models were scanned using three different intraoral scanners (iTero, Cadent; Trios, 3Shape; and True Definition, 3M ESPE) and a dental lab scanner (D250, 3Shape). For each study model, 10 scans were performed per scanner to produce repeated measurements for the calculation of precision. The distance and angulation between the respective scanbodies were measured. The results of each scanning system were compared using analysis of variance, and post hoc Tukey test was conducted for a pairwise comparison of scanning devices.

RESULTS: The precision values of the scanbodies varied according to the distance between the scanbodies and the scanning device. A distance of a single tooth space and a jaw-traversing distance between scanbodies produced significantly different results for distance and angle measurements between the scanning systems ($P < .05$).

CONCLUSION: The precision of intraoral scanners and the dental lab scanner was significantly different. The precision of intraoral scanners decreased with an increasing distance between the scanbodies, whereas the precision of the dental lab scanner was independent of the distance between the scanbodies.

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In vitro comparison of the accuracy (trueness and precision) of six extraoral dental scanners with different scanning technologies

González de Villaumbrosia P, Martínez-Rus F, García-Orejas A, Salido MP, Pradíes G J Prosthet Dent 2016;116:543-550

STATEMENT OF PROBLEM: The fabrication of prosthetic restorations using computer-aided design and computer-aided manufacturing (CAD-CAM) procedures depends on scanning surfaces. However, limited information is available regarding the effect of extraoral scanning systems on the accuracy of the fabrication process.

PURPOSE: The purpose of this in vitro study was to evaluate and compare the accuracy (trueness and precision) and resolution of 6 CAD-CAM extraoral scanners by comparing features and scan technology.

MATERIAL AND METHODS: A master die was fabricated to simulate a dental preparation. The die was measured with a coordinate measuring machine (CMM) to obtain an accurate digital CAD reference model (CRM). The master die was then scanned 10 times with 3 structured light scanners, 2 laser scanners, and 1 contact scanner. The resulting laboratory scan data (LSD) were converted to a stereolithography (STL) format. The discrepancies between measurements were compared 3-dimensionally and at 3 selected areas of a virtual sagittal cut using CAD software. The Kruskal-Wallis 1-way analysis of variance was first performed to compare scanners and then to group data according to scanner type. The Spearman rank correlation coefficient was used to test the association between resolution and all other variables (α=.05).

RESULTS: For all 6 scanners, the mean resolution value was 133.9 (SD 93.9) points/mm2. The value for trueness was 38.8 (SD 6.2) ·m and for precision 45.5 (SD 4.8) μm. Trueness values were 20.3 μm (SD 32.7) at the axial surfaces, 46.6 ·m (SD 25.9) at the margin of the preparation, and 55.8 μm (SD 29.3) at the center of the occlusal groove. The ZENO Scan was the most accurate and precise of the 6 scanners for most of the variables measured.

CONCLUSIONS: The reliability of CAD-CAM scanners is not affected by a specific technology (light, laser, or contact) but by definite parameters. In addition, the entire scanning procedure is more accurate if the scanned surfaces are smooth and regular.

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In vitro evaluation of marginal, axial, and occlusal discrepancies in metal ceramic restorations produced with new technologies

Kocaağaoğlu H, Kılınç Hİ, Albayrak H, Kara M
J Prosthet Dent 2016;116:368-374

STATEMENT OF PROBLEM: Marginal and axial discrepancies of metal ceramic restorations are key to their long-term success. Little information is available for metal ceramic restorations fabricated with soft metal milling and laser sintering technologies.

PUROSE: The purpose of this in vitro study was to compare the marginal, axial, and occlusal discrepancies in single-unit metal ceramicrestorations fabricated with new production techniques with those in a single-unit restoration fabricated using a conventional technique.

MATERIAL AND METHODS: After the artificial tooth was prepared, impressions were made, and 40 dies were obtained. Dies were randomly divided into 4 groups (n=10). Cobalt-chromium (Co-Cr) cast (C), hard metal milled (HM), laser sintered (LS), and soft metalmilled (SM) copings were fabricated. Marginal, axial, and occlusal discrepancies of these copings were measured using the silicone replica technique before and after the application of veneering ceramic. Data were analyzed with repeated measurements 2-way ANOVAs and Bonferroni post hoc tests (α=.05).

RESULTS: Significant differences were found in the increase of marginal discrepancy after the application of veneering ceramic in the LS group (P=.016). However, no significant differences in marginal discrepancy were found whether veneering ceramic was applied to copings before or after in the other groups (P>.05). With regard to marginal and occlusal discrepancies, significant differences were found among the production techniques (P<.001 and P<.05, respectively). No significant differences in axial discrepancies were found among the groups (P>.05).

CONCLUSION: This in vitro study showed that metal ceramic restorations produced with HM and newly introduced SM techniques exhibited better marginal adaptations than those produced with the LS or C technique.

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Effect of cement space on the marginal fit of CAD-CAM-fabricated monolithic zirconia crowns

Kale E, Seker E, Yilmaz B, Özcelik TB
J Prosthet Dent 2016;116:890-895

STATEMENT OF PROBLEM: Monolithic zirconia crowns fabricated with computer-aided design and computer-aided manufacturing (CAD-CAM) have recently become a common practice for the restoration of posterior teeth. The marginal fit of monolithic zirconia crowns may be affected by different cement space parameters set in the CAD software. Information is scarce regarding the effect of cement space on the marginal fit of monolithic zirconia crowns fabricated with CAD-CAM technology.

PURPOSE: The purpose of this in vitro study was to evaluate the effect of cement space on the marginal fit of CAD-CAM-fabricated monolithic zirconia crowns before cementation.

MATERIAL AND METHODS: Fifteen right maxillary first molar typodont teeth with standardized anatomic preparations for complete-coverage ceramic crowns were scanned with a 3-dimensional laboratory scanner. Crowns were designed 3-dimensionally using software and then milled from presintered monolithic zirconia blocks in a computer numerical control dental milling machine. The cement space was set at 25 μm around the margins for all groups, and additional cement space starting 1 mm above the finish lines of the teeth was set at 30 μm for group 25-30, 40 μm for group 25-40, and 50 μm for group 25-50 in the CAD software. A total of 120 images (3 groups, 5 crowns per group, 8 sites per crown) were measured for vertical marginal discrepancy under a stereoscopic zoom microscope and the data were statistically analyzed with 1-way analysis of variance, followed by the Tukey honestly significant difference test (α=.05).

RESULTS: The results showed that different cement space values had statistically significant effect on the mean vertical marginal discrepancy value of tested crowns (P<.001). The mean marginal discrepancy was 85 μm for group 25-30, 68 μm for group 25-40, and 53 μm for group 25-50.

CONCLUSIONS: Within the limitations of this in vitro study, it was concluded that the cement space had a significant effect on the marginal fit of CAD-CAM-fabricated monolithic zirconia crowns. The marginal fit improved as the cement space decreased.

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In vitro evaluation of marginal, axial, and occlusal discrepancies in metal ceramic restorations produced with new technologies

Kocaağaoğlu H, Kılınç Hİ, Albayrak H, Kara M
J Prosthet Dent 2016;116:368-374

STATEMENT OF PROBLEM: Marginal and axial discrepancies of metal ceramic restorations are key to their long-term success. Little information is available for metal ceramic restorations fabricated with soft metal milling and laser sintering technologies.

PURPOSE: The purpose of this in vitro study was to compare the marginal, axial, and occlusal discrepancies in single-unit metal ceramicrestorations fabricated with new production techniques with those in a single-unit restoration fabricated using a conventional technique.

MATERIAL AND METHODS: After the artificial tooth was prepared, impressions were made, and 40 dies were obtained. Dies were randomly divided into 4 groups (n=10). Cobalt-chromium (Co-Cr) cast (C), hard metal milled (HM), laser sintered (LS), and soft metalmilled (SM) copings were fabricated. Marginal, axial, and occlusal discrepancies of these copings were measured using the silicone replica technique before and after the application of veneering ceramic. Data were analyzed with repeated measurements 2-way ANOVAs and Bonferroni post hoc tests (α=.05).

RESULTS: Significant differences were found in the increase of marginal discrepancy after the application of veneering ceramic in the LS group (P=.016). However, no significant differences in marginal discrepancy were found whether veneering ceramic was applied to copings before or after in the other groups (P>.05). With regard to marginal and occlusal discrepancies, significant differences were found among the production techniques (P<.001 and P<.05, respectively). No significant differences in axial discrepancies were found among the groups (P>.05).

CONCLUSION: This in vitro study showed that metal ceramic restorations produced with HM and newly introduced SM techniques exhibited better marginal adaptations than those produced with the LS or C technique.

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Fit of e.max crowns fabricated using conventional and CAD/CAM technology: A comparative study

Miwa A, Kori H, Tsukiyama Y, Kuwatsuru R, Matsushita Y, Koyano K
Int J Prosthodont 2016;29:602-607

PURPOSE: The aim of this study was to examine the fit accuracy of e.max crowns by investigating marginal and internal gaps.

MATERIALS AND METHODS: In experiment 1, 60 e.max computer-aided design/computer-assisted manufacture (CAD/CAM) crowns were manufactured. The crowns were fabricated using optical scanning of artificial teeth (Op group) or scanning of a plaster model following a silicone impression (M group). Cement space settings of 90, 120, and 150 µm were applied. Marginal and internal crown gaps were compared among six conditions (Op90, Op120, Op150, M90, M120, M150). In experiment 2, e.max CAD crowns from the Op group (CADop group) and the M group (CADm group) were compared with e.max Press crowns (Press group) by measuring marginal and internal gaps of the crowns using Scheffe multiple comparison test. The level of significance was set at .05.

RESULTS: In experiment 1, the marginal gap of the Op90 group was significantly higher than that of the Op120 and Op150 groups. The marginal gap of the M90 group was significantly higher than those of the M120 and M150 groups, and the internal gap of the M90 group was significantly lower than that of the M150 group. Although there was no statistically significant difference in marginal gap among the three groups, the internal gap of the CADm group was significantly higher than the Press group.

CONCLUSIONS: Although the variation in cement space settings and fabrication techniques affected accuracy, e.max CAD crowns fabricated using optical scanning of melamine teeth achieved a clinically acceptable fit.

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Fit of lithium disilicate crowns fabricated from conventional and digital impressions assessed with micro-CT

Kim JH, Jeong JH, Lee JH, Cho HW
J Prosthet Dent 2016;116:551-557

STATEMENT OF PROBLEM: Although the number of lithium disilicate crowns fabricated with computer-aided design and computer-aided manufacturing (CAD-CAM) technology has increased, the accuracy of the prostheses produced by using digital pathways remains unknown.

PURPOSE: The purpose of this in vitro study was to compare marginal and internal discrepancies of lithium disilicate crowns fabricated from digital and conventional impressions.

MATERIAL AND METHODS: A typodont mandibular first molar was prepared for a lithium disilicate crown, and 20 duplicate dies were fabricated by milling poly(methyl methacrylate) resin blocks from laboratory scans. Four groups of 5 lithium disilicate crowns each were created by using a CS3500 (Carestream Dental) intraoral digital impression; Trios (3shape) intraoral digital impression; Ceramill Map400 (Amann Girrbach) extraoral digital impression; and a heat-press technique as a control group. All of the IPS e.max CAD (Ivoclar Vivadent AG) crowns were produced using a 5-axis milling engine (Ceramill Motion2). The lithium disilicate crowns were cemented with zinc phosphate cement under finger pressure. Marginal and internal discrepancies were measured using micro-computed tomography (SkyScan1172). One-way ANOVAs with the Tukey honest significant differences test were used for statistical analysis of the data (α=.05).

RESULTS: The mean marginal discrepancies of CS3500 lithium disilicate crowns were 129.6 μm, 200.9 μm for Ceramill Map400, and 207.8 μm 176.1 μm for the heat-press technique; and the internal discrepancy volumes for CS3500 were 25.3 mm^3, 40.7 mm^3 for Trios, 29.1 mm^3 for Ceramill Map400, and 29.1 and 31.4 mm^3 for the heat-press technique. The CS3500 group showed a significantly better marginal discrepancy than the other 3 groups and a smaller internal discrepancy volume than the Trios group ($P<.05$).

CONCLUSIONS: Significant differences were found between IPS e.max CAD crowns produced using 2 intraoral digital impressions, whereas no differences were found between IPS e.max CAD crowns produced from an extraoral digital impression and IPS e.max Press crowns produced using a heat-press technique.

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Factors influencing the dimensional accuracy of 3D-printed full-coverage dental restorations using stereolithography technology

Alharbi N, Osman RB, Wismeijer D
Int J Prosthodont 2016;29:503-510

PURPOSE: The aim of the present study was to evaluate the effect of the build angle and the support configuration (thick versus thin support) on the dimensional accuracy of 3D-printed full-coverage dental restorations.

MATERIALS AND METHODS: A full-coverage dental crown was digitally designed and 3D-printed using stereolithography-additive manufacturing (SLA-AM) technology. Nine different angles were used during the build process: 90, 120, 135, 150, 180, 210, 225, 240, and 270 degrees. In each angle, the crown was printed using a thin and a thick support type, resulting in 18 specimens. The specimens were digitally scanned using a high resolution optical surface scanner (IScan D104i; Imetric 3D). The dimensional accuracy was evaluated by digital subtraction technique. The 3D digital files of the scanned printed crowns (test model), exported in standard tessellation language (STL) format, were superimposed with the STL file of the designed crown (reference model) using Geomagic Studio 2014 (3D Systems).

RESULTS: The root mean square estimate value and color map results suggest that the build angle and support structure configuration have an influence on the dimensional accuracy of 3D-printed crown restorations. Among the tested angles, the 120-degree build angle showed a minimal deviation of 0.029 mm for thin support and 0.031 mm for thick support, indicating an accurate fit between the test and reference models. Furthermore, the deviation pattern observed in the color map was homogenously distributed and located further away from the critical marginal area.

CONCLUSIONS: Within the limitations of this study, the selection of build angle should offer the crown the highest dimensional accuracy and self-supported geometry. This allows for the smallest necessary support surface area and decreases the time needed for finishing and polishing. These properties were mostly observed with a build angle of 120 degrees combined with a thin support type.

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An in vitro study of factors influencing the performance of digital intraoral impressions operating on active wavefront sampling technology with multiple implants in the edentulous maxilla

Gimenez-Gonzalez B, Hassan B, Özcan M, Pradíes G
J Prosthodont. 2017;26(8):650-655. doi: 10.1111/jopr.12457

PURPOSE: To evaluate the performance (accuracy and repeatability) and the factors affecting the clinical performance of a recently released intraoral scanner based on active wavefront sampling technology.

MATERIAL AND METHODS: A single resin model of an edentulous maxilla fitted with six implants inserted at various depths and angulations was measured with a coordinated measuring machine (CMM) at 3 to 5 µm, and this acted as the "true," or reference, values of the study. Six corresponding cylindrical PEEK scanbodies were then mounted onto the implants, and four calibrated observers independently repeated the digital intraoral scan five times with a True Definition (TrueDef) scanner. Using implant position #15 as a reference, five linear and angular measurements were compared with the reference values (CMM), and the data were analyzed via one-way ANOVA and two-sample t-test.

RESULTS: Mean linear and angular deviations for the TrueDef from CMM measurements were from 5.38 ± 12.61 µm to -26.97 ± 50.56 µm and from 0.16° ± 0.04° to -0.43° ± 0.1°, respectively. Experienced observers performed significantly better than inexperienced ones (p = 0.006), and scan distance (quadrant) significantly affected scanning accuracy (p = 0.003). Visible length of the scanbody affected measurement accuracy (p = 0.0001), while implant angulation did not (p = 0.757).

CONCLUSIONS: The TrueDef scanner provides measurements within clinically accepted limits. Yet scanbody visibility, observer experience, and scan length remain relevant factors affecting accuracy.

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An in vitro comparison of the marginal adaptation accuracy of CAD/CAM restorations using different impression systems

Shembesh M, Ali A, Finkelman M, Weber HP, Zandparsa R
J Prosthodont. 2017;26(7):581-586. doi: 10.1111/jopr.12446.

PURPOSE: To compare the marginal adaptation of 3-unit zirconia fixed dental prostheses (FDPs) obtained from intraoral digital scanners (Lava True Definition, Cadent iTero), scanning of a conventional silicone impression, and the resulting master cast with an extraoral scanner (3Shape lab scanner).

MATERIAL AND METHODS: One reference model was fabricated from intact, non-carious, unrestored human mandibular left first premolar and first molar teeth (teeth #19 and 21), prepared for a three-unit all-ceramic FDP. Impressions of the reference model were obtained using four impression systems (n = 10), group 1 (PVS impression scan), group 2 (stone cast scan), group 3 (Cadent iTero), and group 4 (Lava True Defintion). Then the three-unit zirconia FDPs were milled. Marginal adaptation of the zirconia FDPs was evaluated using an optical comparator at four points on each abutment. The mean (SD) was reported for each group. One-way ANOVA was used to assess the statistical significance of the results, with post hoc tests conducted via Tukey's HSD. $p < 0.05$ was considered statistically significant. All analyses were done using SPSS 22.0.

RESULTS: The mean (SD) marginal gaps for the recorded data from highest to lowest were silicone impression scans 81.4 µm (6.8), Cadent iTero scan 62.4 µm (5.0), master cast scan 50.2 µm (6.1), and Lava True definition scan 26.6 µm (4.7). One-way ANOVA revealed significant differences ($p < 0.001$) in the mean marginal gap among the groups. The Tukey's HSD tests demonstrated that the differences between all groups (silicone impression scan, master cast scan, Lava True definition scan, iTero Cadent scan) were statistically significant (all $p < 0.001$). On the basis of the criterion of 120 µm as the limit of clinical acceptance, all marginal discrepancy values of all groups were clinically acceptable.

CONCLUSIONS: Within the confines of this in vitro study, it can be concluded that the marginal gap of all impression techniques was within the acceptable clinical limit (120 µm). Group 4 (Lava True Defintion) showed the lowest average gap among all groups followed by group 2 (stone cast scan), group 3 (Cadent iTero), and group 1 (PVS impression scan); these differences were statistically significant.

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Comparison of maximum intercuspal contacts of articulated casts and virtual casts requiring posterior fixed partial dentures

Arslan Y, Bankoglu Güngör M, Karakoca Nemli S, Kökdogan Boyacı B, Aydın C
J Prosthodont. 2017;26(7):594-598. doi: 10.1111/jopr.12439.

PURPOSE: To evaluate the accuracy of the CEREC CAD/CAM system in reproducing the maximum intercuspal contacts of the casts, which include posterior teeth preparation for a fixed partial denture (FPD).

MATERIAL AND METHODS: Ten pairs of gypsum casts were mounted in articulators in maximum intercuspal position (MIP) to serve as patient simulation models. Tooth #19 was removed from the cast. Occlusal contacts in MIP were identified with articulating paper, and digital impressions of the casts with unprepared teeth and buccal images in MIP were taken. Teeth #18 and #20 were prepared for an FPD, and full- and half-arch digital impressions of the casts with prepared teeth and buccal images from different sides were taken. In each situation, screenshot images of the virtual casts with occlusal contacts were saved as JPEG files. The proportions of congruence of virtual contacts with cast contacts were analyzed by superimposing screenshot images of the virtual casts onto the screenshot images of the casts with the indicated occlusal contacts in a transparent manner using an image-processing program. The data were statistically analyzed with a paired t-test.

RESULTS: The highest percentages of virtually indicated contacts identical to the cast contacts were observed in non-prepared full-arch digital impressions. Comparison of full-arch impressions taken before and after tooth preparation showed no difference for congruence even if the buccal image was taken from the contralateral or ipsilateral side ($p > 0.05$). After tooth preparation, comparing full- and half-arch digital impressions revealed that half-arch impression showed significantly lower percentages of identical contacts ($p < 0.05$). When comparing the buccal image side, no significant difference was detected between ipsilateral and contralateral images both for non-prepared and prepared casts ($p > 0.05$).

CONCLUSION: When there is no posterior antagonist contact following tooth preparation for an FPD, taking a full-arch digital impression and designing the restoration on full-arch virtual models can be advocated.

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Marginal gap of milled versus cast gold restorations

Johnson R, Verrett R, Haney S, Mansueto M, Challa S
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PURPOSE: This in vitro study evaluated and compared the vertical marginal gap of cast and milled full coverage gold copings using two margin designs (chamfer and chamfer bevel) before and after fitting adjustments.

MATERIALS AND METHODS: Ten impressions were made of two metal master dies (one chamfer margin, one chamfer-bevel margin) and poured twice in Type IV stone. The 20 subsequent casts with 40 dies were split into four groups (n = 10); cast gold bevel, cast gold chamfer, milled gold bevel, and milled gold chamfer groups. The cast specimens received approximately 40 µm die relief no closer than 1 mm from the finish line. Cast copings were hand waxed, cast in a high noble gold alloy, chemically divested, and the sprues were removed. For milled gold copings, casts were scanned and copings designed using 3shape D900 scanner and software. Parameters were set to approximate analog fabrication (cement gap = 0.01 mm; extra cement gap = 0.04 mm, drill radius = 0.65 mm). Copings were milled from the same high noble alloy. All copings were seated on their respective master die in a custom scanning jig and measured using a measuring microscope at 90x (60 measurements per specimen, 15 per surface). Following initial measurements, all copings were adjusted on stone dies. The number of adjustment cycles was recorded and post-adjustment measurements were made using the same method. Data were analyzed using independent and paired t-tests.

RESULTS: Milled gold copings with a beveled margin (11.7 ± 20.4 µm) had a significantly ($p < 0.05$) smaller marginal gap than cast gold copings with a beveled margin (43.6 ± 46.8 µm) after adjustment. Cast gold copings with a chamfer margin (22.7 ± 24.7 µm) had a significantly ($p < 0.05$) smaller marginal gap than milled gold copings with a chamfer margin (27.9 ± 31.6 µm) following adjustments. Adjustments significantly decreased marginal gap for both cast groups ($p < 0.05$) and the milled chamfer bevel group ($p < 0.05$) but had no significant effect on the milled chamfer group.

CONCLUSIONS: Within the limitations of this study, results indicate that gold restorations milled with the tested parameters provide a vertical marginal gap that is an acceptable alternative to traditional gold crown casting techniques.

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Effect of split-file digital workflow on crown margin adaptation

Sheridan RR, Verrett R, Haney S, Schoolfield J
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PURPOSE: Computer-aided design/computer-aided manufacturing (CAD/CAM) is becoming increasingly integrated into dental practice workflow at a pace that exceeds scientific validation. The aim of this study is to evaluate a complete digital split-file protocol relative to segmental digital and analog techniques for restoring a single maxillary anterior edentulous space with custom abutment and crown.

MATERIALS AND METHODS: Four treatment workflows were assessed: complete digital (CD), segmental digital (SD), milled wax (AM), and heat pressed and hand waxed (AH) and heat pressed. The CD workflow "split" an abutment and crown into separate files to fabricate a zirconia abutment and both zirconia/lithium disilicate crown restorations. The SD workflow scanned the existing abutment for design of segmental restorations in zirconia, lithium disilicate, and milled wax (AM). The AH specimens were conventionally hand waxed. Both the AM and AH specimens were heat pressed with lithium disilicate. All restorations were evaluated with standardized measurements using scanning electron microscopy (SEM) as manufactured without internal adjustments and after manual adjustment. The number of adjustments, adjustment time, and location of adjustments were recorded. One-way ANOVA with repeated measures was used to report geometric means with 95% confidence intervals.

RESULTS: The mean marginal gap after adjustment of the CD group was 69 μm, with an upper bound (UB) of 79 μm and a lower bound (LB) of 60 ·m. SD group mean was 26 μm with an UB of 31 μm and LB of 22 μm. The AM group mean was 32 μm, with an UB of 49 μm and a LB of 20 μm; AH group mean of 26 μm with an UB of 34 μm and a LB of 20 μm. The SD, AM, and AH workflows were statistically similar ($p = 1.000$), and the CD workflow was statistically greater than the other three ($p < 0.001$).

CONCLUSIONS: The split-file (CD) protocol results in marginal gap size within clinical standards after adjustment; however, 52 of the 60 digitally produced restorations showed a horizontal marginal offset that required adjustment for proper contours.

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Effect of digital impressions and production protocols on the adaptation of zirconia copings

Kocaağaoğlu H, Kılınç HI, Albayrak H
J Prosthet Dent 2017;117:102-108

STATEMENT OF PROBLEM: Proper marginal, axial, and occlusal adaptation of dental restorations is essential for their long-term success. Production protocols including digital impression systems have been developed, but little information is available on the adaptation of zirconia restorations produced via them.

PURPOSE: The purpose of this in vitro study was to compare the effects of digital impression protocols on the marginal, axial, and occlusal adaptation of zirconia copings.

MATERIAL AND METHODS: Thirty extracted human maxillary premolar teeth without caries or defects were used. The teeth were prepared for zirconia crowns and randomly divided into 3 groups. Zirconia copings were designed at a thickness of 0.5 mm with 30 ·m of simulated die spacer starting 1 mm from the margin of preparations. They were produced using computer-aided design-computer-aided manufacture (CAD-CAM) protocol with a conventional impression (group Cn) and 2 different production protocols with digital impressions (group C) and group Tr. The marginal, axial, and occlusal discrepancies of these copings were measured using the silicone replica technique with stereomicroscopy at x50 magnification, and the data were analyzed with 1-way ANOVAs (α=.05).

RESULTS: The mean marginal discrepancy values were 85.6 μm for group Cn, 58.7 μm for group C, and 47.7 μm for the Tr group. Significant differences were found among the production protocols in marginal, axial, and occlusal discrepancies (P<.05). Copings fabricated with the aid of digital impressions had significantly fewer marginal discrepancies than those of group Cn (P<.05). Group Tr exhibited the lowest marginal discrepancy, whereas groups Cn and C demonstrated similar axial adaptations (P>.05), and group Tr revealed the lowest axial discrepancy (P<.05). With regard to the occlusal discrepancy evaluation, group Tr had the lowest discrepancy. However, no significant differences was found between groups C and Cn (P>.05).

CONCLUSIONS: The copings produced with the aid of digital impression systems exhibited better marginal and occlusal adaptation than those of the copings produced with the aid of conventional impression.

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Quality evaluation of zirconium dioxide frameworks produced in five dental laboratories from different countries

Schneebeli E, Brägger U, Scherrer SS, Keller A, Wittneben JG, Hicklin SP
J Prosthodont 2017;26:399-409

PURPOSE: The aim of this study was to assess and compare quality as well as economic aspects of CAD/CAM high strength ceramic three-unit FDP frameworks ordered from dental laboratories located in emerging countries and Switzerland.

MATERIAL AND METHODS: The master casts of six cases were sent to five dental laboratories located in Thailand (Bangkok), China (Peking and Shenzhen), Turkey (Izmir), and Switzerland (Bern). Each laboratory was using a different CAD/CAM system. The clinical fit of the frameworks was qualitatively assessed, and the thickness of the framework material, the connector height, the width, and the diameter were evaluated using a measuring sensor. The analysis of the internal fit of the frameworks was performed by means of a replica technique, whereas the inner and outer surfaces of the frameworks were evaluated for traces of postprocessing and damage to the intaglio surface with light and electronic microscopes. Groups (dental laboratories and cases) were compared for statistically significant differences using Mann-Whitney U-tests after Bonferroni correction.

RESULTS: An acceptable clinical fit was found at 97.9% of the margins produced in laboratory E, 87.5% in B, 93.7% in C, 79.2% in A, and 62.5% in D. The mean framework thicknesses were not statistically significantly different for the premolar regions; however, for the molar area 4/8 of the evaluated sites were statistically significantly different. Circumference, surface, and width of the connectors produced in the different laboratories were statistically significantly different but not the height. There were great differences in the designs for the pontic and connector regions, and some of the frameworks would not be recommended for clinical use. Traces of heavy postprocessing were found in frameworks from some of the laboratories. The prices per framework ranged from US$177 to US$896.

CONCLUSIONS: By ordering laboratory work in developing countries, a considerable price reduction was obtained compared to the price level in Switzerland. Despite the use of the standardized CAD/CAM chains of production in all laboratories, a large variability in the quality aspects, such as clinical marginal fit, connector and pontic design, as well as post processing traces was noted. Recommended sound handling of post processing was not applied in all laboratories. Dentists should be aware of the true and factitious advantages of CAD/CAM production chains and not lose control over the process.

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Marginal and internal fit of metal copings fabricated with rapid prototyping and conventional waxing

Farjood E, Vojdani M, Torabi K, Khaledi AA
J Prosthet Dent 2017;117:164-170

STATEMENT OF PROBLEM: Given the limitations of conventional waxing, computer-aided design and computer-aided manufacturing (CAD-CAM) technologies have been developed as alternative methods of making patterns.

PURPOSE: The purpose of this in vitro study was to compare the marginal and internal fit of metal copings derived from wax patterns fabricated by rapid prototyping (RP) to those created by the conventional handmade technique.

MATERIAL AND METHODS: Twenty-four standardized brass dies were milled and divided into 2 groups (n=12) according to the wax pattern fabrication method. The CAD-RP group was assigned to the experimental group, and the conventional group to the control group. The cross-sectional technique was used to assess the marginal and internal discrepancies at 15 points on the master die by using a digital microscope. An independent t test was used for statistical analysis (α=.01).

RESULTS: The CAD-RP group had a total mean (±SD) for absolute marginal discrepancy of 117.1 (±11.5) μm and a mean marginal discrepancy of 89.8 (±8.3) μm. The conventional group had an absolute marginal discrepancy 88.1 (±10.7) μm and a mean marginal discrepancy of 69.5 (±15.6) μm. The overall mean (±SD) of the total internal discrepancy, separately calculated as the axial internal discrepancy and occlusal internal discrepancy, was 95.9 (±8.0) μm for the CAD-RP group and 76.9 (±10.2) μm for the conventional group. The independent t test results showed significant differences between the 2 groups. The CAD-RP group had larger discrepancies at all measured areas than the conventional group, which was statistically significant (P<.01).

CONCLUSIONS: Within the limitations of this in vitro study, the conventional method of wax pattern fabrication produced copings with better marginal and internal fit than the CAD-RP method. However, the marginal and internal fit for both group

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Influence of object translucency on the scanning accuracy of a powder-free intraoral scanner: A laboratory study

Li H, Lyu P, Wang Y, Sun Y
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STATEMENT OF PROBLEM: Limited information is available regarding the influence of object translucency on the scanning accuracy of a powder-free intraoral scanner.

PURPOSE: The purpose of this in vitro study was to evaluate the scanning accuracy of a confocal microscopy principle powder-free intraoral scanner on ceramic copings and to analyze the relationship between scanning accuracy and object translucency.

MATERIAL AND METHODS: Six slice specimens (12·10 mm) and 6 offset copings (1.00-mm thickness) were made from different translucent homogeneous ceramic blocks (CEREC Blocs, SO-M to S5-M, highest to lowest translucency). The primary sintered zirconia offset coping was produced in the same way as the control. Optical parameters related to the translucency of each slice were measured with a spectrophotometer. Three-dimensional (3D) datasets of the surface morphology of offset copings were obtained by using the intraoral scanner. The same white wax resin bases were used for registration. Quantitative parameters of scanning trueness and precision were measured. One-way ANOVA was used to analyze the values of each parameter among the 6 ceramic blocks. Bivariate correlation was used to analyze the relationships between each parameter of scanning accuracy and translucency (α=.05).

RESULTS: Translucent copings showed a positive 3D bias (SO-M to S5-M: 0.149 ±0.038 mm to 0.068 ±0.020 mm), a narrower collar diameter (Dd=-0.067 mm), larger convergence angle ($\Delta\Phi$=2.79 degrees), and larger curvature radius of the internal gingivoaxial corner ($\Delta\rho$=0.236 mm). The smaller the percentage sum of scattering and absorption, the greater was the occurrence of scanning bias (r=-0.918) and curvature (r=-0.935) decrease.

CONCLUSIONS: Use of the tested powder-free intraoral scanner, higher translucency objects (greater translucency than S1-M/A1C) resulted in lower scanning accuracy and morphological changes. Therefore, more suitable methods of measurement are still required.

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Randomized controlled within-subject evaluation of digital and conventional workflows for the fabrication of lithium disilicate single crowns. Part III: marginal and internal fit

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J Prosthet Dent 2017;117:354-362

STATEMENT OF PROBLEM: Trials comparing the overall performance of digital with that of conventional workflows in restorative dentistry are needed.

PURPOSE: The purpose of the third part of a series of investigations was to test whether the marginal and internal fit of monolithic crowns fabricated with fully digital workflows differed from that of crowns fabricated with the conventional workflow.

MATERIAL AND METHODS: In each of 10 participants, 5 monolithic lithium disilicate crowns were fabricated for the same abutment tooth according to a randomly generated sequence. Digital workflows were applied for the fabrication of 4 crowns using the Lava, iTero, Cerec inLab, and Cerec infinident systems. The conventional workflow included a polyvinyl siloxane impression, manual waxing, and heat-press technique. The discrepancy between the crown and the tooth was registered using the replica technique with polyvinyl siloxane material. The dimensions of the marginal discrepancy (Discrepancymarginal) and the internal discrepancy in 4 different regions of interest (Discrepancyshoulder, Discrepancyaxial, Discrepancycusp, and Discrepancyocclusal) were assessed using light microscopy. Post hoc Student t test with Bonferroni correction was applied to detect differences (α=.05).

RESULTS: Discrepancymarginal was 83.6 ±51.1 ·m for the Cerec infinident, 90.4 ±66.1 αm for the conventional, 94.3 ffl58.3 αm for the Lava, 127.8 ffl58.3 ·m for the iTero, and 141.5 ±106.2 αm for the Cerec inLab workflow. The differences between the treatment modalities were not statistically significant (P>.05). Discrepancyshoulder was 82.2 ±42.4 αm for the Cerec infinident, 97.2 ±63.8 αm for the conventional, 103.4 ±52.0 αm for the Lava, 133.5 ±73.0 αm for the iTero, and 140.0 ±86.6 αm for the Cerec inLab workflow. Only the differences between the Cerec infinident and the Cerec inLab were statistically significant (P=.036). The conventionally fabricatedcrowns revealed significantly lower values in Discrepancycusp and Discrepancyocclusal than all the crowns fabricated with digitalworkflows (P<.05).

CONCLUSIONS: In terms of marginal crown fit, no significant differences were found between the conventional and digital workflows for the fabrication of monolithic lithium disilicate crowns. In the occlusal regions, the conventionally manufactured crowns revealed better fit than the digitally fabricated crowns. Chairside milling resulted in less favorable crown fit than centralized milling production.

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Accuracy of single-abutment digital cast obtained using intraoral and cast scanners

Lee JJ, Jeong ID, Park JY, Jeon JH, Kim JH, Kim WC
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STATEMENT OF PROBLEM: Scanners are frequently used in the fabrication of dental prostheses. However, the accuracy of these scanners is variable, and little information is available.

PURPOSE: The purpose of this in vitro study was to compare the accuracy of cast scanners with that of intraoral scanners by using different image impression techniques.

MATERIAL AND METHODS: A poly(methyl methacrylate) master model was fabricated to replicate a maxillary first molar single-abutmenttooth model. The master model was scanned with an accurate engineering scanner to obtain a true value (n=1) and with 2 intraoralscanners (CEREC Bluecam and CEREC Omnicam; n=6 each). The cast scanner scanned the master model and duplicated the dental stone cast from the master model (n=6). The trueness and precision of the data were measured using a 3-dimensional analysis program. The Kruskal-Wallis test was used to compare the different sets of scanning data, followed by a post hoc Mann-Whitney U test with a significance level modified by Bonferroni correction (α/6=.0083). The type 1 error level (α) was set at .05.

RESULTS: The trueness value (root mean square: mean ±standard deviation) was 17.5 ±1.8 ·m for the Bluecam, 13.8 ±1.4 μm for the Omnicam, 17.4 ±1.7 μm for cast scanner 1, and 12.3 ±0.1 μm for cast scanner 2. The differences between the Bluecam and the castscanner 1 and between the Omnicam and the cast scanner 2 were not statistically significant (P>.0083), but a statistically significant difference was found between all the other pairs (P<.0083). The precision of the scanners was 12.7 ±2.6 μm for the Bluecam, 12.5 ±3.7 μm for the Omnicam, 9.2 ±1.2 μm for cast scanner 1, and 6.9 ±2.6 μm for cast scanner 2. The differences between Bluecam and Omnicam and between Omnicam and cast scanner 1 were not statistically significant (P>.0083), but there was a statistically significant difference between all the other pairs (P<.0083).

CONCLUSIONS: An Omnicam in video image impression had better trueness than a cast scanner but with a similar level of precision.

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Marginal and internal fit of CAD-CAM-fabricated composite resin and ceramic crowns scanned by 2 intraoral cameras

de Paula Silveira AC, Chaves SB, Hilgert LA, Ribeiro AP
J Prosthet Dent 2017;117:386-392

STATEMENT OF PROBLEM: The precision of fit of chairside computer-aided design and computer-aided manufacturing (CAD-CAM) complete crowns is affected by digital impression and restorative material.

PURPOSE: The purpose of this in vitro study was to evaluate by microcomputed tomography (·CT) the marginal and internal adaptation of composite resin and ceramic complete crowns fabricated with 2 different intraoral cameras and 2 restorative materials.

MATERIAL AND METHODS: Ten extracted human third molars received crown preparations. For each prepared molar, 2 digital impressions were made with different intraoral cameras of the CEREC system, Bluecam and Omnicam. Four groups were formed: LB (Lava Ultimate+Bluecam), EB (Emax+Bluecam), LO (Lava Ultimate+Omnicam), and EO (Emax+Omnicam). Before measuring the precision of fit, all crowns were stabilized with a silicone material. Each unit (crown + prepared tooth) was imaged with ·CT, and marginal and internal discrepancies were analyzed. For the 2D analysis, 120 measurements were made of each crown for marginaladaptation, 20 for marginal discrepancy (MD), and 20 for absolute marginal discrepancy (AMD); and for internal adaptation, 40 for axial space (AS) and 40 for occlusal space (OS). After reconstructing the 3D images, the average internal space (AIS) was calculated by dividing the total volume of the internal space by the contact surface. Data were analyzed with 2-way ANOVA and quantile regression.

RESULTS: Regarding marginal adaptation, no significant differences were observed among groups. For internal adaptation measured in the 2D evaluation, a significant difference was observed between LO and EO for the AS variable (Mann-Whitney test; P<.008). In assessment of AIS by the 3D reconstruction, LB presented significantly lower values than the other groups (Tukey post hoc test; P<.05). Bluecam presented lower values of AIS than Omnicam, and composite resin crowns showed less discrepancy than did ceramic crowns.

CONCLUSIONS: The marginal adaptations assessed in all groups showed values within the clinically accepted range. Moreover, the composite resin blocks associated with the Bluecam intraoral camera demonstrated the best results for AIS compared with those of the other groups.

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Marginal fit and photoelastic stress analysis of CAD-CAM and overcast 3-unit implant-supported frameworks

Presotto AG, Bhering CL, Mesquita MF, Barão VA
J Prosthet Dent 2017;117:373-379

STATEMENT OF PROBLEM: Several studies have shown the superiority of computer-assisted design and computer-assisted manufacturing (CAD-CAM) technology compared with conventional casting. However, an advanced technology exists for casting procedures (the overcasting technique), which may serve as an acceptable and affordable alternative to CAD-CAM technology for fabricating 3-unit implant-supported fixed dental prostheses (FDPs).

PURPOSE: The purpose of this in vitro study was to evaluate, using quantitative photoelastic analysis, the effect of the prosthetic framework fabrication method (CAD-CAM and overcasting) on the marginal fit and stress transmitted to implants. The correlation between marginal fit and stress was also investigated.

MATERIAL AND METHODS: Three-unit implant-supported FDP frameworks were made using the CAD-CAM (n=10) and overcasting (n=10) methods. The frameworks were waxed to simulate a mandibular first premolar (PM region) to first molar (M region) FDP using overcast mini-abutment cylinders. The wax patterns were overcast (overcast experimental group) or scanned to obtain the frameworks (CAD-CAM control group). All frameworks were fabricated from cobalt-chromium (CoCr) alloy. The marginal fit was analyzed according to the single-screw test protocol, obtaining an average value for each region (M and PM) and each framework. The frameworks were tightened for the photoelastic model with standardized 10-Ncm torque. Stress was measured by quantitative photoelastic analysis. The results were submitted to the Student t test, 2-way ANOVA, and Pearson correlation test (α=.05).

RESULTS: The framework fabrication method (FM) and evaluation site (ES; M and PM regions) did not affect the marginal fit values (P=.559 for FM and P=.065 for ES) and stress (P=.685 for FM and P=.468 for ES) in the implant-supported system. Positive correlations between marginal fit and stress were observed (CAD-CAM: r=0.922; P<.001; overcast: r=0.908; P<.001).

CONCLUSIONS: CAD-CAM and overcasting methods present similar marginal fit and stress values for 3-unit FDP frameworks. The decreased marginal fit of frameworks induces greater stress in the implant-supported system.

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Internal fit of single crowns produced by CAD-CAM and lost-wax metal casting technique assessed by the triple-scan protocol

Dahl BE, Rønold HJ, Dahl JE
J Prosthet Dent 2017;117:400-404

STATEMENT OF PROBLEM: Whether single crowns produced by computer-aided design and computer-aided manufacturing (CAD-CAM) have an internal fit comparable to crowns made by lost-wax metal casting technique is unknown.

PURPOSE: The purpose of this in vitro study was to compare the internal fit of single crowns produced with the lost-wax and metal casting technique with that of single crowns produced with the CAD-CAM technique.

MATERIAL AND METHODS: The internal fit of 5 groups of single crowns produced with the CAD-CAM technique was compared with that of single crowns produced in cobalt-chromium with the conventional lost-wax and metal casting technique. Comparison was performed using the triple-scan protocol; scans of the master model, the crown on the master model, and the intaglio of the crown were superimposed and analyzed with computer software. The 5 groups were milled presintered zirconia, milled hot isostatic pressed zirconia, milled lithium disilicate, milled cobalt-chromium, and laser-sintered cobalt-chromium.

RESULTS: The cement space in both the mesiodistal and buccopalatal directions was statistically smaller ($P<.05$) for crowns made by the conventional lost-wax and metal casting technique compared with that of crowns produced by the CAD-CAM technique.

CONCLUSIONS: Single crowns made using the conventional lost-wax and metal casting technique have better internal fit than crowns produced using the CAD-CAM technique.

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A microcomputed tomography evaluation of the marginal fit of cobalt-chromium alloy copings fabricated by new manufacturing techniques and alloy systems

Kim EH, Lee DH, Kwon SM, Kwon TY
J Prosthet Dent 2017;117:393-399

STATEMENT OF PROBLEM: Although new digital manufacturing techniques are attracting interest in dentistry, few studies have comprehensively investigated the marginal fit of fixed dental prostheses fabricated with such techniques.

PURPOSE: The purpose of this in vitro microcomputed tomography (μCT) study was to evaluate the marginal fit of cobalt-chromium (Co-Cr) alloy copings fabricated by casting and 3 different computer-aided design and computer-aided manufacturing (CAD-CAM)-based processing techniques and alloy systems.

MATERIAL AND METHODS: Single Co-Cr metal crowns were fabricated using 4 different manufacturing techniques: casting (control), milling, selective laser melting, and milling/sintering. Two different commercial alloy systems were used for each fabrication technique (a total of 8 groups; n=10 for each group). The marginal discrepancy and absolute marginal discrepancy of the crowns were determined with μCT. For each specimen, the values were determined from 4 different regions (sagittal buccal, sagittal lingual, coronal mesial, and coronal distal) by using imaging software and recorded as the average of the 4 readings. For each parameter, the results were statistically compared with 2-way analysis of variance and appropriate post hoc analysis (using Tukey or Student t test) (α=.05).

RESULTS: The milling and selective laser melting groups showed significantly larger marginal discrepancies than the control groups (70.4 ±12.0 and 65.3 ±10.1 ·m, respectively; P<.001), whereas the milling/sintering groups exhibited significantly smaller values than the controls (P=.004). The milling groups showed significantly larger absolute marginal discrepancy than the control groups (137.4 ±29.0 and 139.2 ±18.9 ·m, respectively; P<.05). In the selective laser melting and milling/sintering groups, the absolute marginal discrepancy values were material-specific (P<.05). Nonetheless, the milling/sintering groups yielded statistically comparable (P=.935) or smaller (P<.001) absolute marginal discrepancies to the control groups.

CONCLUSIONS: The findings of this in vitro ·CT study showed that the marginal fit values of the Co-Cr alloy greatly depended on the fabrication methods and, occasionally, the alloy systems. Fixed dental prostheses produced by using the milling/sintering technique can be considered clinically acceptable in terms of marginal fit.

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Fit of pressed crowns fabricated from two CAD-CAM wax pattern process plans: A comparative in vitro study

Shamseddine L, Mortada R, Rifai K, Chidiac JJ
J Prosthet Dent 2017;118:49-54

STATEMENT OF PROBLEM: Subtractive and additive computer-aided design and computer-aided manufacturing (CAD-CAM) wax pattern processing are 2 methods of fabricating a pressed ceramic crown. Whether a subtractive milled wax pattern or a pattern from the micro-stereolithography additive process produces lithium disilicate crowns with better marginal and internal fit is unclear.

MATERIAL AND METHODS: Ten silicone impressions were made for a prepared canine tooth. Each die received 2 lithium disilicate (IPS e.max) copings, 1 from milled wax blocks and 1 from additive wax. The replica technique was used to measure the fit by scanning electron microscopy at ·80 magnification. Collected data were analyzed using the paired Student t test for the marginal and internal fit. For the occlusal fit, the difference in scores did not follow a normal distribution, and the Wilcoxon signed rank test was used (α=.05).

RESULTS: The mean marginal, axial, and occlusal fit showed no significant differences when the 2 CAD-CAM manufacturing processes were compared (P>.05). For the marginal fit, the mean (±SD) values were 105.1 ·m ±39.6 with the milled process and 126.2 αm ±25.2 for the additive process. The mean values were 98.1 ·m ±26.1 for the axial fit in the milled process and 106.8 ·m ±21.2 in the additive process. For the occlusal fit, median values (interquartile interval) were 199.0 αm (141.5 to 269.9) for subtractive manufacturing and 257.2 αm (171.6 to 266.0) for micro-SLA manufacturing.

CONCLUSIONS: No significant difference was found between the fit of the 2 techniques. The mean values of axial and occlusal median values were 10 and 5 to 6 times greater than machine's nominal values.

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In vitro evaluation of marginal discrepancy of monolithic zirconia restorations fabricated with different CAD-CAM systems

Hamza TA, Sherif RM
J Prosthet Dent 2017;117:762-766

STATEMENT OF PROBLEM: Dental laboratories use different computer-aided design and computer-aided manufacturing (CAD-CAM) systems to fabricate fixed prostheses; however, limited evidence is available concerning which system provides the best marginal discrepancy.

PURPOSE: The purpose of this in vitro study was to evaluate the marginal fit of 5 different monolithic zirconia restorations milled with different CAD-CAM systems.

MATERIAL AND METHODS: Thirty monolithic zirconia crowns were fabricated on a custom-designed stainless steel die and were divided into 5 groups according to the type of monolithic zirconia crown and the CAD-CAM system used: group TZ, milled with an MCXL milling machine; group CZ, translucent zirconia milled with a motion milling machine; group ZZ, zirconia milled with a dental milling unit; group PZ, translucent zirconia milled with a zirconia milling unit; and group BZ, solid zirconia milled using an S1 VHF milling machine. The marginal fit was measured with a binocular microscope at an original magnification of x100. The results were tabulated and statistically analyzed with 1-way ANOVA and post hoc surface range test, and pairwise multiple comparisons were made using Bonferroni correction (α=.05).

RESULTS: The type of CAD-CAM used affected the marginal fit of the monolithic restoration. The mean (ffISD) highest marginal discrepancy was recorded in group TZI at 39.3 ±2.3 μm, while the least mean marginal discrepancy was recorded in group IZ (22.8 ±8.9 μm). The Bonferroni post hoc test showed that group TZI was significantly different from all other groups tested (P<.05).

CONCLUSIONS: Within the limitation of this in vitro study, all tested CAD-CAM systems produced monolithic zirconia restorations with clinically acceptable marginal discrepancies; however, the CAD-CAM system with the 5-axis milling unit produced the best marginal fit.

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Effect of production method on surface roughness, marginal and internal fit, and retention of cobalt-chromium single crowns

Lövgren N, Roxner R, Klemendz S, Larsson C
J Prosthet Dent 2017;118:95-101

STATEMENT OF PROBLEM: New production methods have been developed for metal-ceramic restorations. Different production methods may show different surface roughness and fit, which may affect retention and long-term success.

PURPOSE: The purpose of this in vitro study was to examine 3 different production methods with regard to surface roughness, marginal and internal fit, and retention of cobalt-chromium alloy single-crown copings.

MATERIAL AND METHODS: A master abutment of a premolar mandibular tooth preparation with 4-mm height and a 0.6-mm deep 120-degree chamfer finish line with a 12-degree angle of convergence was replicated in die stone and scanned. Thirty-six cobalt-chromium alloy copings were produced using 3 different production techniques. Twelve copings were produced by laser-sintering, 12 by milling, and 12 by milled wax/lost wax. The surface microstructure of 2 copings in each group was analyzed using interferometry. The remaining 10 copings in each group were used to evaluate marginal and internal fit by using an impression material replica method, and retention was evaluated by using a uniaxial tensile force pull-off test. The copings from each test group were cemented with zinc phosphate cement onto resin abutments. Statistical analyses of differences in marginal and internal fit were performed using 1-way ANOVA and the Mann-Whitney U test. Differences in surface topography were analyzed with the Kruskal-Wallis and Mann-Whitney U tests for nonparametric data. Differences in retentive values were analyzed using the Mann-Whitney U test for nonparametric data (all α=.05).

RESULTS: Differences in surface microstructure were seen. The laser-sintered copings showed increased surface roughness compared with milled and milled wax/lost wax copings. Differences in marginal and internal fit were noted. Laser-sintered showed significantly smaller spaces between coping and abutment than milled wax/lost wax copings (P=.003). At the margins, laser-sintered copings showed significantly smaller spaces than either the milled wax/lost wax group (P=.002) or the milled group (P=.002). At the chamfer, laser-sintered copings showed significantly smaller spaces than milled wax/lost wax copings (P=.005). At the center of the axial walls, laser-sintered copings showed significantly smaller spaces than those in the milled wax/lost wax (P=.004) and milled copings (P=.005). No significant differences were noted between milled and milled wax/lost wax copings (P>.05). No significant differences were detected regarding retentive forces in the pull-off tests (P>.05).

CONCLUSIONS: Laser-sintered Co-Cr crown copings showed increased surface roughness and better internal and marginal fit than copings produced by milling or milled wax/lost wax technique. However, the crown pull-off tests did not reveal any significant differences.

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Comparison of margin discrepancy of complete gold crowns fabricated using printed, milled, and conventional hand-waxed patterns

Munoz S, Ramos V Jr, Dickinson DP
J Prosthet Dent 2017;118:89-94

STATEMENT OF PROBLEM: The recent application of printing for the fabrication of dental restorations has not been compared and evaluated for margin discrepancy (margin fit) with restorations fabricated using milling and conventional hand-waxing techniques.

PURPOSE: The purpose of this in vitro study was to evaluate and compare margin discrepancy of complete gold crowns (CGCs) fabricated from printed, milled, and conventional hand-waxed patterns.

MATERIAL AND METHODS: Thirty crown patterns were produced by each of 3 different methods: printed by ProJet DP 3000, milled by LAVA CNC 500, and hand waxed, then invested and cast into CGCs. Each crown was evaluated at 10 positions around the margin on the corresponding epoxy die under x50 light microscopy to determine the mean and maximum margin discrepancy. Measurements were made using a micrometer positioning stage. The results were compared by ANOVA (α=.05).

RESULTS: Milled and hand-waxed patterns were not statistically different from each other ($P>.05$), while printed patterns produced significantly higher mean and maximum margin discrepancy than milled and hand-waxed patterns ($P<.05$).

CONCLUSIONS: Relative to margin discrepancy, the LAVA CNC 500 milled and hand-waxed patterns were not significantly different from each other. The ProJet DP 3000 printed patterns were significantly different from LAVA CNC 500 milled and hand-waxed patterns, with an overall poorer result. Fabricating CGCs from printed patterns produced a significantly higher number of crowns with unacceptable margin discrepancy (>120 μm).

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Evaluation of marginal and internal adaptation of hybrid and nanoceramic systems with microcomputed tomography: An in vitro study

Yildirim G, Uzun IH, Keles A
J Prosthet Dent 2017;118:200-207

STATEMENT OF PROBLEM: The accuracy of recently introduced chairside computer-aided design and computer-aided manufacturing (CAD-CAM) blocks is not well established, and marginal integrity and internal adaptation are not known.

PURPOSE: The purpose of this in vitro study was to evaluate the marginal and internal adaptation of hybrid and nanoceramics using microcomputed tomography (μ-CT).

MATERIAL AND METHODS: The marginal and internal adaptation of 3 polymer-infiltrated ceramic-network (PICN) materials (Vita Enamic [VE]; Lava Ultimate [LU]; Vita Suprinity [VS]) were compared with lithium disilicate (IPS e.max.CAD, IPS). Ninety-six specimens (48 dies and 48 crowns) were prepared (n=12 each group) using a chairside CAD-CAM system. The restorations were scanned with μ-CT, with 160 measurements made for each crown, and used in 2-dimensional (2D) analysis. The marginal adaptation of marginal discrepancy (MD), absolute marginal discrepancy (AMD), internal adaptation of shoulder area (SA), axial space (AS), and occlusal space (OS) were compared using appropriate statistical analysis methods (α=.05). Cement volumes were compared using 3D analysis.

RESULTS: The IPS blocks showed higher MD (130 ·m), AMD (156 μm), SA (111 μm) ($P<.05$), AS (52 μm), and OS (192 μm) than the other blocks ($P<.01$). The adaptation values of VS were significantly lower than those of the IPS block ($P<.05$). The adaption values of the LU and VE blocks were significantly lower than those of others ($P<.01$) but were statistically similar to one another ($P>.05$). IPS had the largest cement space at 18 mm^3 ($P<.01$).

CONCLUSIONS: The marginal and internal adaptation values were within a clinically acceptable range for all 3 hybrids and nanoceramics tested.

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A comparative study of additive and subtractive manufacturing for dental restorations

Bae EJ, Jeong ID, Kim WC, Kim JH
J Prosthet Dent 2017;118:187-193

STATEMENT OF PROBLEM: Digital systems have recently found widespread application in the fabrication of dental restorations. For the clinical assessment of dental restorations fabricated digitally, it is necessary to evaluate their accuracy. However, studies of the accuracy of inlay restorations fabricated with additive manufacturing are lacking.

PURPOSE: The purpose of this in vitro study was to evaluate and compare the accuracy of inlay restorations fabricated by using recently introduced additive manufacturing with the accuracy of subtractive methods.

MATERIAL AND METHODS: The inlay (distal occlusal cavity) shape was fabricated using 3-dimensional image (reference data) software. Specimens were fabricated using 4 different methods (each n=10, total N=40), including 2 additive manufacturing methods, stereolithography apparatus and selective laser sintering; and 2 subtractive methods, wax and zirconia milling. Fabricated specimens were scanned using a dental scanner and then compared by overlapping reference data. The results were statistically analyzed using a 1-way analysis of variance (α=.05). Additionally, the surface morphology of 1 randomly (the first of each specimen) selected specimen from each group was evaluated using a digital microscope.

RESULTS: The results of the overlap analysis of the dental restorations indicated that the root mean square (RMS) deviation observed in the restorations fabricated using the additive manufacturing methods were significantly different from those fabricated using the subtractive methods (P<.05). However, no significant differences were found between restorations fabricated using stereolithography apparatus and selective laser sintering, the additive manufacturing methods (P=.466). Similarly, no significant differences were found between wax and zirconia, the subtractive methods (P=.986). The observed RMS values were 106 μm for stereolithography apparatus, 113 μm for selective laser sintering, 116 μm for wax, and 119 μm for zirconia. Microscopic evaluation of the surface revealed a fine linear gap between the layers of restorations fabricated using stereolithography apparatus and a grooved hole with inconsistent weak scratches when fabricated using selective laser sintering. In the wax and zirconia restorations, possible traces of milling bur passes were observed.

CONCLUSIONS: The results indicate that the accuracy of dental restorations fabricated using the additive manufacturing methods is higher than that of subtractive methods. Therefore, additive manufacturing methods are a viable alternative to subtractive methods.

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Accuracy evaluation of intraoral optical impressions: A clinical study using a reference appliance

Atieh MA, Ritter AV, Ko CC, Duqum I
J Prosthet Dent 2017;118:400-405

STATEMENT OF PROBLEM: Trueness and precision are used to evaluate the accuracy of intraoral optical impressions. Although the in vivo precision of intraoral optical impressions has been reported, in vivo trueness has not been evaluated because of limitations in the available protocols.

PURPOSE: The purpose of this clinical study was to compare the accuracy (trueness and precision) of optical and conventional impressions by using a novel study design.

MATERIAL AND METHODS: Five study participants consented and were enrolled. For each participant, optical and conventional (vinylsiloxanether) impressions of a custom-made intraoral Co-Cr alloy reference appliance fitted to the mandibular arch were obtained by 1 operator. Three-dimensional (3D) digital models were created for stone casts obtained from the conventional impression group and for the reference appliances by using a validated high-accuracy reference scanner. For the optical impression group, 3D digital models were obtained directly from the intraoral scans. The total mean trueness of each impression system was calculated by averaging the mean absolute deviations of the impression replicates from their 3D reference model for each participant, followed by averaging the obtained values across all participants. The total mean precision for each impression system was calculated by averaging the mean absolute deviations between all the impression replicas for each participant (10 pairs), followed by averaging the obtained values across all participants. Data were analyzed using repeated measures ANOVA (α=.05), first to assess whether a systematic difference in trueness or precision of replicate impressions could be found among participants and second to assess whether the mean trueness and precision values differed between the 2 impression systems.

RESULTS: Statistically significant differences were found between the 2 impression systems for both mean trueness (P=.010) and mean precision (P=.007). Conventional impressions had higher accuracy with a mean trueness of 17.0 ffl6.6 μm and mean precision of 16.9 ffl5.8 μm than optical impressions with a mean trueness of 46.2 ffl11.4 μm and mean precision of 61.1 ffl4.9 μm.

CONCLUSIONS: Complete arch (first molar-to-first molar) optical impressions were less accurate than conventional impressions but may be adequate for quadrant impressions.

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Clinical marginal fit of zirconia crowns and patients' preferences for impression techniques using intraoral digital scanner versus polyvinyl siloxane material

Sakornwimon N, Leevailoj C
Prosthet Dent 2017;118:386-391

STATEMENT OF PROBLEM: The use of digital intraoral scanners is increasing; however, evidence of its precision in making crown impressions clinically remains scarce. Patients should also feel more comfortable with digital impressions, but only a few studies evaluating this subject have been performed.

PURPOSE: The purpose of this clinical study was to evaluate the marginal fit of monolithic zirconia crowns and patients' preferences for digital impressions versus polyvinyl siloxane (PVS) impressions.

MATERIAL AND METHODS: Sixteen participants with indications for single molar crowns were included. After crown preparation, digital impressions by intraoral scanner and PVS impressions were made. The participants were asked to complete a 6-item questionnaire with a visual analog scale related to perceptions of each of the following topics: time involved, taste/smell, occlusal registration, size of impression tray/scanner, gag reflex, and overall preference. Computer-aided design and computer-aided manufacturing monolithic zirconia crowns were fabricated from both impressions. The crowns were evaluated intraorally, and a blinded examiner measured the marginal discrepancy of silicone replicas under a stereomicroscope. Intraexaminer reliability was evaluated by calculating the intraclass correlation coefficient. Data for patients' preferences and marginal discrepancies were analyzed using the paired t test (α=.05).

RESULTS: Visual analog scale scores for digital impressions were statistically significantly higher than those for PVS impressions in every topic ($P<.05$), except for occlusal registration. The results showed excellent reliability of the examiner with an intraclass correlation coefficient of .996. No significant difference was found in marginal discrepancies between the PVS group and the digital group on all sides ($P>.05$).

CONCLUSIONS: No differences were found in the clinical marginal fit of zirconia crowns fabricated from either digital impressions compared with PVS impressions. Furthermore, patients' satisfaction with digital impressions was significantly higher than with conventional impressions.

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A comparative study of additive and subtractive manufacturing for dental restorations

Bae EJ, Jeong ID, Kim WC, Kim JH
J Prosthet Dent 2017;118:187-193

STATEMENT OF PROBLEM: Digital systems have recently found widespread application in the fabrication of dental restorations. For the clinical assessment of dental restorations fabricated digitally, it is necessary to evaluate their accuracy. However, studies of the accuracy of inlay restorations fabricated with additive manufacturing are lacking.

PURPOSE: The purpose of this in vitro study was to evaluate and compare the accuracy of inlay restorations fabricated by using recently introduced additive manufacturing with the accuracy of subtractive methods.

MATERIAL AND METHODS: The inlay (distal occlusal cavity) shape was fabricated using 3-dimensional image (reference data) software. Specimens were fabricated using 4 different methods (each n=10, total N=40), including 2 additive manufacturing methods, stereolithography apparatus and selective laser sintering; and 2 subtractive methods, wax and zirconia milling. Fabricated specimens were scanned using a dental scanner and then compared by overlapping reference data. The results were statistically analyzed using a 1-way analysis of variance (α=.05). Additionally, the surface morphology of 1 randomly (the first of each specimen) selected specimen from each group was evaluated using a digital microscope.

RESULTS: The results of the overlap analysis of the dental restorations indicated that the root mean square (RMS) deviation observed in the restorations fabricated using the additive manufacturing methods were significantly different from those fabricated using the subtractive methods (P<.05). However, no significant differences were found between restorations fabricated using stereolithography apparatus and selective laser sintering, the additive manufacturing methods (P=.466). Similarly, no significant differences were found between wax and zirconia, the subtractive methods (P=.986). The observed RMS values were 106 ·m for stereolithography apparatus, 113 ·m for selective laser sintering, 116 ·m for wax, and 119 ·m for zirconia. Microscopic evaluation of the surface revealed a fine linear gap between the layers of restorations fabricated using stereolithography apparatus and a grooved hole with inconsistent weak scratches when fabricated using selective laser sintering. In the wax and zirconia restorations, possible traces of milling bur passes were observed.

CONCLUSIONS: The results indicate that the accuracy of dental restorations fabricated using the additive manufacturing methods is higher than that of subtractive methods. Therefore, additive manufacturing methods are a viable alternative to subtractive methods.

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Comparison of the Marginal Fit of Cobalt-Chromium Metal-Ceramic Crowns Fabricated by CAD/CAM Techniques and Conventional Methods at Three Production Stages

Real-Voltas F, Romano-Cardozo E, Figueras-Alvarez O, Brufau-de Barbera M, Cabratosa-Termes J
Int J Prosthodont 2017;30:304-305

PURPOSE: The aim of this study was to compare the marginal fit of cobalt-chromium crowns fabricated using conventional casts and computer-aided design/computer-assisted manufacturing (CAD/CAM) techniques at three stages of production: metal coping, after porcelain firing, and after cementation.

MATERIALS AND METHODS: A total of 80 metal-ceramic crowns were fabricated using four different techniques: lost wax casting, milling, laser sintering, and milling of a presintered metal block. Marginal fit was measured at each manufacturing stage.

RESULTS: The porcelain firing stage improved marginal fit. CAD/CAM techniques resulted in better marginal fit than did conventional casting techniques at all manufacturing stages.

CONCLUSIONS: CAD/CAM techniques improve marginal fit.

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Accuracy of intraoral digital impressions using an artificial landmark

Kim JE, Amelya A, Shin Y, Shim JS
J Prosthet Dent 2017;117:755-761

STATEMENT OF PROBLEM: Intraoral scanners have been reported to have limited accuracy in edentulous areas. Large amounts of mobile tissue and the lack of obvious anatomic landmarks make it difficult to acquire a precise digital impression of an edentulous area with an intraoral scanner.

PURPOSE: The purpose of this in vitro study was to determine the effect of an artificial landmark on a long edentulous space on the accuracy outcomes of intraoral digital impressions.

MATERIAL AND METHODS: A mandibular model containing 4 prepared teeth and an edentulous space of 26 mm in length was used. A blue-light light-emitting diode tabletop scanner was used as a control scanner, and 3 intraoral scanners were used as experimental groups. Five scans were made using each intraoral scanner without an artificial landmark, and another 5 scans were performed after application of an artificial landmark (a 4·3 mm alumina material) on the edentulous area. The obtained datasets were used to evaluate trueness and precision.

RESULTS: Without an artificial landmark on the edentulous area, the mean trueness for the intraoral scanner ranged from 36.1 to 38.8 ·m and the mean precision ranged from 13.0 to 43.6 ·m. With an artificial landmark on the edentulous area, accuracy was improved significantly: the mean trueness was 26.7 to 31.8 ·m, and the mean precision was 9.2 to 12.4 ·m.

CONCLUSIONS: The use of an alumina artificial landmark in an edentulous space improved the trueness and precision of the intraoral scanners tested.

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Evaluation of the accuracy of 7 digital scanners: An in vitro analysis based on 3-dimensional comparisons

Renne W, Ludlow M, Fryml J, Schurch Z, Mennito A, Kessler R, Lauer A
J Prosthet Dent 2017;118:36-42

STATEMENT OF PROBLEM: As digital impressions become more common and more digital impression systems are released onto the market, it is essential to systematically and objectively evaluate their accuracy.

PURPOSE: The purpose of this in vitro study was to evaluate and compare the trueness and precision of 6 intraoral scanners and 1 laboratory scanner in both sextant and complete-arch scenarios. Furthermore, time of scanning was evaluated and correlated with trueness and precision.

MATERIAL AND METHODS: A custom complete-arch model was fabricated with a refractive index similar to that of tooth structure. Seven digital impression systems were used to scan the custom model for both posterior sextant and complete arch scenarios. Analysis was performed using 3-dimensional metrology software to measure discrepancies between the master model and experimental casts.

RESULTS: Of the intraoral scanners, the Planscan was found to have the best trueness and precision while the 3Shape Trios was found to have the poorest for sextant scanning (P<.001). The order of trueness for complete arch scanning was as follows: 3Shape D800 >iTero >3Shape TRIOS 3 >Carestream 3500 >Planscan >CEREC Omnicam >CEREC Bluecam. The order of precision for complete-arch scanning was as follows: CS3500 >iTero >3Shape D800 >3Shape TRIOS 3 >CEREC Omnicam >Planscan >CEREC Bluecam. For the secondary outcome evaluating the effect time has on trueness and precision, the complete- arch scan time was highly correlated with both trueness (r=0.771) and precision (r=0.771).

CONCLUSIONS: For sextant scanning, the Planscan was found to be the most precise and true scanner. For complete-arch scanning, the 3Shape Trios was found to have the best balance of speed and accuracy.

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Implant, Esthetic, and Reconstructive Dentistry

Effect of crystallization firing on marginal gap of CAD/CAM fabricated lithium disilicate crowns

Gold SA, Ferracane JL, da Costa J
J Prosthodont. 2018;27(1):63-66. doi: 10.1111/jopr.

PURPOSE: To evaluate the marginal gaps of CAD/CAM (CEREC 3) produced crowns made from leucite-reinforced glass-ceramic (IPS Empress CAD) blocks (LG), and lithium-disilicate (IPS e.max CAD) blocks before (LD-B), and after (LD-A) crystallization firing.

MATERIAL AND METHODS: A human molar tooth (#19) was mounted with adjacent teeth on a typodont and prepared for a full-coverage ceramic crown. The typodont was assembled in the mannequin head to simulate clinical conditions. After tooth preparation 15 individual optical impressions were taken by the same operator using titanium dioxide powder and a CEREC 3 camera per manufacturer's instructions. One operator designed and machined the crowns in leucite-reinforced glass-ceramic blocks (n = 5) and lithium-disilicate blocks (n = 10) using the CEREC 3 system. The crowns were rigidly seated on the prepared tooth, and marginal gaps (·m) were measured with an optical microscope (500·) at 12 points, 3 on each of the M, B, D, and L surfaces of the leucite-reinforced glass-ceramic crowns and the lithium-disilicate crowns before and after crystallization firing. Results were analyzed by two-way ANOVA followed by a Tukey's post hoc multiple comparison test (α = 0.05).

RESULTS: The overall mean marginal gaps (·m) for the crowns evaluated were: LG = 49.2 ± 5.5, LD-B = 42.9 ± 12.2, and LD-A = 57.2 ± 16.0. The marginal gaps for LG and LD-B were not significantly different, but both were significantly less than for LD-A.

CONCLUSIONS: The type of ceramic material did not affect the marginal gap of CAD/CAM crowns. The crystallization firing process required for lithium-disilicate crowns resulted in a significant increase in marginal gap size, likely due to shrinkage of the ceramic during the crystallization process.

CLINICAL RELEANCE: The marginal gap of CAD/CAM-fabricated lithium disilicate crowns increases following crystallization firing. The marginal gap still remains within clinically acceptable parameters.

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Marginal fit of lithium disilicate crowns fabricated using conventional and digital methodology: A three-dimensional analysis

Mostafa NZ, Ruse ND, Ford NL, Carvalho RM, Wyatt CCL
J Prosthodont. 2018;27(2):145-152. doi: 10.1111/jopr.12656.

PURPOSE: To compare the marginal fit of lithium disilicate (LD) crowns fabricated with digital impression and manufacturing (DD), digital impression and traditional pressed manufacturing (DP), and traditional impression and manufacturing (TP).

MATERIALS AND METHODS: Tooth #15 was prepared for all-ceramic crowns on an ivorine typodont. There were 45 LD crowns fabricated using three techniques: DD, DP, and TP. Microcomputed tomography (micro-CT) was used to assess the 2D and 3D marginal fit of crowns in all three groups. The 2D vertical marginal gap (MG) measurements were done at 20 systematically selected points/crown, while the 3D measurements represented the 3D volume of the gap measured circumferentially at the crown margin. Frequencies of different marginal discrepancies were also recorded, including overextension (OE), underextension (UE), and marginal chipping. Crowns with vertical MG > 120 μm at more than five points were considered unacceptable and were rejected. The results were analyzed by one-way ANOVA with Scheffe post hoc test (α = 0.05).

RESULTS: DD crowns demonstrated significantly smaller mean vertical MG (33.3 ± 19.99 μm) compared to DP (54.08 ffl 32.34 μm) and TP (51.88 ± 35.34 μm) crowns. Similarly, MG volume was significantly lower in the DD group (3.32 ± 0.58 mm(3)) compared to TP group (4.16 ± 0.59 mm(3)). The mean MG volume for the DP group (3.55 ± 0.78 mm(3)) was not significantly different from the other groups. The occurrence of underextension error was higher in DP (6.25%) and TP (5.4%) than in DD (0.33%) group, while overextension was more frequent in DD (37.67%) than in TP (28.85%) and DP (18.75%) groups. Overall, 4 out of 45 crowns fabricated were deemed unacceptable based on the vertical MG measurements (three in TP group and one in DP group; all crowns in DD group were deemed acceptable).

CONCLUSION: The results suggested that digital impression and CAD/CAM technology is a suitable, better alternative to traditional impression and manufacturing.

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Three-dimensional accuracy of digital static interocclusal registration by three intraoral scanner systems

Wong KY, Esguerra RJ, Chia VAP, Tan YH, Tan KBC
J Prosthodont 2018;27:120-128

PURPOSE: Prior studies have defined the accuracy of intraoral scanner (IOS) systems but the accuracy of the digital static interocclusal registration function of these systems has not been reported. This study compared the three-dimensional (3D) accuracy of the digital static interocclusal registration of 3 IOS systems using the buccal bite scan function.

MATERIALS AND METHODS: Three IOS systems compared were 3MTM True Definition Scanner (TDS), TRIOS Color (TRC), and CEREC AC with CEREC Omnicam (CER). Using each scanner, 7 scans (n = 7) of the mounted and articulated SLA master models were obtained. The measurement targets (SiN reference spheres and implant abutment analogs) were in the opposing models at the right (R), central (C), and left (L) regions; abutments #26 and #36, respectively. A coordinate measuring machine with metrology software compared the physical and virtual targets to derive the global 3D linear distortion between the centroids of the respective target reference spheres and abutment analogs (dRR , dRC , dRL , and dRM) and 2D distances between the pierce points of the abutment analogs (dXM , dYM , dZM), with 3 measurement repetitions for each scan.

RESULTS: Mean 3D distortion ranged from -471.9 to 31.7 ·m for dRR , -579.0 to -87.0 ·m for dRC , -381.5 to 69.4 ·m for dRL , and -184.9 to -23.1 ·m for dRM . Mean 2D distortion ranged from -225.9 to 0.8 ·m for dXM , -130.6 to -126.1 ·m for dYM , and -34.3 to 26.3 ·m for dZM . Significant differences were found for interarch distortions across the three systems. For dRR and dRL , all three test groups were significantly different, whereas for dRC , the TDS was significantly different from the TRC and CER. For 2D distortion, significant differences were found for dXM only.

CONCLUSIONS: Interarch and global interocclusal distortions for the three IOS systems were significantly different. TRC performed overall the best and TDS was the worst. The interarch (dRR , dRC , dRL) and interocclusal (dXM) distortions observed will affect the magnitude of occlusal contacts of restorations clinically. The final restoration may be either hyperoccluded or infraoccluded, requiring compensations during the CAD design stage or clinical adjustments at issue.

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Position accuracy of implant analogs on 3D printed polymer versus conventional dental stone casts measured using a coordinate measuring machine

Revilla-León M, Gonzalez-Martín Ó, Pérez López J, Sánchez-Rubio JL, Özcan M
J Prosthodont 2018;27:560-567

PURPOSE: To compare the accuracy of implant analog positions on complete edentulous maxillary casts made of either dental stone or additive manufactured polymers using a coordinate measuring machine (CMM).

MATERIAL AND METHODS: A completely edentulous maxillary model of a patient with 7 implant analogs was obtained. From this model, two types of casts were duplicated, namely conventional dental stone (CDS) using a custom tray impression technique after splinting (N = 5) and polymer cast using additive manufacturing based on the STL file generated. Polymer casts (N = 20; n = 5 per group) were fabricated using 4 different additive manufacturing technologies (multijet printing-MJP1, direct light processing-DLP, stereolithography-SLA, multijet printing-MJP2). CMM was used to measure the correct position of each implant, and distortion was calculated for each system at x-, y-, and z-axes. Measurements were repeated 3 times per specimen in each axis yielding a total of 546 measurements. Data were analyzed using ANOVA, Sheffé tests, and Bonferroni correction (α = 0.05).

RESULTS: Compared to CMM, the mean distortion (·m) ranged from 22.7 to 74.9, 23.4 to 49.1, and 11.0 to 85.8 in the x-, y-, and z-axes, respectively. CDS method (x-axis: 37.1; z-axis: 27.62) showed a significant difference compared to DLP on the x-axis (22.7) (p = 0.037) and to MJP1 on the z-axis (11.0) (p = 0.003). Regardless of the cast system, x-axes showed more distortion (42.6) compared to y- (34.6) and z-axes (35.97). Among additive manufacturing technologies, MJP2 presented the highest (64.3 ffl 83.6), and MJP1 (21.57 ffl 16.3) and DLP (27.07 ffl 20.23) the lowest distortion, which was not significantly different from CDS (32.3 ffl 22.73) (p > 0.05).

CONCLUSIONS: For the fabrication of the definitive casts for implant prostheses, one of the multijet printing systems and direct light processing additive manufacturing technologies showed similar results to conventional dental stone.

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Complete-arch accuracy of intraoral scanners

Treesh JC, Liacouras PC, Taft RM, Brooks DI, Raiciulescu S, Ellert DO, Grant GT, Ye L
J Prosthet Dent 2018;120:382-388

STATEMENT OF PROBLEM: Intraoral scanners have shown varied results in complete-arch applications.

PURPOSE: The purpose of this in vitro study was to evaluate the complete-arch accuracy of 4 intraoral scanners based on trueness and precision measurements compared with a known reference (trueness) and with each other (precision).

MATERIAL AND METHODS: Four intraoral scanners were evaluated: CEREC Bluecam, CEREC Omnicam, TRIOS Color, and Carestream CS 3500. A complete-arch reference cast was created and printed using a 3-dimensional dental cast printer with photopolymer resin. The reference cast was digitized using a laboratory-based white light 3-dimensional scanner. The printed reference cast was scanned 10 times with each intraoral scanner. The digital standard tessellation language (STL) files from each scanner were then registered to the reference file and compared with differences in trueness and precision using a 3-dimensional modeling software. Additionally, scanning time was recorded for each scan performed. The Wilcoxon signed rank, Kruskal-Wallis, and Dunn tests were used to detect differences for trueness, precision, and scanning time (α=.05).

RESULTS: Carestream CS 3500 had the lowest overall trueness and precision compared with Bluecam and TRIOS Color. The fourth scanner, Omnicam, had intermediate trueness and precision. All of the scanners tended to underestimate the size of the reference file, with exception of the Carestream CS 3500, which was more variable. Based on visual inspection of the color rendering of signed differences, the greatest amount of error tended to be in the posterior aspects of the arch, with local errors exceeding 100 ·m for all scans. The single capture scanner Carestream CS 3500 had the overall longest scan times and was significantly slower than the continuous capture scanners TRIOS Color and Omnicam.

CONCLUSIONS: Significant differences in both trueness and precision were found among the scanners. Scan times of the continuous capture scanners were faster than the single capture scanners.

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Accuracy of 9 intraoral scanners for complete-arch image acquisition: A qualitative and quantitative evaluation

Kim RJ, Park JM, Shim JS
J Prosthet Dent 2018;120:895-903

STATEMENT OF PROBLEM: Different intraoral scanners (IOSs) are available for digital dentistry. However, information on the accuracy of various IOSs for complete-arch digital scans is limited.

PURPOSE: The purpose of this in vitro study was to evaluate the trueness and precision of complete-arch digital scans produced by 9IOSs, using the superimposition method, and to compare them based on characteristics including the data capture principle and mode and the need for powder coating.

MATERIAL AND METHODS: Nine IOSs were used to obtain standard tessellation language (STL) data for a bimaxillary complete-archmodel with various cavity preparations (N=10). The scanning performance was evaluated quantitatively and qualitatively. For quantitative evaluation, the images were processed and analyzed using 3-dimensional (3D) analysis software. After we superimposed the datasets, trueness was obtained by comparing it with the reference scan, and precision was obtained from intragroup comparisons. The IOSs were compared based on the data capture principle and mode and the need for powder coating. Statistical analyses were conducted using a Kruskal-Wallis test, followed by multiple Mann-Whitney U tests for pairwise comparisons among groups (α=.05). For qualitative evaluation, surface smoothness and sharp edge reproducibility of the digital images were compared.

RESULTS: The median precision values were lowest in the TRIOS model (average, 34.70 ·m; maximum, 263.55 ·m) and highest in the E4D model (average, 357.05 ·m; maximum 2309.45 ·m). Median average trueness values were lowest in the TRIOS model (42.30 ·m) and highest in the Zfx IntraScan model (153.80 ·m). The CS 3500 model had the lowest median maximum trueness values (450.75 ·m); the E4D model had the highest values (2680.55 ·m). Individual image and video sequence data captures showed similar median average trueness values (P>.05); the median maximum values of individual images were higher than those of the video sequence (P<.05). Swept source optical coherence tomography (SS-OCT) exhibited higher trueness values than those of other scanning principles (P<.05). The FastScan and True Definition, which require powder coating, showed significantly better trueness than other IOSs that did not require powdering (P<.05). The E4D, PlanScan, and Zfx IntraScan models had an increased tendency to produce images with imperfect surface features and to round off sharp edges.

CONCLUSIONS: The E4D and Zfx IntraScan models did not perform as accurately as the other IOSs. The data capture principle of SS-OCT and the mode of individual image acquisition exhibited inferior trueness. The FastScan and True Definition, which require powder coating, exhibited better trueness. The qualitative aspects of the IOSs varied in terms of polygon shapes, sharp edge reproducibility, and surface smoothness.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

A comparison of marginal gaps of all-ceramic crowns constructed from scanned impressions and models

Tabesh R, Dudley J
Int J Prosthodont. 2018;31:71–73

PURPOSE: This study compared the marginal gaps of computer-aided design/computer-aided manufacture (CAD/CAM)-fabricated all-ceramic crowns constructed from scanned impressions and models and with two different occlusal reduction designs.

MATERIALS AND METHODS: Two typodont mandibular first molars were prepared to receive CAD/CAM-fabricated all-ceramic crowns. Both molars were prepared to ideal crown reduction, the first with anatomical occlusal reduction (AOR) and the second with completely flat occlusal reduction (FOR). Nine polyvinyl siloxane impressions (PVS) were taken, and nine stone replicas fabricated for each preparation. All impressions and stone models were scanned using a laser scanner (Planmeca Planscan, E4D technologies), and 36 lithium disilicate (IPS e.max CAD) crowns were milled. The marginal gap was measured in four locations using a light stereomicroscope.

RESULTS: Crowns constructed from preparations with both occlusal reduction designs demonstrated similar marginal gaps (FOR = 97.98; AOR = 89.12; P = .739). However, all crowns constructed from scanned impressions presented significantly larger marginal gapsthan the crowns fabricated from scanned models (impressions = 109.26; models = 77.84; P = .002).

CONCLUSIONS: Scanning stone models produced all-ceramic crowns with significantly smaller marginal gaps than scanning impressions, irrespective of the occlusal reduction design.

Journal of
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The marginal fit of CAD/CAM monolithic ceramic and metal-ceramic crowns

Freire Y, Gonzalo E, Lopez-Suarez C, Suarez MJ
J Prosthodont. 2019;28(3):299-304. doi: 10.1111/jopr.12590.

PURPOSE: Studies on the marginal fit of monolithic restorations are limited. This study aimed to evaluate the marginal fit among monolithic zirconia, monolithic lithium disilicate, and conventional metal-ceramic crowns and to compare the buccal and lingual surfaces.

MATERIAL AND METHODS: Thirty standardized stainless steel master dies were fabricated (height: 5 mm; convergence: 6°; chamfer: 1 mm). The dies were randomly divided into three groups (n = 10 each) according to the material used to construct the crowns: group 1 (LM): Lava Plus; group 2 (DM): IPS e.max CAD; and group 3 (MC): Metal-ceramic. The crowns were luted in a standard manner onto the stainless steel master dies using conventional glass ionomer cement. The vertical marginal gap of the restorations was evaluated under a scanning electron microscope (SEM) at 500x magnification. One-way ANOVA, Tukey ' s HSD test, and Student's paired t test were used to assess the marginal discrepancy among the groups. The cutoff value for statistical significance was set at α = 0.05.

RESULTS: Significant differences among the three groups (p = 0.0001) were recorded. DM group showed the lowest discrepancies (27.95 ffl 9.37 ·m). Significant differences were observed for the buccal (p = 0.007) and lingual (p = 0.0001) surfaces between the DM group and the other groups.

CONCLUSIONS: The accuracy of fit achieved for the three groups was within the range of clinical acceptance. IPS e.max CAD showed the lowest discrepancies.

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Feasibility of using an intraoral scanner for a complete-arch digital scan

Park GH, Son K, Lee KB
J Prosthet Dent 2019;121:803-810

STATEMENT OF PROBLEM: The introduction of intraoral scanners has increased the use of digital technology in dental procedures. However, research on the extent of clinically recommended scans is lacking.

PURPOSE: The purpose of this in vitro study was to compare 3D arch distortion according to the distance from the tooth at the beginning of a complete-arch scan made using an intraoral scanner.

MATERIAL AND METHODS: An industrial scanner was used to digitize a master model for a computer-aided design (CAD) reference model. In addition, the master model was digitized using 4 intraoral scanners (TRIOS2, TRIOS3, CS3500, and CS3600) and 1 dental laboratory scanner (FREEDOM HD) to make the CAD test model (N=20). The scanned teeth were divided using an inspection software program (Geomagic control X), and overlapping and 3D analyses of the CAD reference model and CAD test model were performed. The presence or absence of normal distribution in the root mean square (RMS) values of all divided teeth was assessed and evaluated with the Kruskal-Wallis test (α=.05), and post hoc comparison was performed using the Mann-Whitney U-test and Bonferroni correction method (α=.005).

RESULTS: The overall RMS value was significantly different for all scanners (P<.001). The dental laboratory scanner showed the lowest value (47.5 ffl1.6 ·m), whereas TRIOS2 showed the highest value (343.4 ffl56.4 ·m). TRIOS3 (9.6 ffl1.2 ·m) showed the best trueness in those teeth where the scan started. However, the larger the scan range, the lower the RMS value difference between TRIOS3 and CS3500. The RMS values of the dental laboratory scanners were higher than those of the intraoral scanners in the narrow scan range. CS3600 showed an RMS value less than or equal to that of the dental laboratory scanner at 5 teeth scan ranges. However, the wider the scan range, the lower the RMS values of all the intraoral scanners.

CONCLUSIONS: Current complete-arch scanning is not sufficiently accurate for fabricating fixed prostheses. However, intraoral scanners are useful for short scans, such as those for single (TRIOS2, TRIOS3, and CS3500) or short-span prostheses (CS3600).

Journal of
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Accuracy of dental replica models using photopolymer materials in additive manufacturing: In vitro three dimensional evaluation

Jin SJ, Kim DY, Kim JH, Kim WC
J Prosthodont 2019;28:e557-e562

PURPOSE: To evaluate the accuracy (trueness and precision) of dental replica models produced by using photopolymer materials in additive manufacturing.

MATERIALS AND METHODS: A complete arch model was scanned using an extraoral scanner (Identica Blue) and established as reference. For the control group, 10 stone models were acquired through the conventional method from the reference model. For the experimental groups, digital data were acquired using an intraoral scanner (CEREC Omnicam), and 10 stereolithographic apparatus (SLA) models and 10 PolyJet models were made. All models were scanned with an extraoral scanner. Three-dimensional analysis software was used to measure differences between the 3D scanned images in root mean square values. The ISO-5725-1 specification was followed to measure trueness and precision between two 3D scanned data. Trueness was calculated by overlapping scanned data with the reference model and precision by performing pairwise intragroup comparisons. Also the ratio of region out of tolerance (> ffl50 ·m) was measured. One-way ANOVA and Tukey's post hoc analysis were applied.

RESULTS: There was no statistically significant difference in trueness between the stone and the SLA models (p > 0.05). Dental replicamodels using photopolymer materials showed statistically significantly better precision than that of the stone model (p < 0.05). Regarding tolerance, no statistically significant difference was observed between the stone and the SLA models (p > 0.05).

CONCLUSIONS: Although the dental replica models using photopolymer materials did not show better trueness than the conventional stone models, there was no significant difference between the SLA and the stone models. Concerning precision, dental replica modelsusing photopolymer materials presented better results than that of the conventional stone models. In sum, dental replica models using photopolymer materials showed sufficient accuracy for clinical use.

Journal of Dentistry

A 3 years retrospective study of survival for zirconia-based single crowns fabricated from intraoral digital impressions

Gherlone E, Mandelli F, Capparè P, Pantaleo G, Traini T, Ferrini F
J Dent 2014;42:1151-1155

OBJECTIVES: To evaluate the clinical performance of glass-ceramic/zirconia crowns fabricated using intraoral digital impressions – a retrospective study with a three-year follow-up.

METHODS: 70 consecutive patients with a total of 86 glass-ceramic/zirconia crowns were treated by a single clinician using standardized clinical and laboratory protocols. A complete digital workflow was adopted for the purpose except for the veneering procedure for the glass-ceramic crowns. Occlusal adjustments were made before the ceramic glazing procedure. Before cementation, all abutments where carefully cleaned with a 70% alcoholic solution and air dried. Cementation was performed using dual-curing, self-adhesive resin cement. Patients were re-examined after 12, 24 and 36 months, to assess crown chipping/fractures.

RESULTS: After the three-year follow-up, none of the zirconia-based restoration was lost ("apparent" survival rate 100%) otherwise, the chipping rate of the veneering material increased from 9.3% after 12 months, to 14% after 24 months to 30.2% after 36 months. As a consequence, the "real" success rate after 3 years was 69.8%.

CONCLUSIONS: After 3 years the success rate of zirconia-based crowns was 69.8%, while the incidence of the chipping was 30.2%. Assuming an exponential increase in chipping rate between 12 and 36 months it can be argued that, among others, the fatigue-mechanism could be advocated as the main factor for the failure of glass-ceramic veneered zirconia especially after 24 months.

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Using stereophotogrammetric technology for obtaining intraoral digital impressions of implants

Pradíes G, Ferreiroa A, Özcan M, Giménez B, Martínez-Rus F
J Am Dent Assoc 2014 Apr;145:338-344. doi: 10.14219/jada.2013.45

BACKGROUND: The procedure for making impressions of multiple implants continues to be a challenge, despite the various techniques proposed to date. The authors' objective in this case report is to describe a novel digital impression method for multiple implants involving the use of stereophotogrammetric technology.

CASE DESCRIPTION: The authors present three cases of patients who had multiple implants in which the impressions were obtained with this technology. Initially, a stereo camera with an infrared flash detects the position of special flag abutments screwed into the implants. This process is based on registering the x, y and z coordinates of each implant and the distances between them. This information is converted into a stereolithographic (STL) file. To add the soft-tissue information, the user must obtain another STL file by using an intraoral or extraoral scanner. In the first case presented, this information was acquired from the plaster model with an extraoral scanner; in the second case, from a Digital Imaging and Communication in Medicine (DICOM) file of the plaster model obtained with cone-beam computed tomography; and in the third case, through an intraoral digital impression with a confocal scanner.

RESULTS: In the three cases, the frameworks manufactured from this technique showed a correct clinical passive fit. At follow-up appointments held six, 12 and 24 months after insertion of the prosthesis, no complications were reported.

CONCLUSIONS: Stereophotogrammetric technology is a viable, accurate and easy technique for making multiple implant impressions.

PRACTICAL IMPLICATIONS: Clinicians can use stereophotogrammetric technology to acquire reliable digital master models as a first step in producing frameworks with a correct passive fit.

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The time efficiency of intraoral scanners: an in vitro comparative study

Patzelt SB, Lamprinos C, Stampf S, Att W
J Am Dent Assoc 2014;145:542-551. doi: 10.14219/jada.2014.23

BACKGROUND: Although intraoral scanners are known to have good accuracy in computer-aided impression making (CAIM), their effect on time efficiency is not. Little is known about the time required to make a digital impression. The purpose of the authors' in vitro investigation was to evaluate the time efficiency of intraoral scanners.

METHODS: The authors used three different intraoral scanners to digitize a single abutment (scenario 1), a short-span fixed dental prosthesis (scenario 2) and a full-arch prosthesis preparation (scenario 3). They measured the procedure durations for the several scenarios and compiled and contrasted the procedure durations for three conventional impression materials.

RESULTS: The mean total procedure durations for making digital impressions of scenarios 1, 2 and 3 were as much as 5 minutes 57 seconds, 6 minutes 57 seconds, and 20 minutes 55 seconds, respectively. Results showed statistically significant differences between all scanners ($P < .05$), except Lava (3M ESPE, St. Paul, Minn.) and iTero with foot pedal (Align Technology, San Jose, Calif.) for scenario 1, CEREC (Sirona, Bensheim, Germany) and CEREC with foot pedal for scenario 2, and iTero and iTero with foot pedal for scenarios 2 and 3. The compiled procedure durations for making conventional impressions in scenarios 1 and 2 ranged between 18 minutes 15 seconds and 27 minutes 25 seconds; for scenario 3, they ranged between 21 minutes 25 seconds and 30 minutes 25 seconds.

CONCLUSIONS: The authors found that CAIM was significantly faster for all tested scenarios. This suggests that CAIM might be beneficial in establishing a more time-efficient work flow.

PRACTICAL IMPLICATIONS: On the basis of the results of this in vitro study, the authors found CAIM to be superior regarding time efficiency in comparison with conventional approaches and might accelerate the work flow of making impressions.

Journal of Dentistry

Veneered anatomically designed zirconia FDPs resulting from digital intraoral scans: Preliminary results of a prospective clinical study

Selz CF, Bogler J, Vach K, Strub JR, Guess PC
J Dent 2015;43:1428-1435

OBJECTIVES: The aim of this prospective clinical study was to evaluate the clinical performance of veneered anatomically designed zirconia fixed dental prostheses (FDPs) resulting from intraoral digital impressions.

METHODS: 24 patients requiring treatment were provided with all-ceramic FDPs. Intraoral scans (iTero) were performed and veneered anatomically designed CAD/CAM-zirconia FDPs (Zerion/VitaVM9) were fabricated. A feldspar veneering ceramic following a slow cooling firing protocol was applied. A self-curing resin based luting material was used for adhesive cementation. Clinical evaluations were performed at baseline and 6, 12, and 18 months recalls according to the modified USPHS-criteria. Intraoral digital surface scans (iTero) were performed at each recall examination and were digitally superimposed (Geomagic) to evaluate potential veneer cohesive fractures. Kaplan–Meier survival analysis comprised secondary caries, clinically unacceptable fractures, root canal treatment and debonding. Kaplan–Meier success rate included restorations with minimal crevices, tolerable color deviations and clinically acceptable fractures. Data were statistically analyzed.

RESULTS: The Kaplan–Meier survival rate and success rate of the FDPs were 100% and 91.7%, respectively. Clinically acceptable veneer cohesive fractures and crevices at the restoration margin were observed in two patients. These shallow veneer fractures were only detected by overlapping baseline and recall scans. Ceramic surface roughness increased significantly over time ($p < 0.0001$).

CONCLUSIONS: Veneered zirconia FDPs fabricated from digital intraoral scans showed a favorable clinical performance over an observation period of 18 months. Anatomical zirconia core design and slow cooling firing protocol of the veneering ceramic reduced the incidence of chip fractures to a level that could not be detected clinically.

CLINICAL SIGNIFICANCE: The digital workflow on the basis of intraoral digital impressions resulted in clinically satisfying outcomes for veneered zirconia FDPs.

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Full 3-dimensional digital workflow for multicomponent dental appliances: A proof of concept

van der Meer WJ, Vissink A, Ren Y
J Am Dent Assoc 2016;147:288-291. doi: 10.1016/j.adaj.2015.11.018

BACKGROUND: The authors used a 3-dimensional (3D) printer and a bending robot to produce a multicomponent dental appliance to assess whether 3D digital models of the dentition are applicable for a full digital workflow.

METHODS: The authors scanned a volunteer's dentition with an intraoral scanner (Lava Chairside Oral Scanner C.O.S., 3M). A digital impression was used to design 2 multicomponent orthodontic appliances. Biocompatible acrylic baseplates were produced with the aid of a 3D printer. The metal springs and clasps were produced by a bending robot. The fit of the 2 appliances was assessed by 2 experienced orthodontists.

RESULTS: The authors assessed both orthodontic appliances with the volunteer's dentition and found the fit to be excellent.

CONCLUSIONS: Clinicians can fully produce a multicomponent dental appliance consisting of both an acrylic baseplate and other parts, such as clasps, springs, or screws, using a digital workflow process without the need for a physical model of the patient's dentition.

PRACTICAL IMPLICATIONS: Plaster models can be superfluous for orthodontic treatment as digital models can be used in all phases of a full digital workflow in orthodontics. The arduous task of making a multicomponent dental appliance that involves bending wires can possibly be replaced by a computer, design software, a 3D printer, and a bending robot.

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Digital versus analog complete-arch impressions for single-unit premolar implant crowns: Operating time and patient preference

Schepke U, Meijer H, Kerdijk W, Cune MS
J Prosthet Dent 2015;114:403-406

STATEMENT OF PROBLEM: Digital impression-making techniques are supposedly more patient friendly and less time-consuming than analog techniques, but evidence is lacking to substantiate this assumption.

PURPOSE: The purpose of this in vivo within-subject comparison study was to examine patient perception and time consumption for 2 complete-arch impression-making methods: a digital and an analog technique.

MATERIAL AND METHODS: Fifty participants with a single missing premolar were included. Treatment consisted of implant therapy. Three months after implant placement, complete-arch digital (Cerec Omnicam; Sirona) and analog impressions (semi-individual tray, Impregum; 3M ESPE) were made, and the participant's opinion was evaluated with a standard questionnaire addressing several domains (inconvenience, shortness of breath, fear of repeating the impression, and feelings of helplessness during the procedure) with the visual analog scale. All participants were asked which procedure they preferred. Operating time was measured with a stopwatch. The differences between impressions made for maxillary and mandibular implants were also compared. The data were analyzed with paired and independent sample t tests, and effect sizes were calculated.

RESULTS: Statistically significant differences were found in favor of the digital procedure regarding all subjective domains (P<.001), with medium to large effect sizes. Of all the participants, over 80% preferred the digital procedure to the analog procedure. The mean duration of digital impression making was 6 minutes and 39 seconds (SD=1:51) versus 12 minutes and 13 seconds (SD=1:24) for the analog impression (P<.001, effect size=2.7).

CONCLUSIONS: Digital impression making for the restoration of a single implant crown takes less time than analog impression making. Furthermore, participants preferred the digital scan and reported less inconvenience, less shortness of breath, less fear of repeating the impression, and fewer feelings of helplessness during the procedure.

CLINICAL IMPLICATIONS: Patients to a great extent prefer digital impression making to the analog. Also, the digital approach is substantially less time-consuming.

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Randomized controlled within-subject evaluation of digital and conventional workflows for the fabrication of lithium disilicate single crowns. Part I: digital versus conventional unilateral impressions

Benic GI, Mühlemann S, Fehmer V, Hämmerle CH, Sailer I
J Prosthet Dent 2016;116:777-782

STATEMENT OF PROBLEM: Trials comparing the overall performance of fully digital and conventional workflows in reconstructive dentistry are needed.

PURPOSE: The purpose of the first part of this randomized controlled clinical trial was to determine whether optical impressions produce different results from conventional impressions with respect to time efficiency and patient and operator perceptions of the clinical workflow.

MATERIAL AND METHODS: Three digital impressions and 1 conventional impression were made in each of 10 participants according to a randomly generated sequence. The digital systems were Lava COS, iTero, and Cerec Bluecam. The conventional impression was made with the closed-mouth technique and polyvinyl siloxane material. The time needed for powdering, impressions, and interocclusal record was recorded. Patient and clinician perceptions of the procedures were rated by means of visual analog scales. The paired t test with Bonferroni correction was applied to detect differences (α=.05/6=.0083).

RESULTS: The mean total working time fflstandard deviation amounted to 260 ±66 seconds for the conventional impression, 493 ±193 seconds for Lava, 372 ±126 seconds for iTero, and 357 ±55 seconds for Cerec. The total working time for the conventional impression was significantly lower than that for Lava and Cerec. With regard to the working time without powdering, the differences between the methods were not statistically significant. The patient rating (very uncomfortable=0; comfortable=100) measured 61 ±34 for conventional impression, 71 ±18 for Lava, 66 ±20 for iTero, and 48 ±18 for Cerec. The differences were not statistically significant. The clinician rating (simple=0; very difficult=100) was 13 ±13 for the conventional impression, 54 ±27 for Lava, 22 ±11 for iTero, and 36 ±23 for Cerec. The differences between the conventional impression and Lava and between iTero and Lava were statistically significant.

CONCLUSIONS: The conventional impression was more time-effective than the digital impressions. In terms of patient comfort, no differences were found between the conventional and the digital techniques. With respect to the clinician perception of difficulty, the conventional impression and the digital impression with iTero revealed more favorable outcomes than the digital impression with Lava.

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Accuracy in the digital workflow: From data acquisition to the digitally milled cast

Koch GK, Gallucci GO, Lee SJ
J Prosthet Dent 2016;115:749-754

STATEMENT OF PROBLEM: The accuracy of digital impressions and the milling of implant crowns greatly influence the clinical outcome of implant restorations.

PURPOSE: The purpose of this in vitro study was to calculate the propagation of error in the process of milling an implant crown.

MATERIAL AND METHODS: Thirty digitally milled casts made directly from a reference model were prepared. The casts were scanned with a laboratory scanner, and 30 standard tesselation language (STL) datasets from each group were imported to inspection software. In each analysis, STL datasets were aligned by a repeated best fit algorithm, and 18 specified contact locations of interest were measured in mean volumetric deviations. The master reference dataset was aligned 30 times to the master reference dataset to determine the software variation. The reference datasets were aligned to the master reference dataset to determine the scanner variation. The milled cast datasets were aligned to the master reference dataset to determine the milling variation. The 18 specified contact locations of interest were pooled by cusps, occlusal ridge/fossae, interproximal contacts, facial/lingual aspect, and implant position. The pooled areas were statistically analyzed by comparing each group with the reference model to investigate the mean volumetric deviations accounting for accuracy and standard deviations for precision.

RESULTS: Software and scanner variation were negligible. Variations in the milled models resulting from software and scanner error exhibited statistical significance ($P<.001$). Software, scanner, and milling error were shown to propagate through the digital workflow to the milled model.

CONCLUSIONS: The pooled locations may describe the reliability of the milling process as it applies to specific anatomic locations on the tooth.

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Maxillary full-arch immediately loaded implant-supported fixed prosthesis designed and produced by photogrammetry and digital printing: A clinical report

Peñarrocha-Oltra D, Agustín-Panadero R, Pradíes G, Gomar-Vercher S, Peñarrocha-Diago M
J Prosthodont. 2017;26(1):75-81. doi: 10.1111/jopr.12364.

The present clinical report describes the use of a photogrammetry system (PICcamera) for obtaining impressions and designing and producing an immediately loaded CAD/CAM provisional fixed prosthesis delivered in the mouth within 24 hours after implant placement in the maxilla. The stereo camera was used to capture the implant positions, automatically taking 350 images in less than 2 minutes. This photogrammetry system takes 10 pictures per second with a margin of error of under 10 µm between two scan bodies, and identifies the spatial position of each implant without physical contact. The three-dimensional data for each implant are registered in vector format, together with all interrelated implant angles and distances. The information is stored in an STL file (PICfile). Information on soft tissues was obtained from an irreversible hydrocolloid impression that was poured in stone and scanned. An immediately loaded screw-retained fixed prosthesis was made from acetalic resin using CAD/CAM, and its passive fit was evaluated in the mouth using the Sheffield test and screw resistance test.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

CAD/CAM Ceramic Overlays to Restore Reduced Vertical Dimension of Occlusion Resulting from Worn Dentitions: A Case History Report

Ting J, Shuhui H, Hongqiang Y, Lu J
Int J Prosthodont 2017;30:238-241

Two patients with a reduced vertical dimension of occlusion as a result of teeth wear were prescribed ceramic overlays. Their 2-year follow-up suggested good adaptation to the recovered muscle support without associated symptoms or adverse alterations in the restorations.

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A digital approach integrating facial scanning in a CAD-CAM workflow for complete-mouth implant-supported rehabilitation of patients with edentulism: A pilot clinical study

Hassan B, Gimenez Gonzalez B, Tahmaseb A, Greven M, Wismeijer D
J Prosthet Dent 2017;117:486-492

STATEMENT OF PROBLEM: Complete-mouth implant-supported rehabilitations are challenging because of the multiple surgical and prosthetic steps involved in clinical evaluations to assure passive prosthesis fit and optimal esthetic and functional outcomes. As a result, these rehabilitations are usually associated with substantial clinical time, patient discomfort, and high treatment cost.

PURPOSE: The purpose of this pilot clinical study was to evaluate a novel digital approach integrating digital intraoral dental and extraoral facial scanning information to design and mill a computer-aided design and computer-aided manufacturing (CAD-CAM) implant-retained prosthesis for patients with complete edentulism.

MATERIAL AND METHODS: Ten patients in need of complete-mouth rehabilitation were included in this pilot study. Digital intraoral records were obtained through optical scanning the duplicate interim prosthesis using a laboratory scanner, while digital extraoral records were obtained through facial scanning using an in-office scanner. The scanned impressions and occlusal records were used to create a virtual tooth arrangement, which was matched to the patient's 3-dimensional face scan to create a virtual clinical evaluation phase. After applying the necessary adjustments, the virtual arrangement was submitted to a CAM procedure where a 5-axis industrial milling machine was used to fabricate an interim prosthesis.

RESULTS: Digital intraoral and extraoral records were integrated and used to fabricate CAD-CAM milled interim prostheses, which were inserted and assessed for clinical fit, occlusion/articulation, and esthetics. The prostheses remained in function for at least 6 months with no notable technical or biological complications except for 1 prosthesis that fractured.

CONCLUSIONS: A novel digital workflow incorporating facial scanning in a CAD-CAM workflow was used to fully digitally design and mill 10 implant-retained interim prostheses. More research is required to further develop and assess the accuracy and applicability of this approach.

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Randomized controlled within-subject evaluation of digital and conventional workflows for the fabrication of lithium disilicate single crowns. Part II: CAD-CAM versus conventional laboratory procedures

Sailer I, Benic GI, Fehmer V, Hämmerle CHF, Mühlemann S
J Prosthet Dent 2017;118:43-48

STATEMENT OF PROBLEM: Clinical studies are needed to evaluate the entire digital and conventional workflows in prosthetic dentistry.

PURPOSE: The purpose of the second part of this clinical study was to compare the laboratory production time for tooth-supported single crowns made with 4 different digital workflows and 1 conventional workflow and to compare these crowns clinically.

MATERIAL AND METHODS: For each of 10 participants, a monolithic crown was fabricated in lithium disilicate-reinforced glass ceramic (IPS e.max CAD). The computer-aided design and computer-aided manufacturing (CAD-CAM) systems were Lava C.O.S. CAD software and centralized CAM (group L), Cares CAD software and centralized CAM (group iT), Cerec Connect CAD software and lab side CAM (group CiL), and Cerec Connect CAD software with centralized CAM (group CiD). The conventional fabrication (group K) included a wax pattern of the crown and heat pressing according to the lost-wax technique (IPS e.max Press). The time for the fabrication of the casts and the crowns was recorded. Subsequently, the crowns were clinically evaluated and the corresponding treatment times were recorded. The Paired Wilcoxon test with the Bonferroni correction was applied to detect differences among treatment groups (α=.05).

RESULTS: The total mean (±standard deviation) active working time for the dental technician was 88 ±6 minutes in group L, 74 ±12 minutes in group iT, 74 ±5 minutes in group CiL, 92 ±8 minutes in group CiD, and 148 ±11 minutes in group K. The dental technician spent significantly more working time for the conventional workflow than for the digital workflows ($P<.001$). No statistically significant differences were found between group L and group CiD or between group iT and group CiL. No statistical differences in time for the clinical evaluation were found among groups, indicating similar outcomes ($P>.05$).

CONCLUSIONS: Irrespective of the CAD-CAM system, the overall laboratory working time for a digital workflow was significantly shorter than for the conventional workflow, since the dental technician needed less active working time

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Digital workflow for a dental prosthesis that considers lateral mandibular relation

Park JH, Kim JE, Shim JS
J Prosthet Dent 2017;117:340-344

ABSTRACT: Most digital prosthesis designs consider only the maximal intercuspal position (MIP) and not the lateral movement. During the computer-aided design and computer-aided manufacture (CAD-CAM) prosthesis delivery process, the clinician has to adjust the prosthesis to avoid occlusal interference during lateral excursion. The novel digital workflow described in this report can be divided into 2 steps. After obtaining interocclusal records for the MIP and the lateral excursion position, the crown CAD data were designed using a general digital workflow considering only the MIP. The previous crown CAD data were then adjusted in the lateral excursion state before manufacturing the prosthesis. This process using information for 2 occlusal positions means that the definitive prosthesis design reflects not only static occlusion but also lateral mandibular relation.

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Prosthodontic rehabilitation of an ectodermal dysplasia patient with implant telescopic crown attachments

Alsayed HD, Alqahtani NM, Levon JA, Morton D
J Prosthodont. 2017;26:622-627

Telescopic crown attachments have been successfully used in completely and partially edentulous patients. This type of attachment provides retention, support, and stability with optimal hygiene for the removable dental prosthesis (RDP). With the emergence of CAD/CAM technology, telescopic crown attachments can be virtually designed and milled precisely to ensure a passive fit of the attachment parts and maximal functionality of the RDP. This article reviews both the clinical outcome and prosthodontic rehabilitation of telescopic crown attachments of an edentulous ectodermal dysplasia patient with solitary rigid conical telescopic crown attachments.

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A digital approach integrating facial scanning in a CAD-CAM workflow for complete-mouthimplant-supported rehabilitation of patients with edentulism: A pilot clinical study

Hassan B, Gimenez Gonzalez B, Tahmaseb A, Greven M, Wismeijer D
J Prosthet Dent 2017;117:486-492

STATEMENT OF PROBLEM: Complete-mouth implant-supported rehabilitations are challenging because of the multiple surgical and prosthetic steps involved in clinical evaluations to assure passive prosthesis fit and optimal esthetic and functional outcomes. As a result, these rehabilitations are usually associated with substantial clinical time, patient discomfort, and high treatment cost.

PURPOSE: The purpose of this pilot clinical study was to evaluate a novel digital approach integrating digital intraoral dental and extraoral facial scanning information to design and mill a computer-aided design and computer-aided manufacturing (CAD-CAM) implant-retained prosthesis for patients with complete edentulism.

MATERIAL AND METHODS: Ten patients in need of complete-mouth rehabilitation were included in this pilot study. Digital intraoral records were obtained through optical scanning the duplicate interim prosthesis using a laboratory scanner, while digital extraoral records were obtained through facial scanning using an in-office scanner. The scanned impressions and occlusal records were used to create a virtual tooth arrangement, which was matched to the patient's 3-dimensional face scan to create a virtual clinical evaluation phase. After applying the necessary adjustments, the virtual arrangement was submitted to a CAM procedure where a 5-axis industrial milling machine was used to fabricate an interim prosthesis.

RESULTS: Digital intraoral and extraoral records were integrated and used to fabricate CAD-CAM milled interim prostheses, which were inserted and assessed for clinical fit, occlusion/articulation, and esthetics. The prostheses remained in function for at least 6 months with no notable technical or biological complications except for 1 prosthesis that fractured.

CONCLUSIONS: A novel digital workflow incorporating facial scanning in a CAD-CAM workflow was used to fully digitally design and mill 10 implant-retained interim prostheses. More research is required to further develop and assess the accuracy and applicability of this approach.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Evaluation of operating time and patient perception using conventional impression taking and intraoral scanning for crown manufacture: A split-mouth, randomized clinical study

Haddadi Y, Bahrami G, Isidor F
Int J Prosthodont 2018;31:55–59

PURPOSE: To compare operating time and patient perception of conventional impression (CI) taking and intraoral scanning (IOS) for manufacture of a tooth-supported crown.

MATERIAL AND METHODS: A total of 19 patients needing indirect full-coverage restorations fitting the requirements for a split-mouth design were recruited. Each patient received two lithium disilicate crowns, one manufactured from CI taking and one from IOS. Both teeth were prepared following the manufacturers' recommendations. For both impression techniques, two retraction cords soaked in 15% ferric sulphate were used for tissue management. CIs were taken in a full-arch metallic tray using one-step, two-viscosity technique with polyvinyl siloxane silicone. The operating time for each step of the two impression methods was registered. Patient perception associated with each method was scored using a 100-mm visual analog scale (VAS), with 100 indicating maximum discomfort.

RESULTS: Median total operating time for CI taking was 15:47 minutes (interquartile range [IQR] 15:18 to 17:30), and for IOS was 5:05 minutes (IQR 4:35 to 5:23). The median VAS score for patient perception was 73 (IQR 16 to 89) for CI taking and 6 (IQR 2 to 9) for IOS. The differences between the two groups were statistically significant ($P < .05$) for both parameters.

CONCLUSIONS: IOS was less time consuming than CI taking, and patient perception was in favor of IOS.

JPD THE JOURNAL OF PROSTHETIC DENTISTRY

Integrating a facial scan, virtual smile design, and 3D virtual patient for treatment with CAD-CAMceramic veneers: A clinical report

Lin WS, Harris BT, Phasuk K, Llop DR, Morton D
J Prosthet Dent 2018;119:200-205

This clinical report describes a digital workflow using the virtual smile design approach augmented with a static 3-dimensional (3D) virtual patient with photorealistic appearance to restore maxillary central incisors by using computer-aided design and computer-aided manufacturing (CAD-CAM) monolithic lithium disilicate ceramic veneers.

JPD THE JOURNAL OF PROSTHETIC DENTISTRY

A 3D-printed guide for lateral approach sinus grafting: A dental technique

Goodacre BJ, Swamidass RS, Lozada J, Al-Ardah A, Sahl E
J Prosthet Dent 2018;119:897-901

Lateral approach sinus grafting has become a routine and predictable surgical method of augmenting the pneumatized sinus for implant placement. Outlining the lateral window access can be a challenging task for the clinician to envision and execute. Improper extension and access to the maxillary sinus can prevent proper placement of graft materials and lead to complications. The purpose of this report was to demonstrate a technique that will allow the precise planning of the lateral approach using radiographic information and 3-dimensional (3D) software to 3D-print a surgical guide.

JPD THE JOURNAL OF PROSTHETIC DENTISTRY

A clinical technique for virtual articulator mounting with natural head position by using calibrated stereophotogrammetry

Lam WYH, Hsung RTC, Choi WWS, Luk HWK, Cheng LYY, Pow EHN
J Prosthet Dent 2018;119:902-908

Accurate articulator-mounted casts are essential for occlusion analysis and for fabrication of dental prostheses. Although the axis orbital plane has been commonly used as the reference horizontal plane, some clinicians prefer to register the horizontal plane with a spirit level when the patient is in the natural head position (NHP) to avoid anatomic landmark variations. This article presents a digital workflow for registering the patient's horizontal plane in NHP on a virtual articulator. An orientation reference board is used to calibrate a stereophotogrammetry device and a 3-dimensional facial photograph with the patient in NHP. The horizontal plane can then be automatically registered to the patient's virtual model and aligned to the virtual articulator at the transverse horizontal axis level. This technique showed good repeatability with positional differences of less than 1 degree and 1 mm in 5 repeated measurements in 1 patient.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Digital impression-taking facilitates prosthetic rehabilitation of microstomia patients: A case history report

Adali U, Schober S, Beuer F, Spies BC
Int J Prosthodont 2019;32:110–112

In most cases, prosthetic rehabilitation of patients suffering from microstomia is inconvenient for the patient and challenging for both the dentist and dental technician. In such cases, conventional impression-taking requires an individualized tray design and modified impression techniques, amplifying the risk for impression and cast deformation and thereby compromising the final outcome. An intraoral scanner (IOS) might overcome these limitations due to its reduced size compared to an impression tray. In the present case history report, a microstomia patient was successfully restored with a telescopic prosthesis by digitizing both retaining teeth and the palate with an IOS.

Journal of
Prosthodontics
Implant, Esthetic, and Reconstructive Dentistry

A full-digital technique to mount a maxillary arch scan on a virtual articulator

Lepidi L, Chen Z, Ravida A, Lan T, Wang HL, Li J
J Prosthodont 2019;28:335-338

Mounting casts accurately on an articulator is a prerequisite for the treatment planning/execution of complex dental cases that require occlusal rehabilitation. A full digital approach to transfer the position of maxillary dentition to a virtual articulator, by using intraoral scans and cone beam computed tomography (CBCT) files is presented. This technique offers reduced chairside time and the flexibility of choosing the orientation plane. It can be used in orthognathic surgeries, complex interdisciplinary treatments requiring a CBCT scan with a large field of view, or treatments that already have the head CT or CBCT scans from previous diagnosis/treatment.

JPD THE JOURNAL OF PROSTHETIC DENTISTRY

Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic posterior fixed partial dentures. Part II: Time efficiency of CAD-CAM versus conventional laboratory procedures

Mühlemann S, Benic GI, Fehmer V, Hämmerle CHF, Sailer I
J Prosthet Dent 2019;121:252-257

STATEMENT OF PROBLEM: Clinical trials are needed to evaluate the digital and conventional fabrication technology for providing fixed partial dentures (FPDs).

PURPOSE: The purpose of the second part of this clinical study was to compare the laboratory production time for tooth-supported, 3-unit FPDs by means of computer-aided design and computer-aided manufacturing (CAD-CAM) systems and a conventional workflow. In addition, the quality of the 3-unit framework of each treatment group was evaluated clinically.

MATERIAL AND METHODS: For each of 10 participants, a 3-unit FPD was fabricated. Zirconia was used as the framework material in the CAD-CAM systems and included Lava C.O.S. CAD software (3M) and centralized CAM (group L); CARES CAD software (Institut Straumann AG) and centralized CAM (group iT); and CEREC Connect CAD software (Dentsply Sirona) and centralized CAM (group C). The noble metal framework in the conventional workflow (group K) was fabricated by means of the traditional lost-wax technique. All frameworks were evaluated clinically before veneering. The time for the fabrication of the cast, the 3-unit framework, and the veneering process was recorded. In addition, chairside time during the clinical appointment for the evaluation of the framework was recorded. The paired Wilcoxon test together with appropriate Bonferroni correction was applied to detect differences among treatment groups (α=.05).

RESULTS: The total effective working time (mean ffIstandard deviation) for the dental technician was 220 ffI29 minutes in group L, 217 ffI23 minutes in group iT, 262 ffI22 minutes in group C, and 370 ffI34 minutes in group K. The dental technician spent significantly more time in the conventional workflow than in the digital workflow, independent of the CAD-CAM systems used (P<.001).

CONCLUSIONS: Irrespective of the CAD-CAM system, the overall laboratory time for the dental technician was significantly less for a digital workflow than for the conventional workflow.

JPD THE JOURNAL OF PROSTHETIC DENTISTRY

Fully digital fabrication of an occlusal device using an intraoral scanner and 3D printing: A dental technique

Waldecker M, Leckel M, Rammelsberg P, Bömicke W
J Prosthet Dent 2019;121:576-580

This dental technique describes a fully digital method for fabricating occlusal devices using a complete-arch intraoral scan and 3D printing. The maxillary and mandibular arches of a healthy, fully dentate volunteer were digitized using an intraoral scanner. A second scan and modified recording of the centric relation enabled a virtual arrangement of the maxillary and mandibular arches, both in centric relation and in the desired vertical dimension of occlusion. An occlusal device was subsequently designed virtually and fabricated from a light-polymerizing acrylic resin using a 3D printer. The occlusal device was tested for fit, occlusion, and patient-friendly handling. As only minor occlusal corrections were required, the fully digital procedure described is suitable for the fabrication of occlusal devices.

Journal of Dentistry

Non-destructive 3D imaging of composite restorations using optical coherence tomography: Marginal adaptation of self-etch adhesives

Makishi P, Shimada Y, Sadr A, Tagami J, Sumi Y
J Dent 2011;39: 316-325

OBJECTIVES: To investigate the potential use of swept-source optical coherence tomography (SS-OCT) as a new tool to evaluate marginal adaptation of composite restorations in class I cavities.

METHODS: Round-shaped class I cavities (3 mm diameter · 1.5 mm depth) were prepared on buccal enamel of bovine teeth with cavity floor located in dentine. The cavities were restored with a flowable resin composite (Clearfil Majesty LV) using two-step self-etch adhesive (SE Bond), all-in-one self-etch adhesive (G-Bond) or no adhesive (Control). The specimens were subjected to water storage (37 °C, 24 h) or thermal stress challenge (5000 cycles, 5 °C and 55 °C). 3D scans (4 mm · 4 mm · 2.6 mm obtained in 4 s) of the restoration were obtained using SS-OCT before and after immersion into a contrast agent. 2D images obtained from the 3D scans (n = 30/group) were analysed to evaluate marginal adaptation. Area fraction of pixels with high brightness values at the interfacial zone was calculated using a digital image analysis software. The results were statistically compared with statistical significance defined as $p \leq 0.05$.

RESULTS: Wilcoxon signed ranks test showed that there was no statistically significant difference in the results of SS-OCT before and after infiltration of the contrast agent when a ranking transformation was applied on to the data ($p > 0.05$). A significant positive linear correlation was found between the two SS-OCT images. Confocal laser scanning photomicrographs of samples cut after silver infiltration confirmed the presence of gap.

CONCLUSIONS: 3D imaging by SS-OCT can be considered as a non-invasive technique for fast detection of gaps at the restoration interface.

Journal of Dentistry

The effect of surface defects in early caries assessment using quantitative light-induced fluorescence (QLF) and micro-digital-photography (MDP)

Meharry MR, Dawson D, Wefel JS, Harless JD, Kummet CM, Xiao X
J Dent 2012;40:955-961

OBJECTIVES: The purpose of this study was to consider the impact of surface defects on quantitative light-induced fluorescence (QLF) and micro-digital-photography (MDP) measures, in relationship to lesion depth.

METHODS: Simulated enamel carious lesions were developed on 45 extracted human teeth. Images of each tooth were captured with both QLF and MDP. The teeth were sectioned and lesion depth was measured with polarized light microscopy (PLM). Pearson correlations were computed using data from the 27 lesions which did not have surface loss, and then separately based upon the 18 lesions which did display surface loss. MDP variables ΔR and ΔX measure reflected light, whereas QLF variables ΔF and ΔQ measure fluorescence.

RESULTS: A strong correlation was identified between lesion depth and ·F ($r = -0.765$, $p < 0.0001$), and ·Q ($r = -0.827$, $p < 0.0001$) on intact lesions while a weak but suggestive, although non-significant, correlation was identified between average lesion depth and ·R ($r = 0.369$, $p = 0.059$) and ·X ($r = 0.595$, $p = 0.0011$). However, the corresponding correlation was not statistically significant, when lesions with surface loss were considered for QLF and MDP measures.

CONCLUSIONS: QLF measures ·F and ·Q were strongly correlated with lesion depth in lab-simulated lesions with no surface loss, but not among lesions with surface defects. The two MDP-associated measures, ·R and ·X, could not be said to differ significantly when lesions with and without surface defects were compared with lesion depth. Because intact lesions can be remineralized, accurate assessment of their status is imperative for caries treatment.

CLINICAL SIGNICANCE: Dental caries is still widely prevalent today. We now know that with early stage detection, remineralization can be accomplished. Being able to identify dental caries in its reversible stage (before physical surface loss) is paramount for the clinician to be able to treat the disease non-invasively.

Journal of Dentistry

Quantitative light-induced fluorescence (QLF): A tool for early occlusal dental caries detection and supporting decision making in vivo

Alammari MR, Smith PW, de Josselin de Jong E, Higham SM
J Dent 2013;41:127-132

OBJECTIVES: This study reports the development and assessment of a novel method using quantitative light-induced fluorescence (QLF), to determine whether QLF parameters ΔF and ΔQ were appropriate for aiding diagnosis and clinical decision making of early occlusal mineral loss by comparing QLF analysis with actual restorative management.

METHODS: Following ethical approval, 46 subjects attending a dental teaching hospital were enrolled. White light digital (WL) and QLF images/analyses of 46 unrestored posterior teeth with suspected occlusal caries were made after a clinical decision had already been taken to explore fissures operatively. WL and QLF imaging/analysis were repeated after initial cavity preparation. The type of restorative treatment was determined by the supervising clinician independent of any imaging performed. Actual restorative management carried out was recorded as fissure sealant/preventive resin restoration (F/P) or class I occlusal restoration (Rest.) thus reflecting the extent of intervention (=gold standard). All QLF images were analysed independently.

RESULTS: The results showed statistically significant differences between the two treatment groups ΔF (p = 0.002) (mean 22.60 – F/P and 28.80 – Rest.) and ΔQ (p = 0.012) (mean 230.49 – F/P and 348.30 – Rest.).

CONCLUSIONS: ΔF and ΔQ values may be useful in aiding clinical diagnosis and decision making in relation to the management of early mineral loss and restorative intervention of occlusal caries.

CLINICAL SIGNIFICANCE: QLF has the potential to be a valuable tool for caries diagnosis in clinical practice.

Journal of Dentistry

Quantification of incisal tooth wear in upper anterior teeth: Conventional vs new method using toolmakers microscope and a three-dimensional measuring technique

AL-Omiri MK, Sghaireen MG, AlZarea BK, Lynch E
J Dent 2013;41:1214-1221

OBJECTIVES: This study aimed to quantify tooth wear in upper anterior teeth using a new CAD-CAM Laser scanning machine, tool maker microscope and conventional tooth wear index.

METHODS: Fifty participants (25 males and 25 females, mean age = 25 ± 4 years) were assessed for incisal tooth wear of upper anterior teeth using Smith and Knight clinical tooth wear index (TWI) on two occasions, the study baseline and 1 year later. Stone dies for each tooth were prepared and scanned using the CAD-CAM Laser Cercon System. Scanned images were printed and examined under a toolmaker microscope to quantify tooth wear and then the dies were directly assessed under the microscope to measure tooth wear. The Wilcoxon Signed Ranks Test was used to analyze the data.

RESULTS: TWI scores for incisal edges were 0–3 and were similar at both occasions. Score 4 was not detected. Wear values measured by directly assessing the dies under the toolmaker microscope (range = 113–150 μm, mean = 130 ffl 20 μm) were significantly more than those measured from Cercon Digital Machine images (range = 52–80 μm, mean = 68 ffl 23 μm) and both showed significant differences between the two occasions.

CONCLUSIONS: Wear progression in upper anterior teeth was effectively detected by directly measuring the dies or the images of dies under toolmaker microscope. Measuring the dies of worn dentition directly under tool maker microscope enabled detection of wear progression more accurately than measuring die images obtained with Cercon Digital Machine. Conventional method was the least sensitive for tooth wear quantification and was unable to identify wear progression in most cases.

Journal of Dentistry

Association between the cariogenicity of a dental microcosm biofilm and its red fluorescence detected by Quantitative Light-induced Fluorescence-Digital (QLF-D)

Lee E-S, Kang S-M, Ko H-Y, Kwon H-K, Kim B-I
J Dent 2013;41:1264-1270

OBJECTIVE: This study evaluated whether Quantitative Light-induced Fluorescence-Digital (QLF-D) can detect the levels of cariogenicity of dental microcosm biofilms by assessing the red fluorescence intensity.

METHODS: Dental microcosm biofilms were initiated from human saliva on bovine enamel discs. Biofilms with various levels of cariogenicity were then grown in artificial saliva supplemented with sucrose at different concentrations (0.05%, 0.1%, 0.2%, and 0.5%) in 24-well microplates. After 10 days, fluorescence images of the biofilms were captured by the QLF-D to analyse the red fluorescence intensity, which was quantified as the red/green ratio (R/G value). The supernatant pH was also measured, as well as the total and aciduric bacteria counts of the collected biofilms. Mineral loss in enamel was also evaluated by calculating the percentage of surface microhardness changes (%SHC).

RESULTS: The *R/G* values of the biofilms differed significantly with the sucrose concentration ($p < 0.0001$), increasing consistently as the sucrose concentration increased from 0.05% (=0.91) to 0.5% (=2.56). Strong correlation was identified between the R/G value and the number of aciduric bacteria ($r = 0.83$, $p < 0.0001$), supernatant pH ($r = -0.95$, $p < 0.0001$), and %SHC ($r = 0.90$, $p < 0.0001$).

CONCLUSIONS: The red fluorescence as observed by the QLF-D was correlated with the cariogenic properties of dental microcosm biofilms *in vitro*, which indicates that this device can be used to detect the levels of cariogenicity of a dental biofilm.

CLINICAL SIGNICANCE: The QLF-D is able to assess the cariogenic levels of dental plaque based on the intensity of red fluorescence.

Journal of Dentistry

Can the intra-examiner variability of Little's Irregularity Index be improved using 3D digital models of study casts?

Dowling AH, Burns A, Macauley D, Garvey TM, Fleming GJP
J Dent 2013;41:1271-1280

OBJECTIVES: To compare contact point displacement measurements, used to determine the Little's Irregularity Index (LII) score on study casts and digital models of study casts by an independent examiner.

METHODS: The contact point displacement measurements of the six maxillary anterior labial teeth were measured on ten study casts using digital callipers and their associated digital models using Creo Parametric software on five occasions following scanning using a LAVA Chairside Oral Scanner (LCOS) three-dimensional (3D) intra oral scanner. Means, standard deviations and coefficients of variation (CoV) were determined, data analyses (Pearson's correlation coefficients (PCCs) and Intraclass correlation coefficients (ICCs)) and statistical analyses (three and two-way analyses of variance (ANOVAs) and Independent Sample Student's t-tests) were carried out ($p < 0.05$).

RESULTS: Significant positive correlations for the contact point displacement measurements were evident between all measurement time points for the study casts ($r > 0.978$; $p < 0.0001$ and ICC > 0.910; $p < 0.0001$) and the digital models ($r > 0.963$; $p < 0.0001$ and ICC > 0.986; $p < 0.0001$). The CoV results showed that the contact point displacement measurement data from the digital models was more reproducible than the study casts. Of the 50 Independent Sample Student's t-tests, 21 significant increases ($p < 0.042$) were reported in contact point displacement measurements <2.9 mm for the digital models compared with the study casts.

CONCLUSION: The use of 3D digital models can improve the reliability of LII measurements by reducing the subjectivity associated with choosing the anatomic tooth contact points and the awkwardness of measuring the contact point displacements on study casts using a cumbersome calliper technique.

CLINICAL SIGNIFICANCE: Intra-examiner variability in the measurement of LII is still evident with digital models suggesting that either improved software specifically aimed at the orthodontic community be identified or a new method for measuring anterior incisor crowding be sought.

Journal of Dentistry

3D Computer aided treatment planning in endodontics

Bidra AS, Taylor TD, Agar JR
J Prosthet Dent 2013;109:361-366

OBJECTIVES: Obliteration of the root canal system due to accelerated dentinogenesis and dystrophic calcification can challenge the achievement of root canal treatment goals. This paper describes the application of 3D digital mapping technology for predictable navigation of obliterated canal systems during root canal treatment to avoid iatrogenic damage of the root.

METHODS: Digital endodontic treatment planning for anterior teeth with severely obliterated root canal systems was accomplished with the aid of computer software, based on cone beam computer tomography (CBCT) scans and intra-oral scans of the dentition. On the basis of these scans, endodontic guides were created for the planned treatment through digital designing and rapid prototyping fabrication.

RESULTS: The custom-made guides allowed for an uncomplicated and predictable canal location and management.

CONCLUSION: The method of digital designing and rapid prototyping of endodontic guides allows for reliable and predictable location of root canals of teeth with calcifically metamorphosed root canal systems.

CLINICAL SIGNIFICANCE: The endodontic directional guide facilitates difficult endodontic treatments at little additional cost.

Journal of Dentistry

Monitoring the maturation process of a dental microcosm biofilm using the Quantitative Light-induced Fluorescence-Digital (QLF-D)

Kim Y-S, Lee E-S, Kwon H-K, Kim B-I
J Dent 2014;42:691-696

OBJECTIVES: The aim of this study was to investigate whether Quantitative Light-induced Fluorescence-Digital (QLF-D) could monitor the degree of maturation of dental microcosm biofilms by observing the red fluorescence emitted from the biofilms.

METHODS: Dental microcosm the biofilms were grown on bovine enamel discs. They were initiated from human saliva, and then grown in 0.5% sucrose growth media for 10 days. On days 1, 2, 3, 7, and 10 after the inoculation, fluorescence images of the biofilms were captured using the QLF-D and the red fluorescence intensity was quantified by calculating the red/green ratio (R/G value). Total and aciduric bacteria within the biofilms were counted, and the degree of demineralization was evaluated by measuring the percentage of surface microhardness change (·VHN) and lesion depth in the enamel.

RESULTS: The R/G values of the biofilms assessed by the QLF-D increased significantly over time up to 7 days after inoculation ($p < 0.0001$). The R/G values showed significant positive correlations with the total bacterial CFUs ($r = 0.74$, $p = 0.001$), aciduric bacterial CFUs ($r = 0.85$, $p = 0.001$), ·VHN ($r = 0.65$, $p = 0.001$), and lesion depth in the enamel ($r = 0.82$, $p = 0.001$) according to the maturation time.

CONCLUSIONS: The red fluorescence detected by the QLF-D increased according to biofilm maturation and was significantly associated with the cariogenicity of the biofilm. Therefore, this device could be used to monitor the degree of biofilm maturation by observing the red fluorescence emitted from cariogenic biofilms.

CLINICAL SIGNIFICANCE: The QLF-D enables the detection of a mature dental plaque and monitoring of its cariogenic status by observing the plaque fluorescence non-destructively, in real time.

Journal of Dentistry

The reliability of Little's Irregularity Index for the upper dental arch using three dimensional (3D) digital models

Burns A, Dowling AH, Garvey TM, Fleming GJP
J Dent 2014;42:1320-1326

AIM: To investigate the inter-examiner variability of contact point displacement measurements (used to calculate the overall Little's Irregularity Index (LII) score) from digital models of the maxillary arch by four independent examiners.

METHODS: Maxillary orthodontic pre-treatment study models of ten patients were scanned using the Lava(tm) Chairside Oral Scanner (LCOS) and 3D digital models were created using Creo® computer aided design (CAD) software. Four independent examiners measured the contact point displacements of the anterior maxillary teeth using the software. Measurements were recorded randomly on three separate occasions by the examiners and the measurements (n = 600) obtained were analysed using correlation analyses and analyses of variance (ANOVA).

RESULTS: LII contact point displacement measurements for the maxillary arch were reproducible for inter-examiner assessment when using the digital method and were highly correlated between examiner pairs for contact point displacement measurements >2 mm. The digital measurement technique showed poor correlation for smaller contact point displacement measurements (<2 mm) for repeated measurements. The coefficient of variation (CoV) of the digital contact point displacement measurements highlighted 348 of the 600 measurements differed by more than 20% of the mean compared with 516 of 600 for the same measurements performed using the conventional LII measurement technique.

CONCLUSIONS: Although the inter-examiner variability of LII contact point displacement measurements on the maxillary arch was reduced using the digital compared with the conventional LII measurement methodology, neither method was considered appropriate for orthodontic research purposes particularly when measuring small contact point displacements.

Journal of Dentistry

Validation of quantitative light-induced fluorescence-digital (QLF-D) for the detection of approximal caries in vitro

Ko H-Y, Kang S-M, Kim HE, Kwon H-K, Kim B-I
J Dent 2015;43:568-575

OBJECTIVES: Detection of approximal caries lesions can be difficult due to their anatomical position. This study aimed to assess the ability of the quantitative light-induced fluorescence-digital (QLF-D) in detecting approximal caries, and to compare the performance with those of the International Caries Detection and Assessment System II (ICDAS II) and digital radiography (DR).

METHODS: Extracted permanent teeth (n = 100) were selected and mounted in pairs. The simulation pairs were assessed by one calibrated dentist using each detection method. After all the examinations, the teeth (n = 95) were sectioned and examined histologically as gold standard. The modalities were compared in terms of sensitivity, specificity, areas under receiver operating characteristic curves (AUROC) for enamel (D1) and dentine (D3) levels. The intra-examiner reliability was assessed for all modalities.

RESULTS: At D1 threshold, the ICDAS II presented the highest sensitivity (0.80) while the DR showed the highest specificity (0.89); however, the methods with the greatest AUC values at D1 threshold were DR and QLF-D (0.80 and 0.80 respectively). At D3 threshold, the methods with the highest sensitivity were ICDAS II and QLF-D (0.64 and 0.64 respectively) while the method with the lowest sensitivity was DR (0.50). However, with regard to the AUC values at D3 threshold, the QLF-D presented the highest value (0.76). All modalities showed to have excellent intra-examiner reliability.

CONCLUSIONS: The newly developed QLF-D was not only able to detect proximal caries, but also showed to have comparable performance to the visual inspection and radiography in detecting proximal caries.

CLINICAL SIGNIFICANCE: QLF-D has the potential to be a useful detection method for proximal caries.

JPD THE JOURNAL OF PROSTHETIC DENTISTRY

Diagnostic accuracy of conventional and digital radiography for detecting misfit between the tooth and restoration in metal-restored teeth

Liedke GS, Spin-Neto R, Vizzotto MB, Da Silveira PF, Silveira HE, Wenzel A
J Prosthet Dent 2015;113:39-47

STATEMENT OF PROBLEM: Although the postprocessing of digital images with enhancement filters could lead to the presence of artifacts and result in false-positive diagnoses, no study has analyzed whether the use of digital radiographs and/or postprocessing of digital images interferes with the diagnosis of marginal adaptation in metal-restored teeth.

PURPOSE: The purpose of this study was to compare the diagnostic accuracy of conventional and digital radiographic images with and without filters for detecting a misfit between the tooth and restoration in metal-restored teeth.

MATERIAL AND METHODS: Forty teeth with mesial-occlusal-distal inlays and 40 with complete crowns (each with a perfect fit, 20 with a 0.2-mm gap and 20 with a 0.4-mm gap) were imaged with conventional film and digital phosphor plate systems. Digital radiographs were exported as original images and with edge enhancement (high and low), inversion, and pseudo-3-dimensional filters. Four examiners assessed the presence of gaps by using a categorical scale (fit, misfit, cannot decide). Sensitivity, specificity, and overall accuracy were calculated for each variable. In addition, time spent scoring the images was recorded. A multivariate logistic regression was performed with accuracy as the dependent variable.

RESULTS: Of the images, 6.2% received the score "cannot decide," most of them with a high edge enhancement filter and in the crown group. A tendency for higher sensitivity (range 0.67-0.83), specificity (range 0.81-0.92), and accuracy (range 0.73-0.86) values was found in conventional and digital original images. Results of a logistic regression found that restoration type, gap size, and high enhancement and inversion filters had a statistically significant impact on accuracy ($P<.05$).

CONCLUSIONS: Original nonfiltered images should be used to assess teeth with metal restorations. High enhancement filters and image inversion should be avoided, especially when metal crowns are present.

Journal of Dentistry

Assessment of wear facets produced by the ACTA wear machine

Benetti AR, Larsen L, Dowling AH, Fleming GJP
J Dent 2016;45:19-25

OBJECTIVE: To investigate the use of a three-dimensional (3D) digital scanning method in determining the accuracy of the wear performance parameters of resin-based composites (RBCs) determined using a two-dimensional (2D) analogue methodology following in-vitro testing in an Academisch Centrum for Tandheelkunde Amsterdam (ACTA) wear machine.

METHODS: Specimens compatible with the compartments of the ACTA wear machine specimen wheel (n = 10) were prepared from one commercial and four experimental RBCs. The RBC specimens were rotated against an antagonist wheel in a food-like slurry for 220,000 wear cycles. The mean wear depth was measured using the traditionally employed 2D and compared with the 3D profilometric (digital) techniques. Data were submitted to analyses of variance, Tukey's post hoc tests and Independent Samples Student's t-tests (where appropriate) atp < 0.05.

RESULTS: The RBC rank achieved for mean wear depth calculations were similar whether the 2D or 3D techniques were employed. However, the mean wear depth values obtained from the 3D digital technique were significantly increased for two of the five RBC materials compared with the 2D methodology. The total volumetric wear data provided an assessment of the potential of the experimental RBC formulations for clinical usage.

CONCLUSION: The 3D technique allowed for the assessment of mean maximum wear depth and mean total volumetric wear which enables tribological analyses of the wear facet and therefore the wear mechanisms operative. Employing the 2D profile technique ranks RBC materials in terms of in-vitro wear performance.

CLINICAL SIGNIFICANCE: Confidence in the wear volume measurements can only be achieved if the wear facet is analysed with sufficient resolution using a 3D digital measurement technique. However, the employment of 2D profilers is useful when screening potential new RBC formulations for the restoration of posterior dentition.

Journal of Dentistry

Impact of cone beam computed tomography (CBCT) on diagnostic thinking in endodontics of posterior teeth: A before- after study

Al-Salehi SK, Horner K
J Dent 2016;53:57-63

OBJECTIVES: The aim of this study was to evaluate the impact of limited volume CBCT upon diagnosis as part of endodontic management of posterior teeth. The null hypothesis that CBCT does not make any difference in endodontic diagnosis was tested.

METHODS: A single-centre "before-after" study was conducted in a secondary healthcare establishment. Eligible patients were all adults aged 18 years or over who were referred to a specialist endodontic unit. Further inclusion criteria were that the cases were either re-treatment or de novo root canal treatment where the anatomy was judged to be complex. Exclusion criteria included vulnerable groups and de novo endodontic treatment with uncomplicated root canal anatomy. As well as a full history and clinical examination, a high quality colour photographic intraoral image, two paralleling technique periapical radiographs and limited volume CBCT examination were carried out for each patient. All components, except the CBCT dataset, were combined into a Powerpoint presentation and assessed by 4 observers. A questionnaire was designed for the observers as part of the study.

RESULTS: CBCT information only changed the radiological findings and the final diagnosis in a minority of cases. There was no clear evidence that CBCT increases the confidence of observers or that CBCT was helpful in making a diagnosis.

CONCLUSIONS: Routine use of CBCT cannot not be justified on the basis of a change in diagnosis and carefully selected use is appropriate.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Reproducibility of a new computerized planimetric method for the measurement and assessment of removable dental prostheses plaque

Al Jaghsi A, Mundt T, Biffar R
Int J Prosthodont 2017;30:377-383

PURPOSE: The aim of this study was to evaluate the reliability and agreement of a new computerized planimetric method (CPM) for the measurement and assessment of plaque on all types of removable dental prostheses (RDPs).

MATERIALS AND METHODS: From a database containing 780 images taken following a standardized method for 65 RDPs, 55 images were randomly selected for image analysis. Adobe Photoshop software was used according to standard operating procedure (SOP) by one main examiner two times in different sessions, and one time by three additional examiners. To estimate the intra- and interexaminer reliability, intraclass correlation coefficient $ICC_{(2,1)}$ were used. Three parameters were used to estimate agreement: standard error of measurement (SEM), smallest detectable change at the 95% confidence level ($SDC_{95\%}$), and limits of agreement (LoA) according to the Bland-Altman method.

RESULTS: In all steps of the image analysis, both intra- and interexaminer reliability were excellent, with $ICC_{(2,1)}$ values > 0.85 at the 95% confidence level. The intra- and interexaminer values for both the $SEM_{agreement}$ and $SDC_{95\%}$ were ≤ 6% and ≤ 17%, respectively. The Bland-Altman analysis revealed a satisfactory level of agreement.

CONCLUSION: This study shows excellent inter- and intraexaminer reproducibility, a satisfactory level of examiner agreement, and acceptable measurement error. Furthermore, the method can be used with all types of RDPs. The CPM is more suitable for clinical research because of its objectivity, reliability, high level of standardization, and ability to detect and quantify small changes in plaque.

Journal of Dentistry

Is a basic erosive wear examination (BEWE) reliable for recording erosive tooth wear on 3D models?

Alaraudanjoki V, Saarela H, Pesonen R, Laitala ML, Kiviahde H, Tjäderhane L, Lussi A, Pesonen P, Anttonen V
J Dent 2017;59:26-32

OBJECTIVES: To assess the reliability of the BEWE index on 3D models and to compare 3D-assessed erosive tooth wear scores with clinically detected scores.

METHODS: In total, 1964 members of the Northern Finland Birth Cohort 1966 participated in a standardized clinical dental examination including the Basic Erosive Wear Examination (BEWE) and dental 3D modelling at the age of 45-46 years. Of those examined, 586 were randomly selected for this study. 3D models were assessed using the same BEWE criteria as in the clinical examination. Calculated kappa values as well as the prevalence and severity of erosive wear according to the clinical examination and 3D models were compared. Re-examinations were performed to calculate intra- and inter-method and -examiner agreements.

RESULTS: The BEWE index on 3D models was reproducible; the mean intra- and inter-examiner agreement were 0.89 and 0.87, respectively, for sextant level, and 0.64 and 1, respectively, for BEWE sum scores. Erosive tooth wear was recorded as more severe in 3D models than in the clinical examination, and inter-method agreement was 0.41 for severe erosive wear (BEWE sum>8). The biggest inter-method differences were found in upper posterior sextants.

CONCLUSIONS: The BEWE index is reliable for recording erosive tooth wear on 3D models. 3D models seem to be especially sensitive in detecting initial erosive wear. Additionally, it seems that erosive wear may be underscored in the upper posterior sextants when assessed clinically. Due to the nature of 3D models, the assessment of erosive wear clinically and on 3D models may not be entirely comparable.

CLINICAL SIGNIFICANCE: 3D models can serve as an additional tool to detect and document erosive wear, especially during the early stages of the condition and in assessing the progression of wear. When scoring erosive wear clinically, care must be taken especially when assessing upper posterior sextants.

JPD THE JOURNAL OF PROSTHETIC DENTISTRY

Customized procedure to display T-Scan occlusal contacts

Solaberrieta E, Etxaniz O, Otegi JR, Brizuela A, Pradies G
J Prosthet Dent 2017;117:18-21

The virtual technique described in this article integrates reverse engineering and mandibular dynamics into dental computer-aided design and computer-aided manufacturing (CAD-CAM) systems. This technique aims to provide more objective information to the dental technician for the diagnosis, planning, and treatment phases. In order to carry out this protocol, the following devices, currently available in many practices, are necessary: an intraoral scanner, a T-Scan system, and some specific open reverse engineering software. By means of a virtual procedure, the T-Scan system detects the occlusal contacts, and the occlusal surfaces are obtained using an intraoral scanner. Once the alignment between the 3-dimensional occlusal surface and the T-Scan registration is carried out, the resulting contacts are projected onto the patient's occlusal surfaces; in this way, occlusal forces are obtained over time. The results obtained with this procedure demonstrate the feasibility of integrating different tools and software and the full integration of this procedure into a dental digital workflow.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Clinical monitoring of tooth wear progression in patients over a period of one year using CAD/CAM

Ahmed KE, Whitters J, Ju X, Pierce SG, MacLeod CN, Murray CA
Int J Prosthodont 2017;30:153-155

PURPOSE: The aim of this study was to clinically monitor the progression of tooth wear over a period of 1 year in a cohort of referred tooth wear patients through the use of a computer-aided design/computer-assisted manufacture (CAD/CAM) scanner and a standardized scanning/assessment methodology.

MATERIALS AND METHODS: Polyether impressions were made of 11 participants (130 teeth) at baseline and at 1 year. Impressions were poured in type IV dental stone and the anterior teeth were 3D scanned. A surface-matching software was used to compare 1-yearand baseline scans and identify any dimensional differences.

RESULTS: Parafunctional habits were reported by all patients. All participants exhibited tooth wear ≥ 140 µm in depth and extending to ≥ 280 µm in at least one tooth. Maxillary central incisors were the most commonly and severely affected teeth.

CONCLUSION: The ability of the developed CAD/CAM scanning methodology in clinical monitoring of tooth wear was demonstrated. Further research is needed to assess its practicality in large-scale epidemiologic tooth wear studies.

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Diagnosis of disk displacement using real-time MRI: Clinical report of two patients

Krohn S, Frahm J, Merboldt KD, Wassmann T, Joseph AA, Bürgers R
J Prosthet Dent 2018;119:206-209

The clinical application of real-time magnetic resonance imaging (MRI) for the diagnosis of temporomandibular joint disk displacement(DD) with and without reduction is presented. In 2 patients with presumed DD, real-time MRI at 15 frames per second was performed during the natural opening and closing of the mouth. In one patient unilateral DD with reduction and in the other patient bilateral DD without reduction were observed. In contrast with conventional static MRI, real-time MRI moving images of temporomandibular joint DD offer comprehensive information about the dynamics of all involved structures, which in turn promises more reliable diagnoses. Real-time MRI is more rapid, more reliable, more informative, and less stressful for patients with temporomandibular disorders (TMDs).

Journal of Dentistry

In vitro performance of the DIAGNOcam for detecting proximal carious lesions adjacent to composite restorations

Elhennawy K, Askar H, Jost-Brinkmann PG, Reda S, Al-Abdi A, Paris S, Schwendicke F
J Dent 2018;72:39-43

OBJECTIVES: To assess the accuracy of near-infrared-light transillumination (DIAGNO) compared to visual-tactile (VT) and radiographic (RA) evaluation of proximal carious lesions adjacent to composite restorations in vitro.

METHODS: Two hundred extracted posterior permanent human teeth with occluso-proximal composite restorations were allocated to 50 groups of four posterior teeth, and mounted in a pilot-tested diagnostic model in a dummy head. The teeth were independently assessed by two examiners. Transverse microradiography and visual assessment served as reference tests to detect any lesions (prevalence 24%) and cavitated lesions (18%), respectively, adjacent to restorations. Sensitivity, specificity, positive and negative predictive values and the area under the receiver-operating-characteristics curve (AUC) were calculated.

RESULTS: To detect any proximal carious lesions adjacent to composite, the mean sensitivity/specificity were 0.63/0.95 for DIAGNO, 0.70/0.88 for RA when lesions radiographically extending into enamel and dentin were considered, 0.26/0.98 for RA when only lesions extending into dentin were considered, and 0.31/0.96 for VT. For cavitated lesions adjacent to proximal composite restorations, these values were RA (enamel and dentin) 0.84/0.88, RA (dentin) 0.34/0.99, DIAGNO 0.69/0.94 and VT 0.40/0.97. AUC did not differ significantly between RA and DIAGNO, while VT showed significantly lower values ($p < 0.05$).

CONCLUSION: Within the limitations of this study, DIAGNO seems useful for detecting proximal carious lesions adjacent to restorations.

CLINICAL RELEVANCE: Near-infrared-light transillumination could be used as a radiation-free adjunct or alternative to RA for detecting carious lesions adjacent to composite restorations.

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Evaluation of the success rate of cone beam computed tomography in determining the locationand direction of screw access holes in cement-retained implant-supported prostheses: An in vitro study

Neshandar Asli H, Dalili Kajan Z, Gholizade F
J Prosthet Dent 2018;120:220-224

STATEMENT OF PROBLEM: Cement-retained implant-supported restorations have advantages over screw-retained restorations but are difficult to retrieve. Identifying the approximate location of the screw access hole (SAH) may reduce damage to the prosthesis.

PURPOSE: The purpose of this in vitro study was to evaluate the ability of cone beam computed tomography (CBCT) imaging to determine the location and direction of SAHs in cement-retained implant prostheses.

MATERIAL AND METHODS: Five clear acrylic resin casts were made based on a mandibular model. Several implant osteotomies (n=30) were created on the models with surgical burs, and crowns were made using the standard laboratory method with a transfer coping and the closed tray impression technique. CBCT images from the acrylic resin casts were evaluated by a maxillofacial radiologist who was blind to the locations and angles of the osteotomies. The locations of the access holes were determined on multiplanar reconstruction images and transferred to the clinical crown surface as defined points. Based on cross-sectional images, the predicted angle of the access hole was provided to a prosthodontist who was requested to pierce the crown at the proposed location in the specified direction. If the location and/or direction of the access hole were found, the process was considered successful, as the crown could then be removed from the implant abutment through the SAH. The success rate in the detection of the location and direction of the SAH was calculated, and chi-square and Fisher exact tests were applied for data analysis (α=.05).

RESULTS: According to the results of this study, the success rate of CBCT to define the location of SAHs was 83.3% and 80% to determine the direction. No significant differences were found among the different dental groups in determination of the location (P=.79) or the direction (P=.53) of the SAHs. Most of the failures in determining the location and direction of the access hole in the buccolingual and mesiodistal directions were in the buccal and mesial locations of the SAH. The success rate of using CBCT to determine the location of SAHs in straight abutments was 100%. A significant difference was found between angled and straight abutments (P=.042).

CONCLUSIONS: Using CBCT could help determine the direction and location of SAHs in clinical situations.

Journal of
Prosthodontics
Implant, Esthetic, and Reconstructive Dentistry

Evaluating the association of tooth form of maxillary central incisors with face shape using AutoCAD software: A descriptive study

Mehndiratta A, Bembalagi M, Patil R
J Prosthodont 2019;28:e469-e472

PURPOSE: To assess the different forms of maxillary central incisors (MCI) and determine their association with the shape of the face for men and women.

MATERIALS AND METHODS: A total of 200 subjects (100 women, 100 men) aged between 18 and 30 years with healthy dentition were randomly selected from K.L.E. V.K Institute of Dental Sciences, Belagavi, India. Two standardized photographs (portrait and shape of the MCI) were taken for each subject and opened in AutoCAD 2009 software that was used to prepare technical drawings of face and toothforms. The dental ratios (extent of line TA: extent of line TB) obtained after the tracings, were classified as tapered (·0.61), ovoid (>0.61 and <0.69), or square (·0.70). This classification was used to relate tooth form to the shape of the face and compare the form of MCI between men and women. Association between the shape of the MCI and the face was determined by Chi-square test using R 3.3.1 software.

RESULTS: The most prevalent tooth form among the subjects was ovoid (women, 32%; men, 31%) followed by tapered (women, 13%; men, 16%). The least prevalent shape was square (women, 5%; men, 3%). The most prevalent face shape was tapered (women, 34%; men, 25%) followed by ovoid (women, 15%; men, 22%) and the least prevalent was square (women, 1%; men, 3%). An association between face shape and tooth form was statistically not significant.

CONCLUSION: The most prevalent tooth form in both men and women was ovoid, and the least prevalent was square. The association between face shape and tooth form was not significant and did not abide by William's "Law of Harmony." However, there was an association between face shape and gender.

Journal of Dentistry

The sensitivity of digital intraoral scanners at measuring early erosive wear

Kumar S, Keeling A, Osnes C, Bartlett D, O'Toole S
J Dent 2019;81:39-42

OBJECTIVES: To investigate the sensitivity of intraoral scanners to quantitatively detect early erosive tooth wear.

METHODS: Natural buccal enamel samples were mounted in acrylic and scanned at baseline with an intraoral scanner (3 M True Definition Scanner, 3 M, USA). Samples were then exposed to 0.3% citric acid pH 3.2 at intervals of 10 min up to a total of 120 min and scanned after each exposure resulting in analysis of 13 data points per sample. Each scan was aligned with the baseline and data points super-imposed using an iterative closest point (ICP) algorithm on the acrylic surfaces (Geomagic Control Software, 3Dsystems, Darmstadt, Germany). Wear was measured using maximum profile loss, average profile loss and volume change. Data were normally distributed and Pearson correlations between erosion time and wear measurements assessed.

RESULTS: After each 10-minute exposure until 120 min, maximum profile loss (·m) increased from 33.4 to 72.8 ·m, average profile loss from 9.1 to 18.6 ·m. Wear correlated with increasing acid exposure for both maximum profile loss wear ($r = 0.877$ $p < 0.001$) and average profile loss ($r = 0.663$ $p = 0.019$) respectively. Volume measurements were inconsistent at this level of wear.

CONCLUSIONS: Using scan data obtained from the intra oral scanners (IOS), increasing step height changes were observed with increasing exposures to acid. This study indicates there is potential of scans taken with an IOS to be used to detect early erosive tooth wear. However, precision was low suggesting limitations for minimal changes.

CLINICAL SIGNIFICANCE: Although sub-visual wear was detected by intra-oral scanners on natural enamel surfaces, the accuracy was not sufficient to reliably diagnose that wear had occurred and interpretation of measurements should be done with caution. However, these results may be promising for detecting wear at more advanced stages.

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Performance of five commercially available tooth color-measuring devices

Dozić A, Kleverlaan CJ, El-Zohairy A, Feilzer AJ, Khashayar G
J Prosthodont 2007;16:93-100

PURPOSE: Visual tooth color assessment is neither accurate nor precise due to various subjective and objective factors. As newly developed tooth color-measuring devices for dental application provide the possibility of a more objective means of color determination, their performances in vitro and in vivo must be evaluated. The objective of this study was to evaluate the accuracy and precision of five commercially available tooth color-measuring devices in standardized and in clinical environments.

MATERIALS AND METHODS: In an in vitro study, standards (A1, A2, A3, A3.5, and A4 shade tabs of Vita Lumin) were measured five times with five electronic devices (ShadeScan, Easyshade, Ikam, IdentaColor II, and ShadeEye) by two operators. In an in vivo study, the right upper central incisors of 25 dental students were measured with the same electronic devices by a single operator. Vita shade tab codes were expressed as CIE (International Commission on Illumination) L*a*b* values and in terms of the precision and accuracy of ·E color differences. The Mann-Whitney statistical test was used to analyze the differences between the two operators in the in vitro study, and the Kruskal-Wallis one-way analysis of variance on ranks with the post-hoc Tukey test was used to analyze the accuracy and precision of electronic devices.

RESULTS: No statistically significant difference was found between the different operators in the in vitro study. The obtained precision was Easyshade > ShadeScan □ Ikam > IdentaColor II > ShadeEye. The obtained accuracy was Easyshade > ShadeScan □ Ikam > ShadeEye > IdentaColor II. In the in vivo study, the Easyshade and the Ikam were the most precise, and the ShadeEye and the IdentaColor II were more precise than the ShadeScan. With respect to accuracy, there was no statistical difference between the ShadeScan, Ikam, and the Easyshade. The IdentaColor II was considered inaccurate (ΔEa= 3.4).

CONCLUSIONS: In the clinical setting, the Easyshade and Ikam systems were the most reliable. The other devices tested were more reliable in vitro than in vivo.

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Implant, Esthetic, and Reconstructive Dentistry

Shade matching assisted by digital photography and computer software

Schropp L
J Prosthodont 2009;18:235-241

PURPOSE: To evaluate the efficacy of digital photographs and graphic computer software for color matching compared to conventional visual matching.

MATERIAL AND METHODS: The shade of a tab from a shade guide (Vita 3D-Master Guide) placed in a phantom head was matched to a second guide of the same type by nine observers. This was done for twelve selected shade tabs (tests). The shade-matching procedure was performed visually in a simulated clinic environment and with digital photographs, and the time spent for both procedures was recorded. An alternative arrangement of the shade tabs was used in the digital photographs. In addition, a graphic software program was used for color analysis. Hue, chroma, and lightness values of the test tab and all tabs of the second guide were derived from the digital photographs. According to the CIE L*C*h* color system, the color differences between the test tab and tabs of the second guide were calculated. The shade guide tab that deviated least from the test tab was determined to be the match. Shade matching performance by means of graphic software was compared with the two visual methods and tested by Chi-square tests (a= 0.05).

RESULTS: Eight of twelve test tabs (67%) were matched correctly by the computer software method. This was significantly better (p < 0.02) than the performance of the visual shade matching methods conducted in the simulated clinic (32% correct match) and with photographs (28% correct match). No correlation between time consumption for the visual shade matching methods and frequency of correct match was observed.

CONCLUSIONS: Shade matching assisted by digital photographs and computer software was significantly more reliable than by conventional visual methods.

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Reliability and accuracy of four dental shade-matching devices

Kim-Pusateri S, Brewer JD, Davis EL, Wee AG
J Prosthet Dent 2009;101:193-199

STATEMENT OF PROBLEM: There are several electronic shade-matching instruments available for clinical use, but the reliability and accuracy of these instruments have not been thoroughly investigated.

PURPOSE: The purpose of this in vitro study was to evaluate the reliability and accuracy of 4 dental shade-matching instruments in a standardized environment.

MATERIAL AND METHODS: Four shade-matching devices were tested: SpectroShade, ShadeVision, VITA Easyshade, and ShadeScan. Color measurements were made of 3 commercial shade guides (Vitapan Classical, Vitapan 3D-Master, and Chromascop). Shade tabs were placed in the middle of a gingival matrix (Shofu GUMY) with shade tabs of the same nominal shade from additional shade guides placed on both sides. Measurements were made of the central region of the shade tab positioned inside a black box. For the reliability assessment, each shade tab from each of the 3 shade guide types was measured 10 times. For the accuracy assessment, each shade tab from 10 guides of each of the 3 types evaluated was measured once. Differences in reliability and accuracy were evaluated using the Standard Normal z test (2 sided) (α=.05) with Bonferroni correction.

RESULTS: Reliability of devices was as follows: ShadeVision, 99.0%; SpectroShade, 96.9%; VITA Easyshade, 96.4%; and ShadeScan, 87.4%. A significant difference in reliability was found between ShadeVision and ShadeScan (P=.008). All other comparisons showed similar reliability. Accuracy of devices was as follows: VITA Easyshade, 92.6%; ShadeVision, 84.8%; SpectroShade, 80.2%; and ShadeScan, 66.8%. Significant differences in accuracy were found between all device pairs (P<.001) for all comparisons except for SpectroShade versus ShadeVision (P=.033).

CONCLUSIONS: Most devices had similar high reliability (over 96%), indicating predictable shade values from repeated measurements. However, there was more variability in accuracy among devices (67–93%), and differences in accuracy were seen with most device comparisons.

Journal of Dentistry

Four color-measuring devices compared with a spectrophotometric reference system

Lehmann KM, Igiel C, Schmidtmann I, Scheller H
J Dent 2010;38:e65-e70

ABSTRACT: The objective of this study was to compare the L*C*h° color coordinates of dental color-measuring devices with those of a spectrophotometric reference system. The International Commission on Illumination (CIE) L*C*h° color coordinates of ceramic samples, matching the colors of the VITA Linearguide, were recorded using four color-measuring devices (VITA Easyshade (A), VITA Easyshade compact (B), Degudent Shadepilot (C), X-Rite Shadevision (D)) and a spectrophotometric reference system under standardized test conditions. The intraclass correlation coefficients, regression lines with coefficients of determination, and mean deviations of the dental color-measuring devices from the spectrophotometric reference system were calculated. All of the devices had high intraclass correlation coefficients, between 0.979 and 1.000. Nearly all measurements, except the hue values of devices A, B, and D, showed coefficients of determination close to 1.0 over the range of measurements for L*C*h° color coordinates. Similarly, all of the devices had coefficients of determination near the optimum value of 1.0. Devices C and D produced regression line slopes near the optimum value of 1.0 and intercepts close to the optimum value of zero. Only the L* coordinate measurements of devices A and B and the h° coordinate measurements of device B differed not significantly from the spectrophotometric reference values. The electronic dental color-measuring devices tested showed excellent repeatability, but some devices showed substantial deviations in color coordinate values from the spectrophotometric reference system. Devices C and D showed higher precision than devices A and B.

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Effect of abutment tooth color, cement color, and ceramic thickness on the resulting optical color of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown

Chaiyabutr Y, Kois JC, Lebeau D, Nunokawa G
J Prosthet Dent 2011;105:83-90

A dark-colored prepared abutment tooth may negatively affect the esthetic outcome of a ceramic restoration if the tooth is restored using translucent enamel-like ceramic materials.

The purpose of this study was to evaluate the cumulative effect that the tooth abutment color, cement color, and ceramic thickness have on the resulting optical color of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown.

MATERIAL AND METHODS: A CAD/CAM glass-ceramic lithium disilicate-reinforced monolithic crown (IPS e.max CAD LT) was fabricated. Three possible crown restoration variables were tested in vitro. The procedure examined 4 prepared abutment tooth colors (light, medium light, medium dark, and dark), 2 cement (Variolink II) colors (translucent and opaque), and 4 ceramic thickness values (1.0 mm, 1.5 mm, 2.0 mm, and 2.5 mm). The color of each combination was measured using a spectrophotometer, and the average values of the color difference (·E) were calculated. The data were analyzed with a 3-way ANOVA (tooth abutment color, ceramic thickness, and luting agent) and Tukey's HSD test (a=.05), which evaluated within-group effects of the tooth abutment color to the ·E at each ceramic thickness.

RESULTS: The ·E values of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown were significantly influenced by the tooth abutment color (P<.001), cement color (P<.001), and ceramic thickness (P<.001). Significant interactions were present among these 3 variables (P<.001). A dark-colored abutment tooth demonstrated the greatest ·E values relative to other variables tested. An increase in ceramic thickness resulted in a significant decrease in ·E values (P<.01). The ·E values were slightly decreased when the crowns were cemented using the opaque cement.

CONCLUSIONS: This study demonstrated that underlying tooth abutment color, cement color, and ceramic thickness all influence the resulting optical color of CAD/CAM glass-ceramic lithium disilicate-reinforced restorations.

Journal of Dentistry

European dental students' opinions about visual and digital tooth colour determination systems

Dozic A, Kharbanda AK, Kamell H, Brand HS
J Dent 2011;39:e23-e28

OBJECTIVES: The aim of the study was to investigate students' opinion about visual and digital tooth colour determination education at different European dental schools.

METHODS: A cross-sectional web-based survey was created, containing nine dichotomous, multiple choice and 5-point Likert scale questions. The questionnaire was distributed amongst students of 40 European dental schools. Seven hundred and ninety-nine completed questionnaires from students of 15 dental schools were analysed statistically.

RESULTS: Vitapan Classical and Vitapan 3D-Master are the most frequently used visual determination systems at European dental schools. Most students responded with "neutral" regarding whether they find it easy to identify the colour of teeth with a visual determination system (range 2.8–3.6). A minority of the dental students had received education in digital imaging systems (2–47%). The Easyshade was the most frequently mentioned digital system. The majority of the students who did not receive education on digital systems would like to see this topic added to the curriculum (77–100%). The dental students who had worked with both methods found it significantly easier to determine tooth colour with a digital system than with a visual system (mean score 3.5 ffl 0.8 vs. 3.0 ffl 0.8).

CONCLUSIONS: Tooth colour determination programmes show a considerable variation across European dental schools. Based upon the outcomes of this study, students prefer digital imaging systems over visual systems, and like to have (more) education about digital tooth colour imaging.

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Dental shade matching using a digital camera

Bidra AS, Taylor TD, Agar JR
J Prosthet Dent 2013;109:361-366

OBJECTIVES: Digital cameras could be substitutes for contact-type instruments in shade selection and overcome their drawbacks. The images taken show morphology and color texture of teeth. A new method was proposed to compare the color of shade tabs taken by a digital camera using appropriate color features.

METHODS: Vita 3D-MASTER shade guide and Canon EOS 1100D digital camera were employed. Shade tab images were compared in two reference strategies. The color of tooth surface was presented by a content manually cropped out of the image. The content was divided into 10 · 2 blocks to encode the color distribution. Color features from commonly used color spaces were evaluated. The top n matches were selected when the least n shade distances between the shade tabs were attained.

RESULTS: Using Sa*b* features, the top one accuracy was 0.87, where the feature S is defined in HSV color space, a* and b* features are defined in L*a*b* color space. This rate was higher than previous reports using contact-type instruments. The top three matching accuracy was 0.94.

CONCLUSIONS: Sa*b* were suitable features for shade matching using a digital cameras in this study. Both the color and texture of the tooth surface could be presented by the proposed content-based descriptor. Clinical use of digital cameras in shade matching became possible.

CLINICAL SIGNIFICANCE: This in vitro study proposed a method for shade matching using digital cameras through the comparisons of the color patterns on the shade tab surfaces. The method overcame some drawbacks from the devices such as colorimeters or spectrophotometers. The results supported the use of digital cameras in shade matching.

Journal of Dentistry

Chromatic analysis of teeth exposed to different mouthrinses

Moreira AD, Mattos CT, Araújo MV, Ruellas AC, Sant'Anna EF
J Dent 2013;41:e24-e27

OBJECTIVES: The aim of this study was to assess, in vitro, the color of teeth exposed to different mouthrinses for a prolonged period.

METHODS: Bovine teeth were distributed in four groups: control, alcohol-containing mouthrinse (Listerine®), alcohol-free mouthrinse (Oral-B®) and chlorhexidine mouthrinse (Periogard®). The teeth were submitted to two cycles of staining and artificial aging. Color evaluation was performed with a digital spectrophotometer at the beginning of the experiment and after every cycle. Color changes were characterised using the system defined by the Comission Internationale de L'Eclairage (CIE L*, a*, b*). Data were analysed using the ANOVA and Tukey's post hoc test.

RESULTS: After the two cycles of staining and artificial aging, ΔE, ΔL and Δb from the alcohol-containing mouthrinse showed statistically significant differences when compared to the other groups. The ΔE values of the Listerine®group after the two cycles were greater than 3.7, indicating a visually perceptible color change.

The teeth exposed to the alcohol-containing mouthwash Listerine® were the only ones that presented a clinically perceptible color change.

CONCLUSIONS: A blue-colored alcohol-containing mouthwash was shown to be capable of causing dental color change after a prolonged period of exposure. Special care must be taken when choosing and prescribing the prolonged use of the same mouthwash.

Journal of Dentistry

A novel regression model from RGB image data to spectroradiometric correlates optimized for tooth colored shades

Carney MN, Johnston WM
J Dent 2016;51:45-48

OBJECTIVES: Objectives of this study were to correlate RGB data from the VITA Linearguide 3D Master and VITA Bleached Guide 3D Master shade guides with their spectroradiometric correlates through a regression model while indicating a methodology for validation of accuracy of digital imaging systems. Additional objectives were to provide summary RGB data and to determine a relationship between lightness and RGB values for these shade guides.

METHODS: Radiant energy measurements and images were taken with a Canon Rebel T3i and Macro Ring Lite MR-14EX for each shade tab. RGB data was extracted using Image J and compared with spectroradiometric measurements. Regression models relating the RGB data to spectroradiometric counterparts in CIE XYZ and absolute reflectance were developed using SAS 9.3. Image data was statistically analyzed to determine a relationship between RGB values and lightness.

RESULTS: Regression models with R2 values greater than 0.99 for RGB to XYZ and greater than 0.95 for RGB to absolute reflectance were developed. Summary RGB data for the shade guides including Pearson correlation coefficients ranging between ·0.92 and ·0.97 for RGB related to lightness was determined.

CONCLUSIONS: A relationship between RGB and lightness for the shade guides was found. Regression models were developed that allow tooth color information to be translated from digital images to accurate shade tab correlates for color matching purposes in dentistry. This allows for optimal color accuracy when using digital imaging to translate color information and provides a method of validating digital imaging systems for color accuracy.

Journal of
Prosthodontics
Implant, Esthetic, and Reconstructive Dentistry

Evaluation of a novel computer color matching system based on the improved back-propagation neural network model

Wei J, Peng M, Li Q, Wang Y
J Prosthodont 2016 Nov 9. doi: 10.1111/jopr.12561

PURPOSE: To explore the feasibility of a novel computer color-matching (CCM) system based on the improved back-propagation neural network (BPNN) model by comparing it with the traditional visual method.

MATERIAL AND METHODS: Forty-three metal-ceramic specimens were fabricated by proportionally mixing porcelain powders. Thirty-nine specimens were randomly selected to train the BPNN model, while the remaining four specimens were used to test and calibrate the model. A CCM system based on the improved BPNN model was constructed using MATLAB software. A comparison of the novel CCM system and the traditional visual method was conducted by evaluating the color reproduction results of 10 maxillary central incisors. Metal-ceramic specimens were fabricated using two color reproduction approaches. Color distributions (L*, a*, and b*) of the target teeth and of the corresponding metal-ceramic specimens were measured using a spectroradiometer. Color differences (·E) and color distributions (ΔL*, Δa*, and Δb*) between the teeth and their corresponding specimens were calculated.

RESULTS: The average ΔE value of the CCM system was 1.89 ± 0.75, which was lower than that of the visual approach (3.54 ± 1.11, $p < 0.01$). With respect to color distributions, substantial differences were found between the two color-matching systems, except for ΔL* ($p > 0.05$).

CONCLUSION: The novel CCM system produced greater accuracy in color reproduction within the given color space than the traditional visual approach.

Journal of Dentistry

The in vitro and in vivo reproducibility of a video-based digital imaging system for tooth colour measurement

Luo W, Naeeni M, Platten S, Wang J, Sun JN, Westland S, Joiner A
J Dent 2017;67:S15-S19

OBJECTIVES: To assess the robustness of a new custom built video-based digital imaging system (VDIS) for measuring tooth colour and whiteness under in vitro and in vivo conditions.

METHODS: The VDIS imaging system was developed for tooth colour measurement and evaluated in vitro and in vivo. The in vitro validation used extracted human teeth (HT, n=14) stored in water and VITA Classical shade guide tabs (SG, n=16). These were measured by the VDIS at baseline, 5min, 2h, 1 week and 2 weeks to evaluate the system repeatability. For in vivo validation, adult volunteers (male/female, n=34) with two natural, unrestored central incisors had their teeth imaged using the VDIS at baseline, 5min and 2h (3 images each) by two different operators to evaluate time and operator effects. Between taking individual images, subjects moved from the imaging-frame to assess the effect of re-positioning on reproducibility. From the in vitro and in vivo images, the average tooth RGB values were obtained, and the CIELAB values and a tooth whiteness index WIO value were calculated. Repeatability and reproducibility of VDIS imaging system was assessed using appropriate repeated measurement analysis techniques and ANOVA.

RESULTS: The measurement variations in vitro were between 1 and 2 units of ·WIO and the average colour differences were less than 1 ·E*ab unit. For the in vivo study, analysis of the CIELAB parameters and WIO showed that subject variability accounted for between 82 and 99% of the observed variability in the measurement process. The operator variability was less than 0.5% and the overall measurement error was found to be only 0.3% for WIO. Across assessment times the variability was less than 0.5%.

CONCLUSIONS: The dental imaging system V-DIS was shown to be a highly reproducible means for tooth colour and whiteness measurement.

CLINICAL SIGNIFICANCE: Digital imaging based techniques gives a highly reproducible approach to measuring tooth colour.

Journal of
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Implant, Esthetic, and Reconstructive Dentistry

Evaluation of a novel computer color matching system based on the improved back-propagation neural network model

Wei J, Peng M, Li Q, Wang Y
J Prosthodont 2018;27:775-783

PURPOSE: To explore the feasibility of a novel computer color-matching (CCM) system based on the improved back-propagation neural network (BPNN) model by comparing it with the traditional visual method.

MATERIAL AND METHODS: Forty-three metal-ceramic specimens were fabricated by proportionally mixing porcelain powders. Thirty-nine specimens were randomly selected to train the BPNN model, while the remaining four specimens were used to test and calibrate the model. A CCM system based on the improved BPNN model was constructed using MATLAB software. A comparison of the novelCCM system and the traditional visual method was conducted by evaluating the color reproduction results of 10 maxillary central incisors. Metal-ceramic specimens were fabricated using two color reproduction approaches. Color distributions (L*, a*, and b*) of the target teeth and of the corresponding metal-ceramic specimens were measured using a spectroradiometer. Color differences (·E) and color distributions (·L*, ·a*, and ·b*) between the teeth and their corresponding specimens were calculated.

RESULTS: The average ·E value of the CCM system was 1.89 ffl 0.75, which was lower than that of the visual approach (3.54 ffl 1.11, p < 0.01). With respect to color distributions, substantial differences were found between the two color-matching systems, except for ·L* (p > 0.05).

CONCLUSION: The novel CCM system produced greater accuracy in color reproduction within the given color space than the traditional visual approach.

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Implant, Esthetic, and Reconstructive Dentistry

A study on possibility of clinical application for color measurements of shade guides using an intraoral digital scanner

Yoon HI, Bae JW, Park JM, Chun YS, Kim MA, Kim M
J Prosthodont 2018;27:670-675

PURPOSE: To assess if color measurement with intraoral scanner correlates with digital colorimeter and to evaluate the possibility of application of a digital scanner for shade selection.

MATERIALS AND METHODS: The L*a*b* values of the five shade tabs (A1, A2, A3, A3.5, and A4) were obtained with an intraoral scanner (TRIOS Pod) and a colorimeter (ShadeEye). Both devices were calibrated according to the manufacturer's instructions before measurements. Color measurement values were compared with paired t-test, and a Pearson's correlation analysis was performed to evaluate the relationship of two methods.

RESULTS: The L*a*b* values of the colorimeter were significantly different from those of the digital scanner ($p < 0.001$). The L* and b* values of both methods were strongly correlated with each other (both $p < 0.05$). The device repeatability in both methods were reported to be excellent ($p < 0.05$). Within the limitations of this study, color measurements with digital intraoral scanners and computer-assisted image analysis were in accordance with those of the colorimeter with respect to L* and b* values; however, all the coordinates of shade tabs were significantly different between two methods.

CONCLUSIONS: The digital intraoral scanner may not be used as the primary method of color selection in clinical practices, considering significant differences in color parameters with colorimeter. The scanner's capability in shade selection should be further evaluated.

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Accuracy of an intraoral digital scanner in tooth color determination

Rutkūnas V, Dirsė J, Bilius
J Prosthet Dent 2019 J. pii: S0022-3913(19)30074-5. doi: 10.1016/j.prosdent.2018.

STATEMENT OF PROBLEM: Whether intraoral digital scanners with an integrated shade-taking function can substitute for colorimeters, spectrophotometers, or the visual method to reduce working time is unclear.

PURPOSE: The purpose of this clinical study was to evaluate the accuracy of the measurement of tooth shade obtained with an intraoral digital scanner in vivo.

MATERIAL AND METHODS: Shades of 120 maxillary anterior teeth were evaluated by using a SpectroShade spectrophotometer (SS) and a TRIOS 3 intraoral digital scanner (T3) on 20 participants. The matching of shade readings between the T3 and SS was used to estimate the accuracy of the T3. The percentage of readings when a difference between the shades obtained by both devices was visually perceptible (·E>3.7) was calculated. Each of the 120 teeth was measured 5 times to assess repeatability.

RESULTS: The accuracy of the T3 was 53.3% when the color was recorded as a Vita 3D-Master (VM) shade and 27.5% for the Vita Classical (VC) shade guide when the SS was taken as a reference. A visually perceptible color difference was found in 25% (VM) and 50.8% (VC) of situations when the shade was determined with the SS and 48.3% (VM) and 78.3% (VC) with the T3. Repeatability was 92% (VM) and 93.5% (VC) for the SS, and 90.33% (VM) and 87.17% (VC) for the T3.

CONCLUSIONS: The findings of this study revealed that the tooth color determined by the T3 does not exactly match that obtained by the SS that additional methods of measuring tooth color are recommended. The accuracy of the T3 was higher when the color was recorded as VM values rather than VC values.

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Suitability of a mobile phone colorimeter application for use as an objective aid when matching skin color during the fabrication of a maxillofacial prosthesis

Mulcare DC, Coward TJ
J Prosthodont. 2019;28(8):934-943. doi: 10.1111/jopr.12955.

PURPOSE: Color matching a facial prosthesis to human skin is very challenging. Colorimeters aid this process by adding objectivity to what is an otherwise subjective procedure. Mobile phone colorimeter applications offer a less expensive and widely available alternative to dedicated colorimeter devices for color measurement. There is a lack of evidence in the literature regarding the suitability of mobile phone colorimeter applications for the development of silicone shades for facial prosthetics. The purpose of this study is to determine the suitability of a mobile phone colorimeter application for matching natural skin colors during the fabrication of maxillofacial prostheses.

MATERIALS AND METHODS: Ten pigmented maxillofacial silicone elastomer swatches were fabricated to mimic a range of human skin tones. Color measurements of these swatches were recorded using a test instrument-the mobile phone colorimeter application (RGB Colorimeter) and a reference instrument-the commercially available skin color measurement device e-skin spectrocolorimeter. Comparisons in trueness and precision of the color measurements were made using previously described methods. Data analysis was performed on the recorded results for each of the parameters at three distances (25, 30, and 35 mm) of the test instrument from the target against both a black and a white background.

RESULTS: The trueness of the mobile phone colorimeter application relative to the colorimeter device varied depending on the distance from the target and the background color. The relative trueness of the color difference measurements fell just within the documented upper threshold of acceptable limits of color difference (·E 3.0 - 4.4). The calculated precision of the CIE L*a*b* and ·E measurements of the mobile phone colorimeter application was good, with the latter being well within the documented acceptable limits.

CONCLUSIONS: A mobile phone colorimeter application would be a suitable aid in objectifying the process of color matching a silicone maxillofacial prosthesis. Further investigation into image calibration to improve trueness and the control of variables such as background noise, uniformity of illumination, and measuring distance is required.

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Spectrophotometric evaluation of anterior maxillary tooth color distribution according to age and gender

Karaman T, Altintas E, Eser B, Talo Yildirim T, Oztekin F, Bozoglan A
J Prosthodont 2019;28:e96-e102

PURPOSE: To determine the effects of age and gender on the color distribution of the right maxillary central, lateral incisors, and canine teeth.

MATERIALS AND METHODS: The tooth color was measured using the VITA Easyshade V spectrophotometer with a total of 202 volunteers (89 men, 113 women). The age distribution in this study was between 15 and 70 years old (average: 31). A grey background color was used to prevent background reflection while performing the color measurements.

RESULTS: According to the VITAPAN Classical shade guide, the tooth color distribution of the central and lateral incisors showed a maximum of A2, with a maximum of B3 for the canine teeth. When comparing the International Commission on Illumination L* , a* , and b* values (CIELab color space coordinates) of the teeth with subject gender, statistically significant differences were not found between gender and the L* and b* values ($p > 0.05$); however, a statistically significant difference was observed between gender and the a* values ($p < 0.05$).

CONCLUSION: When the distribution ratio of tooth color was examined, different ratios were determined based on gender and age and between the maxillary central, lateral incisors, and canine teeth. A uniform tooth color should not be chosen for anterior restorations, and factors such as gender and age should be considered when making a color selection for patients.

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Analysis of shade matching in natural dentitions using intraoral digital spectrophotometer in LED and filtered LED light sources

Chitrarsu VK, Chidambaranathan AS, Balasubramaniam M
J Prosthodont 2019;28:e68-e73

PURPOSE: To evaluate the shade matching capabilities in natural dentitions using Vita Toothguide 3D-Master and an intraoral digital spectrophotometer (Vita Easyshade Advance 4.0) in various light sources.

MATERIALS AND METHODS: Participants between 20 and 40 years old with natural, unrestored right maxillary central incisors, no history of bleaching, orthodontic treatment, or malocclusion and no rotations were included. According to their shades, subjects were randomly selected and grouped into A1, A2, and A3. A total of 100 participants (50 male and 50 female) in each group were chosen for this study. Shade selection was made between 10 am and 2 pm for all light sources. The same examiner selected the shade of natural teeth with Vita Toothguide 3D-Master under natural light within 2 minutes. Once the Vita Toothguide 3D-Masterwas matched with the maxillary right central incisor, the L*, a*, and b* values, chroma, and hue were recorded with Vita Easyshade Advance 4.0 by placing it on the shade tab under the same light source. The values were statistically analyzed using one-way ANOVA and Tukey's HSD post hoc test with SPSS v22.0 software.

RESULTS: The mean ·E*ab values for shades A1, A2, and A3 for groups 1, 2, and 3 were statistically significantly different from each other ($p < 0.001$).

CONCLUSION: The intraoral digital spectrophotometer showed statistically significant differences in shade matching compared to Vita Toothguide 3D-Master. Incandescent light showed more accurate shade matching than the filtered LED, LED, and daylight.

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A comparison between visual, intraoral scanner, and spectrophotometer shade matching: A clinical study

Liberato WF, Barreto IC, Costa PP, de Almeida CC, Pimentel W, Tiossi R
J Prosthet Dent 2019;121:271-275

STATEMENT OF PROBLEM: Visual shade matching is subjective and a cause of concern for clinicians. Different measurement devices have been developed to assist in tooth color selection and to achieve better esthetic results. However, consensus is lacking as to which method of tooth shade selection provides more predictable results.

PURPOSE: The purpose of this clinical study was to compare the reliability of different visual and instrumental methods for dental shade matching.

MATERIAL AND METHODS: Visual shade matching was performed by 3 experienced clinicians using 2 different shade guides (VITA Classical A1-D4 and VITA Toothguide 3D-MASTER with 29 tabs; VITA Zahnfabrik) with and without the aid of a light-correcting device (Smile Lite; Smile Line). An intraoral scanner (TRIOS; 3Shape A/S) and a spectrophotometer (VITA Easyshade Advance 4.0; VITA Zahnfabrik) were also used for color shade matching. The instrumental methods were repeated 3 times to determine repeatability. Shade-matching sessions for each method were performed under controlled lighting on the middle third of the maxillary right central incisor of 28 participants. The Fleiss' kappa statistical test was used to assess the reliability of each method. The weighted kappa statistical test was used to assess the agreement between the shades matched by different methods (α=.05).

RESULTS: Instrumental methods were more accurate than visual methods. The best performance was found for the intraoral scanner configured for the 3D-MASTER scale (Fleiss' kappa value of .874) and for the spectrophotometer configured for the VITA Classical scale (Fleiss' kappa value of .805). The best visual shade-matching method was the VITA Classical scale associated with the light-correcting device (Fleiss' kappa value of .322). The Classical scale without the light-correcting device showed the poorest reliability (Fleiss' kappa value of .177) ($P<.05$).

CONCLUSION: Instrumental methods for color shade matching were more reliable than the visual methods tested.

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CAD/CAM fabricated complete dentures: concepts and clinical methods of obtaining required morphological data

Goodacre CJ, Garbacea A, Naylor WP, Daher T, Marchack CB, Lowry J
J Prosthet Dent 2012;107:34-46

The clinical impression procedures described in this article provide a method of recording the morphology of the intaglio and cameo surfaces of complete denture bases and also identify muscular and phonetic locations for the prosthetic teeth. When the CAD/CAM technology for fabricating complete dentures becomes commercially available, it will be possible to scan the denture base morphology and tooth positions recorded with this technique and import those data into a virtual tooth arrangement program where teeth can be articulated and then export the data to a milling device for the fabrication of the complete dentures. A prototype 3-D tooth arrangement program is described in this article that serves as an example of the type of program than can be used to arrange prosthetic teeth virtually as part of the overall CAD/CAM fabrication of complete dentures.

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Removable partial dentures: Use of rapid prototyping

Lima JMC, Anami LC, Araujo RM, Pavanelli CA
J Prosthodont. 2014;23:588-591

STATEMENT OF PROBLEM: The CAD/CAM technology associated with rapid prototyping (RP) is already widely used in the fabrication of all-ceramic fixed prostheses and in the biomedical area; however, the use of this technology for the manufacture of metal frames for removable dentures is new. This work reports the results of a literature review conducted on the use of CAD/CAM and RP in the manufacture of removable partial dentures.

PURPOSE: In recent decades, significant scientific and technological advances have led to a reduction in the human mortality rate and increased life expectancy. Thus, the world's population is aging. The United Nations Population Division estimates that average global life expectancy will increase until 2050, resulting in 74 years as the world's average life expectancy.[1] In a survey conducted between 2002 and 2003, the Brazilian Ministry of Health noted that individuals between 65 and 74 years of age had a decayed, missing, and filled teeth (DMFT) index of 27.93, and that 92.16% of this number represented the "missing teeth" component of the index. Given these data, it was concluded that 56% of the sample evaluated in this period required prosthetic mandibular rehabilitation, and 32.4% required maxillary rehabilitation.[2] In the United States 26% of people 65 years and older are edentulous, and in Canada this prevalence is 58%.[3] Although prosthetic implants have become popular, patients are often unable to use this type of prosthesis, due to physiological, anatomical, and/or economic conditions, and must turn to removable partial dentures (RPDs) as an alternative treatment choice. Continuing technological advances (e.g., the use of prototyping in related areas of dentistry), have created new possibilities for the manufacture of prostheses for the field of prosthodontics.[4-6] These new technologies are fundamentally important for patients seeking more rapid, accurate, and functionally efficient prosthetic rehabilitation.[5, 7]

MATERIALS AND METHODS: The use of prototyping in the manufacture of dentures allows for the elimination of the waxing step, and thus reduces the potential for errors, resulting in better quality control in the dental lab.[8-11] Moreover, the determination of the insertion axis is automatic, and the identification of retentive areas is rapid,[12] reducing the preparation time for the removable prosthesis.[7, 8, 13] Dentures made by prototyping present adequate adaptation, similar to that of prostheses prepared conventionally, and require fewer adjustments.[10, 13]

RESULTS: This work reports the results of a literature review conducted on the use of CAD/CAM and rapid prototyping (RP) in the manufacture of RPDs.

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Fabricating complete dentures with CAD/CAM and RP technologies

Bilgin MS, Erdem A, Aglarci OS, Dilber E
J Prosthodont. 2015;24(7):576-579. doi: 10.1111/jopr.12302.

Two techological approaches for fabricating dentures; computer-aided design and computer-aided manufacturing (CAD/CAM) and rapid schwe (RP), are combined with the conventional techniques of impression and jaw relation recording to determine their feasibility and applicability. Maxillary and mandibular edentulous jaw models were produced using silicone molds. After obtaining a gypsum working model, acrylic bases were crafted, and occlusal rims for each model were fabricated with previously determined standard vertical and centric relationships. The maxillary and mandibular relationships were recorded with guides. The occlusal rims were then scanned with a digital scanner. The alignment of the maxillary and mandibular teeth was verified. The teeth in each arch were fabricated in one piece, or set, either by CAM or RP. Conventional waxing and flasking was then performed for both methods. These techniques obviate a practitioner's need for technicians during design and provide the patient with an opportunity to participate in esthetic design with the dentist. In addition, CAD/CAM and RP reduce chair time; however, the materials and techniques need further improvements. Both CAD/CAM and RP techniques seem promising for reducing chair time and allowing the patient to participate in esthetics design Furthermore, the one-set aligned artificial tooth design may increase the acrylic's durability.

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Comparison of treatment outcomes in digital and conventional complete removable dental prosthesis fabrications in a predoctoral setting

Kattadiyil MT, Jekki R, Goodacre CJ, Baba NZ
J Prosthet Dent 2015;114:818-825

STATEMENT OF PROBLEM: Scientific evidence is lacking regarding the clinical effectiveness of digital complete removable dental prostheses (CRDP).

PURPOSE: This prospective clinical study was conducted to compare clinical treatment outcomes, patient satisfaction, and dental student preferences for digitally and conventionally processed CRDP in a predoctoral setting.

MATERIAL AND METHODS: This clinical study rated and compared CRDP fabricated by predoctoral students, using a 2-appointment digital prosthesis fabrication process as opposed to the conventional 5-appointment process. Fifteen completely edentulous patients were treated in the predoctoral clinic at Loma Linda University School of Dentistry. Fifteen predoctoral (third- and fourth-year) dental students fabricated 2 sets of maxillary and mandibular CRDP for each patient. Each patient received 1 conventional set and 1 digital (AvaDent) set of CRDP. Faculty and patient ratings, patient and student preferences, and perceptions of the conventional versus digital prostheses were recorded and analyzed. The average treatment time for the fabrication of each type of prostheses was analyzed.

RESULTS: Significantly higher average scores were observed for digital dentures than for conventional dentures according to criteria evaluated by faculty (P=.007). Patients reported significantly higher overall average satisfaction scores with digital dentures (P=.001). Patients preferred the digital dentures (P<.01). Significantly higher scores were observed for the retention of the digital maxillary complete denture (P=.001) compared with that for the digital mandibular and conventional complete dentures. Students preferred digital prostheses compared with conventional prostheses (P<.05). The conventional process required significantly more clinical time for each patient than with the digital process of fabrication (P<.01).

CONCLUSIONS: The digital process proved to be an equally effective and more time-efficient option than the conventional process of prosthesis fabrication in the predoctoral program. The digital denture process was preferred and effectively used by predoctoral dental students under faculty supervision.

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Part-digitizing system of impression and interocclusal record for complete denture fabrication

Matsuda T, Goto T, Yagi K, Kashiwabara T, Ichikawa T
J Prosthodont. 2016;25(6):503-9. doi: 10.1111/jopr.12375.

Few studies have reported the application of digital technology to removable dentures, particularly for the process of impression and interocclusal recording for complete denture fabrication. This article describes a part-digitizing system of impression and interocclusal records for complete denture fabrication. The denture foundation area in an edentulous mouth, including the border areas and residual ridge, is outlined by tracing the surfaces with a 3-D pen-type digitizer. Specialized trays for final impressions and interocclusal records were generated using computer-aided design and manufactured using the digital data. Final impression and interocclusal records were carried out using these specialized trays. The computer-aided method using preliminary digital impressions and specialized trays would be feasible for clinical use for complete denture fabrication.

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The use of digital impressions to fabricate tooth-supported partial removable dental prostheses: A clinical report

Mansour M, Sanchez E, Machado C
J Prosthodont. 2016;25(6):495-7. doi: 10.1111/jopr.12346.

Impression making is a critical step in the fabrication of a partial removable dental prosthesis (RDP). A technique is described for making final impressions to fabricate partial RDPs for Kennedy class III patients using a computer-aided design and computer-assisted manufacturing digital impression system.

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A comparison of two digital techniques for the fabrication of complete removable dental prostheses: A pilot clinical study

Schwindling FS, Stober T
J Prosthet Dent 2016;116:756-763

STATEMENT OF PROBLEM: The introduction of digital techniques might improve the quality and cost-effectiveness of treatment with complete removable dental prostheses (CDs).

PURPOSE: The purpose of this pilot clinical trial was to study and compare the clinical feasibility, complications during fabrication, and quality of 2 types of digitally designed CDs.

MATERIAL AND METHODS: Five participants were recruited into this preliminary clinical trial. For each participant, 2 pairs of digital CDs were designed. Prosthesis bases were fabricated by using identical data, either by milling from polymethyl methacrylate blanks or by injection molding. The treatment involved 4 clinical appointments. Polyvinyl siloxane impressions were made with custom trays and were subsequently digitalized. After evaluating esthetics and function with trial dentures, the CD bases were fabricated. To evaluate the workflow and quality of the prostheses, the clinical outcome was measured on 6-point scales ranging from poor (grade 6) to excellent (grade 1). For both prosthesis types, the following aspects were examined: fit, retention, esthetics, phonetics, maxillomandibular relation, and occlusion.

RESULTS: Both types of digital CDs could be fabricated without major complications. Only a few minor complications occurred during the fabrication process, predominantly esthetic issues. No pronounced difference was found between the prostheses concerning functional aspects. The definitive esthetic outcome was rated as very good.

CONCLUSIONS: The CDs fabricated using digital technology met the clinical requirements. However, more research is needed to confirm the results of this investigation.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Preliminary clinical application of removable partial denture frameworks fabricated using computer-aided design and rapid prototyping techniques

Ye H, Ning J, Li M, Niu L, Yang J, Sun Y, Zhou Y
Int J Prosthodont 2017;30:348-353

PURPOSE: The aim of this study was to explore the application of computer-aided design and rapid prototyping (CAD/RP) for removable partial denture (RPD) frameworks and evaluate the fitness of the technique for clinical application.

MATERIALS AND METHODS: Three-dimensional (3D) images of dentition defects were obtained using a lab scanner. The RPD frameworks were designed using commercial dental software and manufactured using selective laser melting (SLM). A total of 15 cases of RPD prostheses were selected, wherein each patient received two types of RPD frameworks, prepared by CAD/RP and investment casting. Primary evaluation of the CAD/RP framework was performed by visual inspection. The gap between the occlusal rest and the relevant rest seat was then replaced using silicone, and the specimens were observed and measured. Paired t test was used to compare the average thickness and distributed thickness between the CAD/RP and investment casting frameworks. Analysis of variance test was used to compare the difference in thickness among different zones.

RESULTS: The RPD framework was designed and directly manufactured using the SLM technique. CAD/RP frameworks may meet the clinical requirements with satisfactory retention and stability and no undesired rotation. Although the average gap between the occlusal rest and the corresponding rest seat of the CAD/RP frameworks was slightly larger than that of the investment casting frameworks ($P < .05$), it was acceptable for clinical application.

CONCLUSION: RPD frameworks can be designed and fabricated directly using digital techniques with acceptable results in clinical application.

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Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

CAD/CAM-fabricated nonmetal clasp denture: In vitro pilot study

Takahashi Y, Hamanaka I, Isshi K
Int J Prosthodont 2017;30:277-279

PURPOSE: The purpose of this study was to fabricate a prototype nonmetal clasp denture using computer-aided design/computer-assisted manufacture (CAD/CAM) technology.

MATERIALS AND METHODS: A partially edentulous mandibular working cast was scanned using an optical scanner. A sectional denture separated by two parts was designed on the scanned cast. These parts were milled and combined, and adhered using an adhesive luting agent.

RESULTS: The completed denture was delivered on the working cast and provided an excellent level of fitness.

CONCLUSION: A prototype nonmetal clasp denture could be fabricated using CAD/CAM technology.

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Evaluation of Currently Available CAD/CAM Denture Systems

Steinmassl PA, Klaunzer F, Steinmassl O, Dumfahrt H, Grunert I
Int J Prosthodont 2017;30:116-122

PURPOSE: The introduction of computer-aided design/computer-assisted manufacture (CAD/CAM) technology into removable denture prosthodontics enables denture adaptation in fewer patient visits, an advantage that appeals to dentists and patients. Since manufacturers follow very different approaches, an evaluation of the different clinical CAD/CAM complete denture fabrication protocols is desirable. The aim of this article is to assess and evaluate the different clinical fabrication protocols of currently available CAD/CAM denture systems to provide decision support for dental practitioners.

MATERIALS AND METHODS: The information for the present article was gathered by questionnaires from (in alphabetical order) Global Dental Science, Merz Dental, Wieland Dental + Technik, Ivoclar Vivadent, VITA Zahnfabrik, and Whole You, and complemented with results from the authors' clinical experience.

RESULTS: Wieland Digital Denture involves four patient visits. Both AvaDent digital dentures and Whole You Nexteeth enable denture fabrication in three (including a try-in session) or two (without try-in) visits. Baltic Denture System stipulates complete denture fabrication in two visits, and VITA VIONIC material system is an open system enabling choice between different treatment protocols. It can be combined with several open scanners, CAD software options, and milling machines.

CONCLUSION: The available CAD/CAM denture fabrication systems provide a variety of advantages, and the decision on a system should depend on the dentist's prosthodontic expertise, patient throughput rate, and requirements regarding denture individualization.

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Use of intraoral scanning and 3-dimensional printing in the fabrication of a removable partial denture for a patient with limited mouth opening

Wu J, Li Y, Zhang Y
J Am Dent Assoc 2017;148:338:341

BACKGROUND AND OVERVIEW: When treating patients with severely limited mouth openings, it is difficult for the dentist to obtain an impression and fabricate a removable partial denture (RPD) by using traditional methods. Intraoral scanning, computer-aided design, and 3-dimensional (3D) printing have provided alternative methods for fabricating dental prostheses.

CASE DESCRIPTION: The authors present a case in which they aimed to improve the efficiency and quality of fabricating an RPD framework by integrating the technologies of intraoral scanning, computer-aided design, and 3D printing. Initially, the authors reconstructed the digital cast with multiple intraoral scans. Subsequently, the authors designed the virtual RPD framework. On the basis of the virtual framework, the titanium alloy framework was fabricated by means of a 3D printing process, and the authors fitted the final RPD to the patient.

CONCLUSIONS AND PRACTICAL IMPLICATIONS: Unlike the traditional method, this integrated system has the potential to design a custom-made dental prosthesis and directly make an RPD framework with complicated patterns.

KEYWORDS: 3-dimensional printing; Intraoral scanning; computer-aided design; limited mouth opening; removable partial denture

Journal of Dentistry

Poly(methyl methacrylate) with TiO2 nanoparticles inclusion for stereolitographic completedenture manufacturing - the fututre in dental care for elderly edentulous patients?

Totu EE, Nechifor AC, Nechifor G, Aboul-Enein HY, Cristache CM
J Dent 2017;59:68-77

OBJECTIVES: The aim of this study was to obtain a Poly(methylmethacrylate) (PMMA)-TiO2 nanocomposite material with improved antibacterial characteristics, suitable for manufacturing 3D printed dental prosthesis.

METHODS: 0.2, 0.4, 0.6, 1, 2.5 by weight% of TiO2 nanoparticles have been added to the commercially available stereolithographic PMMA material and the obtained nanocomposites have been analyzed using FTIR, SEM and also tested for antimicrobial efficacy against bacterial cultures from Candida species (C. scotti).

RESULTS: SEM images and EDX results highlighted the presence of TiO2 in PMMA nanocomposites. The elemental composition (EDX) also showed the presence of other fillers included in stereolithographic PMMA solution. FTIR analysis clearly revealed changes in polymeric matrix structure when adding TiO2 nanoparticles. Sample containing 0.4, 1 and 2.5wt% TiO2 nanoparticles inhibited the growth of Candida scotti strain in standard conditions according to the toxicity control method (DHA). Increasing quantity of nano-titania has resulted in particles fooling, forming new aggregates instead of the homogenous dispersion of nanoparticles with modified viscosity characteristics and expected lower mechanical parameters.

CONCLUSIONS: Significant improvements in polymer characteristics and nice dispersion of the TiO2 nanoparticles have been noticed for 0.4wt%, therefore it was used for stereolitographic complete denture prototyping.

CLINICAL SIGNIFICANCE: Incorporation of TiO2 nanoparticles in PMMA polymer matrix was proved to have antibacterial effects, specifically on Candida species. The newly obtained 0.4% nanocomposite was successfully used with stereolitographic technique for complete denture manufacturing. However, mechanical and biocompatibility tests need to be performed in order to extend the clinical usage.

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Design of complete dentures by adopting CAD developed for fixed prostheses

Li Y, Han W, Cao J, Iv Y, Zhang Y, Han Y, Shen Y, Ma Z, Liu H
J Prosthodont. 2018;27(2):212-219. doi: 10.1111/jopr.12554

The demand for complete dentures is expected to increase worldwide, but complete dentures are mainly designed and fabricated manually involving a broad series of clinical and laboratory procedures. Therefore, the quality of complete dentures largely depends on the skills of the dentist and technician, leading to difficulty in quality control. Computer-aided design and manufacturing (CAD/CAM) has been used to design and fabricate various dental restorations including dental inlays, veneers, crowns, partial crowns, and fixed partial dentures (FPDs). It has been envisioned that the application of CAD/CAM technology could reduce intensive clinical/laboratory work for the fabrication of complete dentures; however, CAD/CAM is seldom used to fabricate complete dentures due to the lack of suitable CAD software to design virtual complete dentures although the CAM techniques are in a much advanced stage. Here we report the successful design of virtual complete dentures using CAD software of 3Shape Dental System 2012, which was developed for designing fixed prostheses instead of complete dentures. Our results demonstrated that complete dentures could be successfully designed by the combination of two modeling processes, single coping and full anatomical FPD, available in the 3Shape Dental System 2012.

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A novel computer-aided design/computer-assisted manufacture method for one-piece removable partial denture and evaluation of fit

Ye H, Li X, Wang G, Kang J, Liu Y, Sun Y, Zhou Y
Int J Prosthodont 2018 Feb 15. doi: 10.11607/ijp.5508.

PURPOSE: To investigate a computer-aided design/computer-aided manufacturing (CAD/CAM) process for producing one-piece removable partial dentures (RPDs) and to evaluate their fits in vitro.

MATERIALS AND METHODS: A total of 15 one-piece RPDs were designed using dental CAD and reverse engineering software and then fabricated with polyetheretherketone (PEEK) using CAM. The gaps between RPDs and casts were measured and compared with traditional cast framework RPDs.

RESULTS: Gaps were lower for one-piece PEEK RPDs compared to traditional RPDs.

CONCLUSION: One-piece RPDs can be manufactured by CAD/CAM, and their fits were better than those of traditional RPDs.

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Using intraoral scanning to capture complete denture impressions, tooth positions, and centric relation records

Goodacre BJ, Goodacre CJ, Baba NZ
Int J Prosthodont 2018;31:377–381

Intraoral scanning was used to capture the soft tissue surfaces of both maxillary and mandibular edentulous ridges and the denture borders. Additionally, an intraoral scanner was used to digitize existing dentures with their tooth positions and base forms and a centric relation record obtained with a Gothic arch-tracing device. These scans provided all the required records for fabrication of computer-aided design/computer-assisted manufacturing of complete dentures.

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Comparison of fit of dentures fabricated by traditional techniques versus CAD/CAM technology

McLaughlin JB, Ramos V Jr, Dickinson DP
J Prosthodont 2019;28:428-435

PURPOSE: To compare the shrinkage of denture bases fabricated by three methods: CAD/CAM, compression molding, and injection molding. The effect of arch form and palate depth was also tested.

MATERIALS AND METHODS: Nine titanium casts, representing combinations of tapered, ovoid, and square arch forms and shallow, medium, and deep palate depths, were fabricated using electron beam melting (EBM) technology. For each base fabrication method, three poly(vinyl siloxane) impressions were made from each cast, 27 dentures for each method. Compression-molded dentures were fabricated using Lucitone 199 poly methyl methacrylate (PMMA), and injection molded dentures with Ivobase's Hybrid Pink PMMA. For CAD/CAM, denture bases were designed and milled by Avadent using their Light PMMA. To quantify the space between the denture and the master cast, silicone duplicating material was placed in the intaglio of the dentures, the titanium master cast was seated under pressure, and the silicone was then trimmed and recovered. Three silicone measurements per denture were recorded, for a total of 243 measurements. Each silicone measurement was weighed and adjusted to the surface area of the respective arch, giving an average and standard deviation for each denture.

RESULTS: Comparison of manufacturing methods showed a statistically significant difference ($p = 0.0001$). Using a ratio of the means, compression molding had on average 41% to 47% more space than injection molding and CAD/CAM. Comparison of arch/palate forms showed a statistically significant difference ($p = 0.023$), with shallow palate forms having more space with compression molding. The ovoid shallow form showed CAD/CAM and compression molding had more space than injection molding.

CONCLUSION: Overall, injection molding and CAD/CAM fabrication methods produced equally well-fitting dentures, with both having a better fit than compression molding. Shallow palates appear to be more affected by shrinkage than medium or deep palates. Shallow ovoid arch forms appear to benefit from the use of injection molding compared to CAD/CAM and compression molding.

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Combining conventional impressions and intraoral scans: A technique for the treatment of complete denture patients with flabby tissue

Hong SJ, Lee H, Paek J, Pae A, Kim HS, Kwon KR, Noh K
J Prosthodont 2019;28:592-595

The conventional method for impressions of flabby tissue uses modified trays and highly flowable materials, but mucostatic impressions are difficult to achieve due to the viscous and the elastic natures of impression materials. In this report, a technique is presented in which conventional impression and intraoral scanning for a fully edentulous patient with flabby tissue are combined. The definitive impression was obtained by applying appropriate pressure to each tissue area, and the denture can be maintained passively and stable at rest and during function.

Journal of Dentistry

CAD/CAM milled removable complete dentures: time and cost estimation study

Srinivasan M, Schimmel M, Naharro M, O' Neill C, McKenna G, Müller F
J Dent 2019;80:75-79

OBJECTIVE: This study compared the clinical time spent and the costs incurred whilst constructing complete dentures (CDs) using a two-visit digital-denture protocol with the conventional complete denture protocol, in a university setting.:

METHODS: Twelve undergraduate final-year dental students utilized both the digital denture protocol and the conventional complete denture protocol to construct two sets of CDs for patients requiring either an upper CD opposing a partial natural dentition restored using a partial removable prosthesis [Group#1: students: n = 6, upper CD: n = 12 (6-digital complete dentures +6-conventional completed dentures)] or both upper and lower CDs [Group#2: students: n = 6, upper and lower CDs: n = 24 (12-digital complete dentures+ 12-conventional complete dentures)]. Overall time spent and costs (clinical, materials, and laboratory) were calculated. A cost minimization analysis was performed to compare the economic costs of the two protocols. Paired t-tests were applied for the statistical analyses ($p < 0.05$).

RESULTS: Conventional complete denture protocol required longer clinical time than digital complete dentures for both Group#1 ($p = 0.0206$) and Group#2 ($p = 0.0020$). The materials costs were higher for the digital complete dentures in both groups (Group#1 $p < 0.0001$; Group#2: $p = 0.0002$). The overall costs, were significantly higher for the conventional complete denture protocol than for the digital denture protocol (Group#1: $p = 0.0032$; Group 2: $p = 0.0080$).

CONCLUSIONS: In a university setting student clinic in Geneva in Switzerland, the digital denture protocol is less costly when compared with the conventional complete denture protocol. The costs for clinical chairside time, laboratory and the overall costs were significantly lower for the digital denture protocol, even though the materials costs for this protocol were higher.

CLINICAL SIGNIFICANCE: The digital denture protocol might prove highly beneficial to the elderly and/or the compromised edentulous patient, as it can help decrease the treatment burden on the patient by reducing the clinical procedures, number of visits, treatment time and incurred costs.

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Accuracy analysis of complete-arch digital scans in edentulous arches when using an auxiliary geometric device

Iturrate M, Eguiraun H, Etxaniz O, Solaberrieta E
J Prosthet Dent 2019;121:447-454

STATEMENT OF PROBLEM: Obtaining reliable digital scans of edentulous patients is challenging because of the absence of anatomic landmarks/geometric variations along the dental arch. Whether adding an auxiliary geometric device (AGD) will improve scanning is unclear.

PURPOSE: The purpose of this in vitro study was to analyze the accuracy of complete-arch digital scans of completely edentulous arches by placing a consumable AGD.

MATERIAL AND METHODS: A stainless-steel model of the maxilla of a completely edentulous arch with 4 implants was built. The model was scanned using a reference industrial scanner as the control and using 3 intraoral scanners (True Definition [3M ESPE], TRIOS 3 [3Shape A/S], and iTero [Align Technology, Inc]). Each intraoral scanner was used 10 times without the AGD in place and 10 more times with the AGD fixed on the model. Accuracy in terms of trueness and precision was established by comparing 5 reference distances with or without the AGD in place. A software program for analyzing 3D data was used to measure these 5 distances, and a data analysis software program was used for statistical and measurements analysis (α=.05).

RESULTS: Significant differences (P<.05) were found in all reference distances for trueness and in 4 of the 5 reference distances for precision depending on whether the AGD had been used or not. Without the AGD in place, trueness ranged from 21 ffl16 ·m in the shortest reference distance to 125 ffl80 ·m in the largest reference distance. With the AGD in place, trueness ranged from 11 ffl8 ·m in the shortest reference distance to 64 ffl51 ·m in the largest reference distance. Precision ranged from 18 ffl14 ·m in the shortest reference distance to 84 ffl74 ·m in the largest reference distance without the AGD and from 7 ffl7 ·m in the shortest to 63 ffl46 ·m in the largest with it.

CONCLUSIONS: Complete-arch digital scans of edentulous jaws are more accurate when an AGD is used to resolve the lack of anatomic landmarks. An additional advantage is that the use of the AGD allows for a more fluent scanning process.

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Assessment of the trueness and tissue surface adaptation of CAD-CAM maxillary denture basesmanufactured using digital light processing

Hwang HJ, Lee SJ, Park EJ, Yoon HI
J Prosthet Dent 2019;121:110-117

STATEMENT OF PROBLEM: Limited information is available evaluating the trueness and tissue surface adaptation of computer-aided design and computer-aided manufacturing (CAD-CAM) maxillary denture bases fabricated using digital light processing (DLP).

PURPOSE: The purpose of this in vitro study was to evaluate the trueness of DLP-fabricated denture bases and to compare the tissue surface adaptation of DLP with milling (MIL) and pack and press (PAP).

MATERIAL AND METHODS: The maxillary denture bases were virtually designed on the reference cast and were fabricated using DLP and MIL. Their intaglio surfaces were scanned and superimposed on the reference computer-aided design denture base to evaluate the trueness. A total of 20 denture bases (10 per technique) were also fabricated on the duplicated master casts using DLP and MIL. Ten denture bases were additionally made using PAP. The intaglio surfaces of the dentures were scanned and superimposed on the corresponding casts to compare the degree of tissue surface adaptation among the 3 techniques. The Mann-Whitney test and Kruskal-Wallis ANOVA were used for statistical analyses (α=.05).

RESULTS: The trueness of the DLP denture base was significantly better than that of the MIL denture base ($P<.001$). Statistically significant differences were detected with respect to tissue surface adaptation of the denture base among the groups ($P<.001$). The DLP denture base showed the best denture base fit among the 3 techniques with a small interquartile range.

CONCLUSIONS: Within the limitations of this in vitro study, the DLP maxillary denture base showed better trueness and tissue surface adaptation of ≤100 μm of the 3-dimensional surface deviation than the MIL and PAP denture bases.

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Designing and manufacturing an auricular prosthesis using computed tomography, 3-dimensional photographic imaging, and additive manufacturing: a clinical report

Liacouras P, Garnes J, Roman N, Petrich A, Grant GT
J Prosthet Dent 2011;105:78-82

The method of fabricating an auricular prosthesis by digitally positioning a mirror image of the soft tissue, then designing and using rapid prototyping to produce the mold, can reduce the steps and time needed to create a prosthesis by the traditional approach of sculpting either wax or clay. The purpose of this clinical report is to illustrate how the use of 3-dimensional (3-D) photography, computer technology, and additive manufacturing can extensively reduce many of the preliminary procedures currently used to create an auricular prosthesis.

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Digital capture, design, and manufacturing of a facial prosthesis: Clinical report on a pediatric patient

Grant GT, Aita-Holmes C, Liacouras P, Garnes J, Wilson WO Jr
J Prosthet Dent 2015;114:138-141

A digitally captured, designed, and fabricated facial prosthesis is presented as an alternative to customary maxillofacial prosthodontics fabrication techniques, where a facial moulage and patient cooperation may be difficult.

Journal of
Prosthodontics
Implant, Esthetic, and Reconstructive Dentistry

Innovative approach for interim facial prosthesis using digital technology

Yoshioka F, Ozawa S, Hyodo I, Tanaka Y
J Prosthodont. 2016;25(6):498-502. doi: 10.1111/jopr.12338.

Despite the important role of facial prosthetic treatment in the rehabilitation of head and neck cancer patients, delay in its implementation can be unavoidable, preventing patients from receiving a prompt facial prosthesis and resuming a normal social life. Here, we introduce an innovative method for the fabrication of an interim facial prosthesis. Using a 3D modeling system, we simplified the fabrication method and used a titanium reconstruction plate for facial prosthesis retention. The patient received the facial prosthesis immediately after surgery and resumed a normal social life earlier than is typically observed with conventional facial prosthetic treatment.

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Prosthodontics
Implant, Esthetic, and Reconstructive Dentistry

Reconstruction of an Extensive Midfacial Defect Using Additive Manufacturing Techniques

Fernandes N, van den Heever J, Hoogendijk C, Botha S, Booysen G, Els J
J Prosthodont 2016;25:589-594

ABSTRACT: Malignant peripheral nerve sheath tumors are extremely rare tumors arising in peripheral nerves. Only 17 cases involving the trigeminal nerve have ever been reported. These tumors have a very poor prognosis and very high rates of recurrence and metastases. Their recommended treatment involves complete tumor resection followed by radiation. This can be problematic in the head and neck region. We present a clinical case involving a 33-year-old female patient presenting with a slow-growing, exophytic mass of the anterior maxilla. Incisional biopsy and subsequent histological examination revealed a diagnosis of a malignant peripheral nerve sheath tumor. Surgical resection involved a complete maxillectomy, rhinectomy, and resection of the upper lip and aspects of the left and right cheeks. Reconstruction of the subsequent defect incorporated the placement of four zygomatic oncology implants to aid in retention of a facialprosthesis. These implants, however, were subsequently lost; and an anatomical model of the hard tissues was manufactured via 3D printing. This model was used to design and manufacture a titanium frame (customized implant) for the patient. The frame was then fixated and secured intraoperatively with 21 cortical screws. A maxillary denture and silicone facial prosthesis were also made to fit onto this frame. This is the first known case where additive manufacturing, via the use of rapid prototyping and 3D printing, was employed to manufacture a facial prosthesis.

KEYWORDS: 3D printing; Rapid prototyping; facial prosthesis; malignant peripheral nerve sheath tumors

Journal of
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Implant, Esthetic, and Reconstructive Dentistry

CAD/CAM-assisted auricular prosthesis fabrication for a quick, precise, and more retentive outcome: A clinical report

Yadav S, Narayan AI, Choudhry A, Balakrishnan D
J Prosthodont. 2017;26(7):616-621. doi: 10.1111/jopr.12589.

Auricular defects comprise a large proportion of maxillofacial deformities. Most patients with acquired deformities have psychosocial ineptness and seek cosmetic rehabilitation. Although minor defects can be corrected surgically, extensive deformities are difficult to reconstruct with plastic surgery. Contrary to that, prosthetic restoration can provide excellent esthetic results. The conventional methods of maxillofacial prosthesis fabrication are time consuming and the outcome depends on the technician's skill. The advent of CAD/CAM technology in the field of dentistry has brought enormous improvement in the quality of health care provided. In the past decade, several methods have been described employing CAD/CAM techniques for the cosmetic rehabilitation of auricular defects. This clinical report details the integration of multiple digital technologies of CT scanning, computer aided design, and rapid prototyping to construct an ear prosthesis with limited number of appointments.

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Geometric evaluation of the effect of prosthetic rehabilitation on the facial appearance of mandibulectomy patients: A preliminary study

Aswehlee AM, Elbashti ME, Hattori M, Sumita YI, Taniguchi H
Int J Prosthodont 2017;30:455-457

PURPOSE: The purpose of this study was to geometrically evaluate the effect of prosthetic rehabilitation on the facial appearance of mandibulectomy patients.

MATERIALS AND METHODS: Facial scans (with and without prostheses) were performed for 16 mandibulectomy patients using a noncontact three-dimensional (3D) digitizer, and 3D images were reconstructed with the corresponding software. The 3D datasets were geometrically evaluated and compared using 3D evaluation software.

RESULTS: The mean difference in absolute 3D deviations for full face scans was 382.2 μm.

CONCLUSION: This method may be useful in evaluating the effect of conventional prostheses on the facial appearance of individuals with mandibulectomy defects.

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Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Fabricating a maxillary obturator using an intraoral digital impression: A case history report

Park JH, Lee KS, Lee JY, Shin SW
Int J Prosthodont 2017;30:266-268

Digital impressions can be a useful option that reduces patient discomfort and simplifies clinical procedures such as accurate impression recordings. In this report, a patient with a partial maxillectomy was managed with a metal frame fabricated from a digital impression through an intraoral scanner. The final impression employed the altered cast technique for the fabrication of the obturator.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Digital design and fabrication of surgical obturators based only on preoperative computed tomography data

Rodney J, Chicchon I
Int J Prosthodont 2017;30:111-112

This article describes the digital fabrication of a surgical obturator (SO) using only computed tomography (CT) data from the tumor area. This procedure is a departure from the traditional method of making an impression and obtaining a patient cast prior to surgery to allow for SO fabrication. The present approach allows for a virtual resection based on the patient's CT image; the SO is digitally designed with animation software and fabricated by 3D printing. The SO is relined with a denture reliner at the time of surgery to complete the obturation of the maxillectomy defect.

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Generation and evaluation of 3D digital casts of maxillary defects based on multisource data registration: A pilot clinical study

Ye H, Ma Q, Hou Y, Li M, Zhou Y
J Prosthet Dent. 2017;118(6):790-795. doi: 10.1016/j.prosdent.2017.01.014.

STATEMENT OF PROBLEM: Digital techniques are not clinically applied for 1-piece maxillary prostheses containing an obturator and removable partial denture retained by the remaining teeth because of the difficulty in obtaining sufficiently accurate 3-dimensional (3D) images.

PURPOSE: The purpose of this pilot clinical study was to generate 3D digital casts of maxillary defects, including the defective region and the maxillary dentition, based on multisource data registration and to evaluate their effectiveness.

MATERIAL AND METHODS: Twelve participants with maxillary defects were selected. The maxillofacial region was scanned with spiral computer tomography (CT), and the maxillary arch and palate were scanned using an intraoral optical scanner. The 3D images from the CT and intraoral scanner were registered and merged to form a 3D digital cast of the maxillary defect containing the anatomic structures needed for the maxillary prosthesis. This included the defect cavity, maxillary dentition, and palate. Traditional silicone impressions were also made, and stone casts were poured. The accuracy of the digital cast in comparison with that of the stone cast was evaluated by measuring the distance between 4 anatomic landmarks. Differences and consistencies were assessed using paired Student t tests and the intraclass correlation coefficient (ICC). In 3 participants, physical resin casts were produced by rapid prototyping from digital casts. Based on the resin casts, maxillary prostheses were fabricated by using conventional methods and then evaluated in the participants to assess the clinical applicability of the digital casts.

RESULTS: Digital casts of the maxillary defects were generated and contained all the anatomic details needed for the maxillary prosthesis. Comparing the digital and stone casts, a paired Student t test indicated that differences in the linear distances between landmarks were not statistically significant ($P>.05$). High ICC values (0.977 to 0.998) for the interlandmark distances further indicated the high degree of consistency between the digital and stone casts. The maxillary prostheses showed good clinical effectiveness, indicating that the corresponding digital casts met the requirements for clinical application.

CONCLUSIONS: Based on multisource data from spiral CT and the intraoral scanner, 3D digital casts of maxillary defects were generated using the registration technique. These casts were consistent with conventional stone casts in terms of accuracy and were suitable for clinical use.

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Feasibility and accuracy of digitizing edentulous maxillectomy defects: A comparative study

Elbashti ME, Hattori M, Patzelt SB, Schulze D, Sumita YI, Taniguchi H
Int J Prosthodont 2017;30:147-149

PURPOSE: The aim of this study was to evaluate the feasibility and accuracy of using an intraoral scanner to digitize edentulous maxillectomy defects.

MATERIALS AND METHODS: A total of 20 maxillectomy models with two defect types were digitized using cone beam computed tomography. Conventional and digital impressions were made using silicone impression material and a laboratory optical scanner as well as a chairside intraoral scanner. The 3D datasets were analyzed using 3D evaluation software.

RESULTS: Two-way analysis of variance revealed no interaction between defect types and impression methods, and the accuracy of the impression methods was significantly different (P = .0374).

CONCLUSION: Digitizing edentulous maxillectomy defect models using a chairside intraoral scanner appears to be feasible and accurate.

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Feasibility and accuracy of noncontact three-dimensional digitizers for geometric facial defects: An in vitro comparison

Aswehlee AM, Elbashti ME, Hattori M, Sumita YI, Taniguchi H
Int J Prosthodont 2018;3:601–606

PURPOSE: To evaluate the feasibility and accuracy of noncontact three-dimensional (3D) digitization systems for capturing facial defects.

MATERIALS AND METHODS: A stone model of a facial defect was digitized using high-accuracy industrial computed tomography as a reference scan. The model was also scanned using four different types of noncontact 3D digitizers: a laser beam light-sectioning technology with camera system and three different stereophotogrammetry systems. All 3D images were reconstructed with corresponding software and saved as standard triangulated language (STL) files. The 3D datasets were geometrically evaluated and compared to the reference data using 3D evaluation software. Kruskal-Wallis H tests were performed to assess differences in absolute 3D deviations between scans, with statistical significance defined as $P < .05$.

RESULTS: The four noncontact 3D digitization systems were feasible for digitizing the facial defect model, although the median 3D deviation of the four digitizers varied. There was a significant difference in accuracy among the digitizers ($P < .001$).

CONCLUSIONS: Digitization of facial defect models using various noncontact 3D digitizers appears to be feasible and is most accurate with laser beam light-sectioning technology. Further investigations assessing digitization of facial defects among patients are required to clinically verify the results of this study.

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Direct 3D printing of flexible nasal prosthesis: Optimized digital workflow from scan to fit

Nuseir A, Hatamleh MM, Alnazzawi A, Al-Rabab'ah M, Kamel B, Jaradat E
J Prosthodont 2019;28:10-14

A maxillofacial prosthesis is a successful treatment modality to restore missing facial parts. Digital technologies and 3D printing are employed in constructing facial prostheses such as ears; however, their application is still partial, and final prostheses are usually manufactured conventionally using stone molds. This report aims to introduce a complete digital workflow to construct a nasal prosthesis and compare it to the conventional workflow of a patient requiring a nasal prosthesis. A computer tomography scan showing the defect was exported to specialized software to create 3D reconstructions of the patient's face and underlying bone. The nose was digitally designed restoring facial esthetics, anatomy, shape, and skin color. Different skin tones were digitally matched to skin tissues adjacent to the defect area using the Spectromatch system. The design was 3D printed in flexible and colorful material at 16 ·m resolution using a 3D printer. External color pigmentations were applied to the nose for optimum esthetics, and the prosthetic nose was sealed in silicone and left to heat polymerize for 15 minutes. The prosthetic nose was retained in place using biomedical adhesive, and the patient was pleased with it. This report proposes a complete digital workflow to directly design and fabricate a prosthetic nose of acceptable esthetics. Such a workflow can lead to enhanced prosthesis reproducibility and acceptability and may become an effective treatment option for treatment of patients with facial defects.

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Three-dimensional printed definitive cast for a silicone obturator prosthesis: A clinical report

Palin CL, Huryn JM, Golden M, Booth PR, Randazzo JD
J Prosthet Dent 2019;121:353-357

For patients with head and neck cancer requiring a maxillectomy, obturator prostheses help with quality of life. These patients routinely require adjuvant oncologic treatments with significant adverse effects. Treatment sequelae can leave patients with difficulty speaking and swallowing, reduced salivary function, reduction in maximal incisal opening, and at risk of osteoradionecrosis. A 55-year-old African-American woman presented with significant trismus and reduction in maximal incisal opening after treatment for squamous cell carcinoma of the left maxillary sinus. She had received a left total maxillectomy with adjuvant chemotherapy and radiation treatments. With her reduced opening, she was no longer able to insert her interim obturator prosthesis, which caused difficulty speaking and nasal regurgitation. A cone beam computed tomography scan was made of the patient's maxillectomy defect. From the Digital Imaging and Communications in Medicine file, a definitive cast was 3-dimensionally printed to fabricate a flexible silicone obturator prosthesis. This treatment has allowed the patient to return to a functional quality of life and could help other patients in similar situations.

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Combined use of a facial scanner and an intraoral scanner to acquire a digital scan for the fabrication of an orbital prosthesis

Liu H, Bai S, Yu X, Zhao Y
J Prosthet Dent 2019;121:531-534

For a patient with a unilateral orbital defect, an esthetic orbital prosthesis plays an essential role in enhancing quality of life. This technique describes the combined use of a facial scanner and an intraoral scanner to acquire the digital scan for the design and fabrication of an orbital prosthesis. The method results in an esthetic prosthesis with accurate skin texture reproduction.

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Development of a 3D printable maxillofacial silicone: Part II. Optimization of moderator and thixotropic agent

Palin CL, Huryn JM, Golden M, Booth PR, Randazzo JD
J Prosthet Dent 2019;121:353-357

STATEMENT OF PROBLEM: Conventionally, maxillofacial prostheses are fabricated by hand carving the missing anatomic defect in wax and creating a mold into which pigmented silicone elastomer is placed. Digital technologies such as computer numerical control milling and 3-dimensional (3D) printing have been used to prepare molds, directly or indirectly, into which a biocompatible pigmented silicone elastomer can be placed.

PURPOSE: The purpose of this in vitro study was to develop a silicone elastomer that could be 3D printed directly without a mold to create facial or body prostheses by varying its composition.

MATERIAL AND METHODS: The room temperature vulcanizing silicone composition was divided into 2 components which were mixed 1:1 to initiate polymerization in the printer before printing began. Different types of moderators and thixotropic agents were used, and the base composition was varied to obtain 11 formulations. The specimens were printed and polymerized from these formulations and tested for tear and tensile strength and hardness. Ten readings of the specimens were recorded for tear and tensile strength and 6 for hardness. Results were analyzed using ANOVA (α=.05). Visual assessment of uncured printed specimens was undertaken for 5 formulations to assess any differences in their ability to hold their shape after printing.

RESULTS: The tear and tensile strength of the 11 formulations with varying moderators, thixotropic agents, and base compositions were statistically similar to each other ($P>.05$). Five of 11 formulations were chosen for the visual assessment as they had sufficient thixotropic agent to avoid slumping while printing. The specimens showed varied slumping behavior until they polymerized. The filler content was increased in the selected formulation, and the tear and tensile strength of the formulation was increased to 6.138 kNm-1 and 3.836 MPa; these increases were comparable to those of commercial silicones currently used for the fabrication of facial prostheses.

CONCLUSIONS: The optimum combination of mechanical properties implies the use of one of the formulations as a suitable material for the 3D printing of facial prostheses.

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Accuracy of digital technologies for the scanning of facial, skeletal, and intraoral tissues: A systematic review

Bohner L, Gamba DD, Hanisch M, Marcio BS, Tortamano Neto P, Laganá DC, Sesma N J Prosthet Dent 2019;121:246-251

STATEMENT OF PROBLEM: The accuracy of the virtual images used in digital dentistry is essential to the success of oral rehabilitation.

PURPOSE: The purpose of this systematic review was to estimate the mean accuracy of digital technologies used to scan facial, skeletal, and intraoral tissues.

MATERIAL AND METHODS: A search strategy was applied in 4 databases and in the non-peer-reviewed literature from April through June 2017 and was updated in July 2017. Studies evaluating the dimensional accuracy of 3-dimensional images acquired by the scanning of hard and soft tissues were included.

RESULTS: A total of 2093 studies were identified by the search strategy, of which 183 were initially screened for full-text reading and 34 were considered eligible for this review. The scanning of facial tissues showed deviation values ranging between 140 and 1330 μm, whereas the 3D reconstruction of the jaw bone ranged between 106 and 760 μm. The scanning of a dentate arch by intraoral and laboratorial scanners varied from 17 μm to 378 μm. For edentulous arches, the scanners showed a trueness ranging between 44.1 and 591 μm and between 19.32 and 112 μm for dental implant digital scanning.

CONCLUSIONS: The current digital technologies are reported to be accurate for specific applications. However, the scanning of edentulous arches still represents a challenge.

Journal of Dentistry

Applications of 3D printing on craniofacial bone repair: A systematic review

Maroulakos M, Kamperos G, Tayebi L, Halazonetis D, Ren Y
J Dent 2019;80:1-14

OBJECTIVES: Three-dimensional (3D) bioprinting, a method derived from additive manufacturing technology, is a recent and ongoing trend for the construction of 3D volumetric structures. The purpose of this systematic review is to summarize evidence from existing human and animal studies assessing the application of 3D printing on bone repair and regeneration in the craniofacial region.

DATA & SOURCES: A rigorous search of all relevant clinical trials and case series was performed, based on specific inclusion and exclusion criteria. The search was conducted in all available electronic databases and sources, supplemented by a manual search, in December 2017.

STUDY SELECTION: 43 articles (6 human and 37 animal studies) fulfilled the criteria. The human studies included totally 81 patients with craniofacial bone defects. Titanium or hydroxylapatite scaffolds were most commonly implanted. The follow-up period ranged between 6 and 24 months. Bone repair was reported successful in nearly every case, with minimal complications. Also, animal intervention studies used biomaterials and cells in various combination, offering insights into the techniques, through histological, biochemical, histomorphometric and microcomputed tomographic findings. The results in both humans and animals, though promising, are yet to be verified for clinical impact.

CONCLUSIONS: Future research should be focused on well-designed clinical trials to confirm the short- and long- term efficacy of 3Dprinting strategies for craniofacial bone repair.

CLINICAL SIGNIFICANCE: Emerging 3D printing technology opens a new era for tissue engineering. Humans and animals on application of 3D printing for craniofacial bone repair showed promising results which will lead clinicians to investigate more thoroughly alternative therapeutic methods for craniofacial bone defects.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

The combination of digital surface scanners and cone beam computed tomography technology for guided implant surgery using 3Shape Implant Studio Software: A case history report

Lanis A, del Canto OA
Int J Prosthodont 2015;28:169-178

The incorporation of virtual engineering into dentistry and the digitization of information are providing new perspectives and innovative alternatives for dental treatment modalities. The use of digital surface scanners with surgical planning software allows for the combination of the radiographic, prosthetic, surgical, and laboratory fields under a common virtual scenario, permitting complete digital treatment planning. In this article, the authors present a clinical case in which a guided implant surgery was performed based on a complete digital surgical plan combining the information from a cone beam computed tomography scan and the virtual simulation obtained from the 3Shape TRIOS intraoral surface scanner. The information was imported to and combined in the 3Shape Implant Studio software for guided implant surgery planning. A surgical guide was obtained by a 3D printer, and the surgical procedure was done using the Biohorizons Guided Surgery Kit and its protocol.

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Accuracy of computer-guided surgery: A comparison of operator experience

Rungcharassaeng K, Caruso JM, Kan JYK, Schutyser F, Boumans T
J Prosthet Dent 2015;114:407-413

STATEMENT OF PROBLEM: Even though high-precision technologies have been used in computerguided implant surgery, studies have shown that linear and angular deviations between the planned and placed implants can be expected.

PURPOSE: The purpose of this study was to evaluate the effect of operator experience on the accuracy of implant placement with a computer-guided surgery protocol.

MATERIAL AND METHODS: Ten surgically experienced and 10 surgically inexperienced operators participated in this study. Each operator placed 1 dental implant (Replace Select) on the partially edentulous mandibular model that had been planned with software by following a computerguided surgery (NobelGuide) protocol. Three-dimensional information of the planned and placed implants were then superimposed. The horizontal and vertical linear deviations at both the apex and platform levels and the angular deviation were measured and compared between the experienced and inexperienced groups with the independent t test with Bonferroni adjustment (a=.01). The magnitude and direction of the horizontal deviations were also measured and recorded.

RESULTS: No significant differences were found in the angular and linear deviations between the 2 groups (P>.01). Although not statistically significant (P>.01), the amount of vertical deviation in the coronal direction of the implants placed by the inexperienced operators was about twice that placed by the experienced operators. Overall, buccal apical deviations were most frequent and of the highest magnitude.

CONCLUSIONS: When a computer-guided protocol was used, the accuracy of the vertical dimension (depth of implant placement) was most influenced by the operator's level of experience.

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Digital approach to planning computer-guided surgery and immediate provisionalization in a partially edentulous patient

Arunyanak SP, Harris BT, Grant GT, Morton D, Lin WS
J Prosthet Dent 2016;116:8-14

This report describes a digital approach for computer-guided surgery and immediate provisionalization in a partially edentulous patient. With diagnostic data obtained from cone-beam computed tomography and intraoral digital diagnostic scans, a digital pathway of virtual diagnostic waxing, a virtual prosthetically driven surgical plan, a computer-aided design and computer-aided manufacturing (CAD/CAM) surgical template, and implant-supported screw-retained interim restorations were realized with various open-architecture CAD/CAM systems. The optional CAD/CAM diagnostic casts with planned implant placement were also additively manufactured to facilitate preoperative inspection of the surgical template and customization of the CAD/CAM-fabricated interim restorations.

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Combining guided alveolar ridge reduction and guided implant placement for all-on-4 surgery: A clinical report

Faeghi Nejad M, Proussaefs P, Lozada J
J Prosthet Dent 2016;115:662-667

Immediate restoration with the all-on-4 concept has become an established treatment option. The technique involves alveoloplasty before implant placement to provide space for the prosthetic components and to provide a platform on which dental implants can be placed in clinical situations where a knife-edge alveolar ridge is present. Guided implant surgery involves the fabrication of a guide by using data from cone-beam computed tomography (CBCT) and implant surgery performed without flap reflection. In the presented technique, a printed cast based on a CBCT is used to fabricate a guide for both alveolar ridge reduction and guided implant surgery. The alveolar ridge reduction and implant surgery are virtually simulated in the laboratory to provide space for the restorative components and to avoid critical anatomic landmarks (mental nerve or perforation of the lingual mandibular plate). The described surgical guide enables guided alveolar ridge reduction and guided implant placement where the implant placement performed in the laboratory can be duplicated clinically during implant surgery.

Journal of
Prosthodontics
Implant, Esthetic, and Reconstructive Dentistry

Impact of Surgical Template on the Accuracy of Implant Placement

Xu LW, You J, Zhang JX, Liu YF, Peng W
J Prosthodont 2016;25:641-646

PURPOSE: To achieve functional and esthetic results, implants must be placed accurately; however, little information is available regarding the effect of surgical templates on the accuracy of implant placement. Thus, the aim of this study was to measure the deviation between actual and planned implant positions, and determine the deviation caused by the surgical template.

MATERIALS AND METHODS: Jaws from 16 patients were scanned using cone beam computed tomography (CBCT). For our study, 53 implants were planned in a virtual 3D environment, of which 35 were inserted in the mandible and 18 in the maxilla. A stereolithographic (SLA) surgical template was created. A CBCT scan of the surgical template fitted on a plaster model was performed, and the images obtained were matched to virtual implant plan images that contained the planned implant position. The actual implant position was acquired from the registration position of the surgical template. Deviation between actual and planned implant positions was analyzed.

RESULTS: Mean central deviation at the hex and apex was 0.456 mm and 0.515 mm, respectively. Mean value of horizontal deviation at the hex was 0.193 mm, horizontal deviation at the apex was 0.277 mm, vertical deviation at the hex was 0.388 mm, vertical deviation at the apex was 0.390 mm, and angular deviation was 0.621°.

CONCLUSION: Our study results revealed a significant deviation between actual and planned implant positions caused by the surgical template.

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In-office fabrication of dental implant surgical guides using desktop stereolithographic printing and implant treatment planning software: A clinical report

Whitley D III, Eidson SR, Rudek I, Bencharit S
J Prosthet Dent 2017;118:256-263

Guided surgery is accepted as the most accurate way to place an implant and predictably relate the implant to its definitive prosthesis, although few clinicians use it. However, recent developments in high-quality desktop 3-dimensional stereolithographic printers have led to the in-office fabrication of stereolithographic surgical guides at reduced cost. This clinical report demonstrates a protocol for using a cost-effective, in-office rapid prototyping technique to fabricate a surgical guide for dental implant placement.

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Creation of a 3-dimensional virtual dental patient for computer-guided surgery and CAD-CAM interim complete removable and fixed dental prostheses: A clinical report

Harris BT, Montero D, Grant GT, Morton D, Llop DR, Lin WS
J Prosthet Dent 2017;117:197-204

This clinical report proposes a digital workflow using 2-dimensional (2D) digital photographs, a 3D extraoral facial scan, and cone beam computed tomography (CBCT) volumetric data to create a 3D virtual patient with craniofacial hard tissue, remaining dentition (including surrounding intraoral soft tissue), and the realistic appearance of facial soft tissue at an exaggerated smile under static conditions. The 3D virtual patient was used to assist the virtual diagnostic tooth arrangement process, providing patient with a pleasing preoperative virtual smile design that harmonized with facial features. The 3D virtual patient was also used to gain patient's pretreatment approval (as a communication tool), design a prosthetically driven surgical plan for computer-guided implant surgery, and fabricate the computer-aided design and computer-aided manufacturing (CAD-CAM) interim prostheses.

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Facially generated and cephalometric guided 3D digital design for complete mouth implant rehabilitation: A clinical report

Coachman C, Calamita MA, Coachman FG, Coachman RG, Sesma N
J Prosthet Dent 2017;117:577-586

Harmony among the teeth, lips, and facial components is the goal of prosthodontic treatment, whether performed by conventional or digital workflow methods. This clinical report describes a facial approach to planning computer-guided surgery and immediate computer-aided designed and computer-aided manufactured (CAD-CAM) interim complete-arch fixed dental prostheses on immediately placed dental implants with a digital workflow. A single clinical appointment for data collection included dentofacial documentation with photographs and videos. On these photographs, facial reference lines were drawn to create a smile frame. This digital smile design and sagittal cephalometric analysis were merged with 3-dimensional scanned casts and a cone beam computed tomographic file in virtual planning software, thus guiding virtual waxing and implant positioning. Computer-guided implant surgery and CAD-CAM interim dental prostheses allowed esthetic and functional rehabilitation in a predictable manner and integrated with the patient's face.

The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Reliability of a CAD/CAM surgical guide for implant placement: An in vitro comparison of surgeons' experience levels and implant sites

Park SJ, Leesungbok R, Cui T, Lee SW, Ahn SJ
Int J Prosthodont 2017;30:367-169

PURPOSE: This in vitro study evaluated the reliability of a surgical guide with regard to different levels of operator surgical experience and implant site.

MATERIALS AND METHODS: A stereolithographic surgical guide for epoxy resin mandibles with three edentulous molar sites was produced using a computer-aided design/computer-assisted manufacture (CAD/CAM) system. Two surgeons with and two surgeons without implant surgery experience placed implants in a model either using or not using the CAD/CAM surgical guide. Four groups were created: inexperienced surgeon without the guide (group 1); experienced surgeon without the guide (group 2); inexperienced surgeon with the guide (group 3); and experienced surgeon with the guide (group 4). Planned implants and placed implants were superimposed using digital software, and deviation parameters were calculated.

RESULTS: There were no significant differences in any of the deviation parameters between the groups when using the surgical guide. With respect to the implant sites, there were no significant differences among the groups in any parameter.

CONCLUSION: Use of the CAD/CAM surgical guide reduced discrepancies among operators performing implant surgery regardless of their level of experience. Whether or not the guide was used, differences in the anterior-posterior implant site in the molar area did not affect the accuracy of implant placement.

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Computer-guided implant planning using a preexisting removable partial dental prosthesis

Kim JE, Shim JS
J Prosthet Dent 2017;117:13-17

Converting a conventional removable partial dental prosthesis (RPDP) into an implant-assisted removable partial dental prosthesis (IARPDP) may be facilitated by using data from the intaglio surface of the RPDP for proper implant placement. This procedure can be done by connecting the data from the intaglio surface of the RPDP to the residual ridge data of the cone beam computed tomography scan with implant planning software. However, although a misplaced implant under an RPDP can cause various complications, as yet, no technique has connected the information on a patient's existing RPDP to the implant planning software. This article presents computer-guided implant planning, using a patient's existing RPDP.

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The International Journal of Prosthodontics
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The International Journal of Prosthodontics
Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Determining favorable maxillary implant locations using three-dimensional simulation software and computed tomography data

Gonda T, Kamei K, Maeda Y
Int J Prosthodont 2017;30:58-61

PURPOSE: Success rates for maxillary implant treatment are lower than for mandibular treatment because of the presence of poorer bone quality or quantity in the maxilla. The purpose of this study was to determine favorable implant positions in the maxilla using implant simulation software and clinical anatomical morphology together with bone quality data obtained by computed tomography (CT).

MATERIALS AND METHODS: A convenience research sample of 10 edentulous subjects was recruited, and research information from right and left edentulous sites was obtained from each subject. The height, width, angulation, and Hounsfield unit value of the maxillary alveolar bone were measured using CT data obtained from the subjects.

RESULTS: Bone height in the incisor area was significantly greater than in the molar area, and bone width in the incisor area was significantly narrower than in the molar area. The average bone quality in the maxillary molar area was significantly higher when compared with the premolar and incisor areas. The angle between the occlusal plane and the bisector of the alveolar bone in the incisor area was reduced when compared with the molar area.

CONCLUSIONS: The premolar region appears to be the most favorable area in the maxillary arch for implant placement with regard to bone height, width, angulation, and quality.

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Virtually guided alveolar ridge reduction combined with computer-aided implant placement for a bimaxillary implant-supported rehabilitation: A clinical report

Beretta M, Poli PP, Tansella S, Maiorana C
J Prosthet Dent 2018;120:168-172

Insufficient crown height space, particularly in the interforaminal region of edentulous ridges with knife-edge morphology, may prevent successful prosthetic rehabilitation. Such conditions require osteoplasty, which might complicate computer-guided implant placement. This clinical report illustrates the treatment of a patient with complete edentulism rehabilitated with a mandibular implant-supported fixed dental prosthesis by using a virtually guided approach. Both alveolar ridge reduction and prosthetically driven implant insertions were computer-guided by surgical stents to increase accuracy and predictability. This approach enabled the immediate loading of the implants with an interim prosthesis before the delivery of a definitive screw-retained fixed prosthesis. At the 1-year follow-up visit, clinical and radiographic examination revealed a stable outcome.

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Computer-based implant planning involving a prefabricated custom tray with alumina landmark structures

Kim JE, Park JH, Kim JH, Shim JS
J Prosthet Dent 2019;121:373-377

The purpose of this technical report was to describe a method for the fabrication of a custom tray with landmark structures to coordinate cone beam computed tomography and scan data for use in guided implant surgery in patients with numerous artifact-causing metal prostheses. The fabricated custom tray can be used to coordinate cone beam computed tomography data and scan data from the dentition, as well as to fabricate the prostheses.

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A randomized controlled clinical trial comparing guided with nonguided implant placement: A 3-year follow-up of implant-centered outcomes

Bernard L, Vercruyssen M, Duyck J, Jacobs R, Teughels W, Quirynen M
J Prosthet Dent 2019;121:904-910

STATEMENT OF PROBLEM: Implant-based prosthetic solutions can be time consuming. If implants can be placed successfully with a guide, surgery time can be reduced.

PURPOSE: The purpose of this randomized controlled clinical trial was to assess implant outcomes, both clinical and radiological, comparing guided with nonguided implant placement after 3 years of follow-up.

MATERIAL AND METHODS: A total of 314 implants were placed in 72 jaws (60 participants). The jaws were randomly assigned to 1 of the 6 treatment groups: Materialise Universal/mucosa (Mat Mu), Materialise Universal/bone (Mat Bo), Facilitate/mucosa (Fac Mu), Facilitate/bone (Fac Bo), freehand navigation (Freehand), and a pilot-drill template (Templ). Radiographic and clinical parameters (bone loss, pocket probing depth, bleeding on probing, and plaque scores) were recorded at the time of implant placement, prosthesis installment (baseline), and 1-year, 2-year, and 3-year follow-up. Analysis was performed using a linear mixed model, and correction for simultaneous hypothesis was made according to Sidak (α=.05).

RESULTS: Three participants left the study before the 3-year follow-up; hence, 302 implants in 69 jaws were included in this study. None of the implants failed. The mean marginal bone loss after the third year of loading was 0.7 ffl1.3 mm for the guided surgery group and 0.5 ffl0.6 mm for the control group. No significant intergroup or follow-up period differences were observed (P>.05). In the guided surgery groups, the mean number of surfaces with bleeding on probing and plaque at 3-year follow-up was 1.7 ffl1.5 and 1.7 ffl1.7, respectively; for the control groups, this was 1.6 ffl1.4 and 1.6 ffl1.6, respectively. The mean pocket probing depth was 3.0 ffl1.3 mm for the guided group and 2.6 ffl1.0 mm for the control group. No significant differences were found (P>.1).

CONCLUSIONS: Within the limitation of this study, no statistically significant differences could be found between the guided group and the control group at the 3-year follow-up.

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Accuracy of surgical guides from 2 different desktop 3D printers for computed tomography-guided surgery

Gjelvold B, Mahmood DJH, Wennerberg A
J Prosthet Dent 2019;121:498-503

STATEMENT OF PROBLEM: Different factors influence the degree of deviation in dental implant position after computed tomography-guided surgery. The surgical guide-manufacturing process with desktop 3D printers is such a factor, but its accuracy has not been fully evaluated.

PURPOSE: The purpose of this in vitro study was to evaluate the deviation in final dental implant position after the use of surgical guides fabricated from 2 different desktop 3D printers using a digital workflow.

MATERIAL AND METHODS: Twenty 3D-printed resin models were prepared with missing maxillary premolar. After preoperative planning, 10 surgical guides were produced with a stereolithography printer and 10 with a digital light-processing (DLP) printer. A guided surgery was performed; 20 dental implants (3.8·12 mm) were installed, and a digital scan of the dental implants was made. Deviations between the planned and final position of the dental implants were evaluated for both the groups.

RESULTS: A statistically significant difference between stereolithography and DLP were found for deviation at entry point (P=.023) and the vertical implant position (P=.009). Overall lower deviations were found for the guides from the DLP printer, with the exception of deviation in horizontal implant position.

CONCLUSIONS: The tested desktop 3D printers were able to produce surgical guides with similar deviations with regard to the final dental implant position, but the DLP printer proved more accurate concerning deviations at entry point and vertical implant position.

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Accuracy of computer-guided implant placement in anterior regions

Fang Y, An X, Jeong SM, Choi BH
J Prosthet Dent 2019;121:836-842

STATEMENT OF PROBLEM: Implant placement in the anterior regions is often challenging because of limited space and bone volume availability.

PURPOSE: The purpose of this clinical study was to investigate the accuracy of computer-guided surgery with a long drill key to place implants in the anterior regions.

MATERIAL AND METHODS: Computer-guided implant surgery was performed for 32 participants requiring implants in anterior regions. The procedure involved using a 12-mm-long drill key to guide the 2.0-mm-diameter drill. Deviations between the planned and actual implant positions were evaluated by using cone beam computed tomography (CBCT) scans obtained before and after surgery. A t test was used for comparisons between the planned and placed implants and to determine the influence of the arch (maxilla/mandible) and time (immediate/delayed) on accuracy.

RESULTS: A total of 40 implants (20 implants in the maxilla and 20 implants in the mandible) were placed. The mean linear deviation was 0.46 mm (range, 0 to 1.15 mm) for the implant shoulder and 0.67 mm (range, 0.14 to 1.19 mm) for the implant apex. The mean angular deviation was 1.40 degrees (range, 0.30 to 2.57 degrees). The mean depth deviation was 0.15 mm (range, 0.10 to 0.82 mm).

CONCLUSIONS: This clinical study showed that the accuracy of computer-guided implant placement may be enhanced by using a long drill key and may thus enable more accurate implant placement in anterior regions.

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Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

Surgical template fabrication using cost-effective 3D printers

Koch GK, James B, Gallucci GO, Hamilton A
Int J Prosthodont 2019;32:97-100

PURPOSE: This in vitro study aimed to evaluate the accuracy of surgical templates fabricated using three different 3D printing technologies.

MATERIALS AND METHODS: Ten identical surgical templates were printed using four 3D printers (two of an identical make and model). Each of the surgical templates was scanned by a reference scanner and then imported into the inspection software. Inspection software utilized a best-fit alignment to automatically calculate the 3D variation at all points.

RESULTS: Statistically significant differences were found among the three groups ($\alpha 2[2] = 12.880$, $P = .0016$). Mean 3D deviation was also significantly different between the two printers of an identical make and model ($\alpha 2[1] = 8.251$, $P = .0041$).

CONCLUSION: All of the tested printers had a high level of accuracy in the fabrication of surgical templates, which would justify the trial of cost-effective printers for clinical fabrication of surgical implant templates.

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Novel-design ultra-thin CAD/CAM composite resin and ceramic occlusal veneers for the treatment of severe dental erosion

Schlichting LH, Maia HP, Baratieri LN, Magne P
J Prosthet Dent 2011;105:217-226

STATEMENT OF PROBLEM: Ultra-thin bonded posterior occlusal veneers represent a conservative alternative to traditional inlays and complete coverage crowns for the treatment of severe erosive lesions. There is a lack of data regarding selection of the most appropriate material and its influence on fatigue resistance, which may affect restoration longevity.

PURPOSE: The purpose of this study was to assess the influence of CAD/CAM restorative material (ceramic vs. composite resin) on fatigue resistance of ultra-thin occlusal veneers.

MATERIAL AND METHODS: A standardized nonretentive tooth preparation (simulating advanced occlusal erosion) was applied to 40 extracted molars including removal of occlusal enamel, and immediate dentin sealing (Optibond FL). All teeth were restored with a 0.6 mm-thick occlusal veneer (Cerec3 chairside CAD/CAM system). Reinforced ceramics (Empress CAD and e.max CAD) and composite resins (Paradigm MZ100 and XR (experimental blocks)) were used to mill the restorations (n=10). The intaglio surfaces were HF-etched and silanated (reinforced ceramics) or airborne-particle abraded and silanated (composite resins). Preparations were airborne-particle abraded and etched before restoration insertion. All restorations were adhesively luted with preheated Filtek Z100. Cyclic isometric loading was applied at 5 Hz, beginning with a load of 200N (x5,000), followed by stages of 400, 600, 800, 1000, 1200 and 1,400N at a maximum of 30,000 cycles each. The number of cycles at initial failure (first cracks) was recorded. Specimens were loaded until catastrophic failure (lost restoration fragment) or to a maximum of 185,000 cycles. Groups were compared using the life table survival analysis (a=.008, Bonferroni-method).

RESULTS: Empress CAD and e.max CAD initially failed at an average load of 500N and 800N, respectively with no specimen withstanding all 185,000 load cycles (survival 0%); with MZ100 and XR the survival rate was 60% and 100%, respectively.

CONCLUSIONS: Both composite resins (MZ100 and XR) increased the fatigue resistance of ultra-thin occlusal veneers (P<.001) when compared to the ceramics evaluated (Empress CAD and e.max CAD).

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Effect of surface conditioning with airborne-particle abrasion on the tensile strength of polymeric CAD/CAM crowns luted with self-adhesive and conventional resin cements

Stawarczyk B, Basler T, Ender A, Roos M, Ozcan M, Hämmerle C
J Prosthet Dent 2012;107:94-101

STATEMENT OF PROBLEM: Adhesively bonded, industrially polymerized resins have been suggested as definitive restorative materials. It is claimed that such resins present similar mechanical properties to glass ceramic.

PURPOSE: The purpose of this study was to assess the tensile strength of polymeric crowns after conditioning with 2 different protocols: luted with self-adhesive or with conventional resin cements to dental abutments.

MATERIAL AND METHODS: Human teeth were prepared for crowns and divided into 13 groups (N=312, n=24 per group). Polymeric crowns were CAD/CAM fabricated and divided into 3 groups depending on different surface conditioning methods: A) No treatment, B) airborne-particle abrasion with 50 μm alumina, and C) airborne-particle abrasion with 110 μm alumina. Thereafter, the crowns were luted on dentin abutments with the following cements: 1) RXU (RelyX Unicem, self-adhesive), 2) GCM (G-Cem, self-adhesive), 3) ACG (artCem GI, conventional), and 4) VAR (Variolink II, conventional). Glass ceramic crowns milled and cemented with dual-polymerized resin cement (Variolink II) served as the control group. The tensile strength was measured initially (n=12) and after aging by mechanical thermocycling loading (1 200 000 cycles, 49 N, 5°C to 50°C) (n=12). The tensile strength (MPa) of all crowns was determined by the pull-off test (Zwick/Roell Z010; Ulm, Germany, 1mm/min). Subsequently, the failure types were classified. Data were analyzed with 2-way and 1-way ANOVA followed by a post hoc Scheffé test and t test (α=.05).

RESULTS: No adhesion of the tested cements was observed on unconditioned polymeric CAD/CAM crowns and those luted with VAR. Among the tested cements, GCM showed significantly higher values after airborne-particle abrasion with 110 μm (initial: 2.8 MPa; after aging: 1 MPa) than 50 μm alumina (initial: 1.4 MPa; after aging: 0 MPa). No significant effect was found between 50 and 110 μm particle size alumina in combination with the other 2 cements. After aging, the tensile strength of the crowns luted with GCM (50 μm: 0 MPa and 110 μm: 1 MPa) and ACG (50 μm: 1 MPa and 110 μm: 1.2 MPa) was significantly lower than those luted with RXU (50 μm: 1.9 MPa and 110 μm: 2 MPa). All airborne particle abraded polymeric CAD/CAM crowns (initial: 1.4-2.8; 0-2 MPa) showed significantly lower tensile strength values than the control group (initial: 7.3 MPa; after aging: 6.4 MPa). Although with all polymeric specimens, failure type was adhesive between the cement and the crowns, the control group showed exclusively cohesive failures within the ceramic.

CONCLUSIONS: Airborne-particle abrasion before cementation of polymeric CAD/CAM crowns minimally improved the tensile strength. Both the failure types and the tensile strength values of adhesively luted glass ceramic crowns showed superior results to adhesively cemented polymeric ones. Although the tensile strength results were low, crowns cemented with RXU showed, after aging, the highest tensile strength of all other tested groups.

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Two-body wear rate of CAD/CAM resin blocks and their enamel antagonists

Stawarczyk B, Özcan M, Trottmann A, Schmutz F, Roos M, Hämmerle C
J Prosthet Dent 2013;109:325-332

STATEMENT OF PROBLEM: Computer-aided design and computer-aided manufacturing (CAD/CAM) resins exhibit good mechanical properties and can be used as long-term restorations. The wear rate of such resins and their enamel antagonists is unknown.

PURPOSE: The purpose of this study was to test and compare the 2-body wear rate of CAD/CAM resin blocks.

MATERIAL AND METHODS: Wear specimens (N=42, n=6) were made from 5 CAD/CAM resins: ZENO PMMA (ZP), artBloc Temp (AT), Telio CAD (TC), Blanc High-class (HC), CAD-Temp (CT); 1 manually polymerized resin: Integral esthetic press (negative control group, IEP); and 1 glass-ceramic: VITA Mark II (positive control group, VM2). The specimens for the wear resistance were aged in a thermomechanical loading machine (49 N, 1.67 Hz, 5/50°C) with human enamel antagonists. The material loss of all specimens before, during, and after aging was evaluated with a 3DS profilometer. The measured material loss data of all tested groups were statistically evaluated with linear mixed model analysis (a=.05).

RESULTS: Manually polymerized resin showed significantly higher material wear (P<.001) than all other tested groups. Glass-ceramic showed significantly lower wear values (P<.001) than CAD/CAM resins ZP, AT, HC, CT, and IES. CAD/CAM resin TC was not significantly different from the positive control group. Glass-ceramic showed the highest enamel wear values (P<.001) of all tested resins. No differences were found in the enamel wear among all resins. The glass-ceramic group showed damage in the form of cracks on the worn enamel surface in 50% of specimens.

CONCLUSIONS: CAD/CAM resins showed lower wear rates than those conventionally polymerized. Only one CAD/CAM resin, TC, presented material wear values comparable with glass-ceramic. The tested glass-ceramic developed cracks in the enamel antagonist and showed the highest enamel wear values of all other tested groups.

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The digital one-abutment/one-time concept. A clinical report

Beuer F, Groesser J, Schweiger J, Hey J, Güth JF, Stimmelmayr M
J Prosthodont. 2015;24(7):580-585. doi: 10.1111/jopr.12256

The digital fabrication of dental restorations on implants has become a standard procedure during the last decade. Avoiding changing abutments during prosthetic treatment has been shown to be superior to the traditional protocol. The presented concept for implant-supported single crowns describes a digital approach without a physical model from implant placement to final delivery in two appointments. A 54-year-old man was provided with a single-tooth implant on his left mandibular first molar. Before wound closure, the implant position was captured digitally with an intraoral scanning device. After bone healing at the time of second-stage surgery the final screw-retained crown fabricated without a physical model was inserted. Soft tissue healing took place at the definitive restoration, avoiding abutment changes or changes of the healing cap. These led to stable soft tissues with a minimum of surgery. The benefits of digital fabrication and the unique way to scan the implant right after placement give an additional value that would not be achieved by analog techniques. In addition to financial benefits it represents a biologically advantageous, one-abutment/one-time approach with customized screw-retained, full-contour crowns or cemented crowns on custom abutments.

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Translucency of esthetic dental restorative CAD/CAM materials and composite resins with respect to thickness and surface roughness

Awad D, Stawarczyk B, Liebermann A, Ilie N
J Prosthet Dent 2015;113:534-540

STATEMENT OF PROBLEM: Little information is available about the translucency of monolithic CAD/CAM materials.

PURPOSE: The purpose of this study was to evaluate the translucency of restorative CAD/CAM materials and direct composite resins with respect to thickness and surface roughness.

MATERIALS AND METHODS: In total, 240 disk-shaped specimens (12×14×1 mm and 12×14×2 mm) of 3 different CAD/CAM glass ceramics (CELTRA Duo, IPS e.max CAD, IPS Empress CAD), a fine-structure feldspathic ceramic (VITA Mark II), a hybrid ceramic (VITA Enamic), a resin nanoceramic composite resin (LAVA Ultimate), an experimental (CAD/CAM nanohybrid composite resin), 2 interim materials (Telio CAD; VITA CAD-Temp), and 3 direct composite resins (Tetric EvoCeram; Filtek Supreme XTE; Tetric EvoCeram Bulk Fill) were fabricated (n=10). After 3 different surface pretreatments (polished, rough SiC P1200, or SiC P500), absolute translucency and surface roughness were measured using spectrophotometry and tactile profilometry. The influence of material type, thickness, and roughness on absolute translucency was analyzed using a multivariate analysis, 1-way ANOVA, and the Tukey HSD post hoc test ($P<.05$). Pearson correlations and statistical hypothesis tests were used to assess the results ($P<.05$).

RESULTS: The effect of all tested parameters was significant among the materials ($P<.05$). The greatest influence on the measured translucency was thickness (partial eta squared $\eta p^2=.988$), closely followed by material (.982), and the pretreatment method (.835). The surface roughness was strongly influenced by the pretreatment method (.975) and type of material (.941).

CONCLUSION: Thickness and surface roughness are major factors affecting the absolute translucency of adhesively luted restorations.

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Comparison of 64-detector-multislice and cone beam computed Ttomographies in the evaluation of linear measurements in the alveolar ridge

Pena de Andrade JG, Valerio CS, de Oliveira Monteiro MA, de Carvalho Machado V, Manzi FR
Int J Prosthodont 2016;29:132-134

ABSTRACT: This study compared the accuracy of linear measurements of the alveolar ridge in images obtained using 64-detector-multislice computed tomography (CT) and cone beam CT (CBCT). Eight sites were selected corresponding to the regions of molars, premolars, canines, and incisors in six dry human jaws. After the completion of multislice CT and CBCT, the jaws were sectioned into specific regions. Results showed there was no statistically significant difference between the measurements obtained from the CT images and those obtained from dry jaws (actual measurements) for all the evaluated sites (molars, premolars, and anterior teeth). There was also no statistically significant difference between the measurements obtained by the two CT methods.

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Enhancing fracture and wear resistance of dentures/overdentures utilizing digital technology: A case series report

Afify A, Haney S
J Prosthodont. 2016;25(6):489-94. doi: 10.1111/jopr.12462.

Since it was first introduced into the dental world, computer-aided design/computer-aided manufacturing (CAD/CAM) technology has improved dramatically in regards to both data acquisition and fabrication abilities. CAD/CAM is capable of providing well-fitting intra- and extraoral prostheses when sound guidelines are followed. As CAD/CAM technology encompasses both surgical and prosthetic dental applications as well as fixed and removable aspects, it could improve the average quality of dental prostheses compared with the results obtained by conventional manufacturing methods. The purpose of this article is to provide an introduction into the methods in which this technology may be used to enhance the wear and fracture resistance of dentures and overdentures. This article will also showcase two clinical reports in which CAD/CAM technology ha been implemented.

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Complete-mouth rehabilitation using a 3D printing technique and the CAD/CAM double scanning method: A clinical report

Joo HS, Park SW, Yun KD, Lim HP
J Prosthet Dent 2016;116:3-7

According to evolving computer-aided design/computer-aided manufacturing (CAD/CAM) technology, ceramic materials such as zirconia can be used to create fixed dental prostheses for partial removable dental prostheses. Since 3D printing technology was introduced a few years ago, dental applications of this technique have gradually increased. This clinical report presents a complete-mouth rehabilitation using 3D printing and the CAD/CAM double-scanning method.

Journal of Dentistry

A pilot study to assess the feasibility and accuracy of using haptic technology to occlude digital dental models

Wu W, Cen Y, Hong Y, Keeling A, Khambay B
J Dent 2016;46:54-60

OBJECTIVES: The use of haptic technology as an adjunct to clinical teaching is well documented in medicine and dentistry. However its application in clinical patient care is less well documented. The aim of this pilot study was to determine the feasibility and accuracy of using a haptic device to determine the occlusion of virtual dental models.

METHODS: The non-occluded digital models of 20 pre-treatment individuals were chosen from the database of Faculty of Dentistry, The University of Hong Kong. Following minimal training with the haptic device (Geomagic®Touch™), the upper model was occluded with the lower model until a stable occlusion was achieved. Seven landmarks were placed on each of the corners of the original and haptically aligned upper model bases. The absolute distance between the landmarks was calculated. Intra- and inter-operator errors were assessed.

RESULTS: The absolute distance between the 7 landmarks for each original and corresponding haptically aligned model was 0.54 ffl 0.40 mm in the x-direction (lateral), 0.73 ffl 0.63 mm in the y-direction (anterior–posterior) and 0.55 ffl 0.48 mm in the z-direction (inferior–superior).

CONCLUSION: Based on initial collision detection to prevent interpenetration of the upper and lower digital model surfaces, and contact form resistance during contact, it is possible to use a haptic device to occlude digital study models.

CLINICAL SIGNIFICANCE: The use of 3D digital study models is routine, but new problems arise, such as the lack of "touch" in a virtual environment. Occluding study models requires the sense of touch. For the first time, using haptic technology, it is possible to occlude digital study models in a virtual environment.

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Parallel randomized controlled clinical trial in patients with temporomandibular disorders treated with a CAD/CAM versus a conventional stabilization splint

Pho Duc JM, Hüning SV, Grossi ML
Int J Prosthodont 2016;29:340-350

PURPOSE: This parallel randomized controlled trial (RCT) compared the efficacy of a computer-aided design/computer-assisted manufacture (CAD/CAM) splint versus a conventional stabilization splint in patients with temporomandibular disorders (TMD).

MATERIALS AND METHODS: A sample of 48 age-matched TMD patients from the Ludwig Maximilian University Prosthodontic Department in Munich, Germany, were randomly allocated into groups 1 (CAD/CAM splint) and 2 (conventional splint). The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) was used for TMD Axis I (groups I, II, and III) and Axis II (chronic pain grade [CPG]) diagnoses. Numeric scales (TMD/NS, 10 cm) were used to measure headaches, face pain, jaw joint pain, jaw joint noises, mastication pain, neck pain, face tension, limitation of mouth opening, complaints during mastication, and teeth sensitivity at baseline and then monthly for 9 months (T_1 to T_{10}). Optical axiography was used to measure right and left condyle movements (mm) at baseline, 3 months, and 6 months (T_1, T_4, and T_7).

RESULTS: A total of 32 patients (drop-out rate = 33%; 68.75% women; 28.51 ffl 7.13 years old), 16 per group, completed the study. RDC/TMD Axis I showed the following diagnoses: 93.75% muscle disorders, 37.75% disc displacement with reduction, 3.12% disc displacement without reduction, and 56.25% arthralgia. There was a significant reduction in 10 out of 13 items of the TMD/NS in the CAD/CAM splint versus 8 out of 13 in the conventional splint. However, no significant improvement in mandibular movements (ie, increase in range of motion and reduction in asymmetry between right and left condyles) was observed.

CONCLUSION: Both treatments were equally efficacious and no difference was found between them.

Journal of Dentistry

A new method for assessing the accuracy of full arch impressions in patients

Kuhr F, Schmidt A, Rehmann P, Wöstmann B
J Dent 2016;55:68-74

OBJECTIVE: To evaluate a new method of measuring the real deviation (trueness) of full arch impressions intraorally and to investigate the trueness of digital full arch impressions in comparison to a conventional impression procedure in clinical use.

METHODS: Four metal spheres were fixed with composite using a metal application aid to the lower teeth of 50 test subjects as reference structures. One conventional impression (Impregum Penta Soft) with subsequent type-IV gypsum model casting (CI) and three different digital impressions were performed in the lower jaw of each test person with the following intraoral scanners: Sirona CEREC Omnicam (OC), 3M True Definition (TD), Heraeus Cara TRIOS (cT). The digital and conventional (gypsum) models were analyzed relative to the spheres. Linear distance and angle measurements between the spheres, as well as digital superimpositions of the spheres with the reference data set were executed.

RESULTS: With regard to the distance measurements, CI showed the smallest deviations followed by intraoral scanners TD, cT and OC. A digital superimposition procedure yielded the same order for the outcomes: CI (15±4µm), TD (23±9µm), cT (37±14µm), OC (214±38µm). Angle measurements revealed the smallest deviation for TD (0.06°±0,07°) followed by CI (0.07°±0.07°), cT (0.13°±0.15°) and OC (0.28°±0.21°).

CONCLUSION: The new measuring method is suitable for measuring the dimensional accuracy of full arch impressions intraorally. CI is still significantly more accurate than full arch scans with intraoral scanners in clinical use.

CLINICAL SIGNIFICANCE: Conventional full arch impressions with polyether impression materials are still more accurate than full archdigital impressions. Digital impression systems using powder application and active wavefront sampling technology achieve the most accurate results in comparison to other intraoral scanning systems (DRKS-ID: DRKS00009360, German Clinical Trials Register).

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Implant ball attachment fabricated with CAD/CAM to overcome an unfavorable clinical situation: A case report

Shim JS, Lim JH, Shin JH, Ryu JJ, Lee JY, Shin SW
Int J Prosthodont 2016;29:611-613

ABSTRACT: The most common complication of implant ball attachments is loss of retention via structural wear. Hence, parallel placement of implants was identified as a prerequisite for long-term success. In this case, although severe angulation was formed between implants due to severe alveolar bone resorption, parallel ball attachments on the implants could be fabricated using computer-aided design/computer-assisted manufacture. This procedure can be a solution when implants are placed with angulation and offers additional advantages such as long-term stability.

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The use of CAD/CAM technology for fabricating cast gold survey crowns under existing partial removable dental prosthesis. A clinical report

El Kerdani T, Roushdy S.
J Prosthodont. 2017;26(4):321-326. doi: 10.1111/jopr.12525.

The fabrication of a survey crown under an existing partial removable dental prosthesis (PRDP) has always been a challenge to many dental practitioners. This clinical report presents a technique for fabricating accurate cast gold survey crowns to fit existing PRDPs using CAD/CAM technology. The report describes a technique that would digitally scan the coronal anatomy of a cast gold survey crown and an abutment tooth under existing PRDPs planned for restoration, prior to any preparation. The information is stored in the digital software where all the coronal anatomical details are preserved without any modifications. The scanned designs are then applied to the scanned teeth preparations, sent to the milling machine and milled into full-contour clear acrylic resin burn-out patterns. The acrylic resin patterns are tried in the patient's mouth the same day to verify the full seating of the PRDP components. The patterns are then invested and cast into gold crowns and cemented in the conventional manner.

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Clinical monitoring of tooth wear progression in patients over a period of one year using CAD/CAM

Ahmed KE, Whitters J, Ju X, Pierce SG, MacLeod CN, Murray CA
Int J Prosthodont 2017;30:153-155

PURPOSE: The aim of this study was to clinically monitor the progression of tooth wear over a period of 1 year in a cohort of referred tooth wear patients through the use of a computer-aided design/computer-assisted manufacture (CAD/CAM) scanner and a standardized scanning/assessment methodology.

MATERIAL AND METHODS: Polyether impressions were made of 11 participants (130 teeth) at baseline and at 1 year. Impressions were poured in type IV dental stone and the anterior teeth were 3D scanned. A surface-matching software was used to compare 1-year and baseline scans and identify any dimensional differences.

RESULTS: Parafunctional habits were reported by all patients. All participants exhibited tooth wear ≥ 140 μm in depth and extending to ≥ 280 μm in at least one tooth. Maxillary central incisors were the most commonly and severely affected teeth.

CONCLUSION: The ability of the developed CAD/CAM scanning methodology in clinical monitoring of tooth wear was demonstrated. Further research is needed to assess its practicality in large-scale epidemiologic tooth wear studies.

Journal of Dentistry

Biomechanical behavior of endodontically treated premolars using different preparation designs and CAD/CAM materials

Lise DP, Ende AV, De Munck J, Suzuki TYU, Vieira LCC, Van Meerbeek B
J Dent 2017;59:54-61

OBJECTIVES: To evaluate the effect of restoration design ('2.5-mm deep endocrown', '5-mm deep endocrown' or '5-mm deep post&crown') and CAD/CAM material type (composite or lithium disilicate glass-ceramic) on the load-to-failure of endodontically treated premolars in absence of any ferrule.

METHODS: The crowns of 48 single-rooted premolars were cut and the roots were endodontically treated. Teeth were randomly divided into six groups (n=8); teeth in each group were restored using one of the two tested materials with standardized CAD/CAM fabricated endocrowns (with either 2.5-mm or 5-mm deep intra-radicular extension) or conventional crowns (5-mm deep post&crown). After cementation using luting composite, the specimens were immersed in distilled water and subjected to 1,200,000 chewing cycles with a load of 50N applied parallel to the long axis of the tooth (0°). After cyclic loading, a compressive load was applied at 45° to the tooth's long axis using a universal testing machine until failure. Load-to-failure was recorded (N) and the specimens were examined under a stereomicroscope with 3.5x magnification to determine the mode of failure.

RESULTS: All specimens survived the 1,200,000 chewing cycles. A significant interaction between restoration design and CAD/CAM material was found using two-way ANOVA. In the '2.5-mm deep endocrown' groups, the composite achieved a significantly higher load-to-failure than the lithium disilicate glass-ceramic, while no differences between materials were found in the '5-mm deep endocrown' and '5-mm deep post&crown' groups. More unfavorable failures (root fractures) were observed for higher load-to-failure values.

CONCLUSIONS: Only following a '2.5-mm deep endocrown' design, composite appeared more favorable than lithium disilicate glass-ceramic as crown material; this may be explained by their difference in elastic modulus.

CLINICAL SIGNIFICANCE: Shallow endocrown preparations on premolars present less surface for adhesive luting and a difference in crown material becomes apparent in terms of load-to-failure. The use of a more flexible composite crown material appeared then a better option.

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Build angle: does it influence the accuracy of 3D-printed dental restorations using digital light-processing technology?

Osman RB, Alharbi N, Wismeijer D
Int J Prosthodont 2017;30:182-188

PURPOSE: The aim of this study was to evaluate the effect of the build orientation/build angle on the dimensional accuracy of full-coverage dental restorations manufactured using digital light-processing technology (DLP-AM).

MATERIALS AND METHODS: A full dental crown was digitally designed and 3D-printed using DLP-AM. Nine build angles were used: 90, 120, 135, 150, 180, 210, 225, 240, and 270 degrees. The specimens were digitally scanned using a high-resolution optical surface scanner (IScan D104i, Imetric). Dimensional accuracy was evaluated using the digital subtraction technique. The 3D digital files of the scanned printed crowns (test model) were exported in standard tessellation language (STL) format and superimposed on the STL file of the designed crown [reference model] using Geomagic Studio 2014 (3D Systems). The root mean square estimate (RMSE) values were evaluated, and the deviation patterns on the color maps were further assessed.

RESULTS: The build angle influenced the dimensional accuracy of 3D-printed restorations. The lowest RMSE was recorded for the 135-degree and 210-degree build angles. However, the overall deviation pattern on the color map was more favorable with the 135-degree build angle in contrast with the 210-degree build angle where the deviation was observed around the critical marginal area.

CONCLUSIONS: Within the limitations of this study, the recommended build angle using the current DLP system was 135 degrees. Among the selected build angles, it offers the highest dimensional accuracy and the most favorable deviation pattern. It also offers a self-supporting crown geometry throughout the building process.

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Additive manufacturing techniques in prosthodontics: where do we currently stand? A critical review.

Alharbi N, Wismeijer D, Osman RB
Int J Prosthodont 2017;30:474-484

PURPOSE: The aim of this article was to critically review the current application of additive manufacturing (AM)/3D-printing techniques in prosthodontics and to highlight the influence of various technical factors involved in different AM technologies.

MATERIALS AND METHODS: A standard approach of searching MEDLINE, EMBASE, and Google Scholar databases was followed. The following search terms were used: (Prosth* OR Restoration) AND (Prototype OR Additive Manufacture* OR Compute* OR 3D-print* OR CAD/CAM) AND (Dentistry OR Dental). Hand searching the reference lists of the included articles and personal connections revealed additional relevant articles. Selection criteria were any article written in English and reporting on the application of AM in prosthodontics from 1990 to February 2016.

RESULTS: From a total of 4,290 articles identified, 33 were seen as relevant. Of these, 3 were narrative reviews, 18 were in vitro studies, and 12 were clinical in vivo studies. Different AM technologies are applied in prosthodontics, directly and indirectly for the fabrication of fixed metal copings, metal frameworks for removable partial dentures, and plastic mock-ups and resin patterns for further conventional metal castings. Technical factors involved in different AM techniques influence the overall quality, the mechanical properties of the printed parts, and the total cost and manufacturing time.

CONCLUSION: AM is promising and offers new possibilities in the field of prosthodontics, though its application is still limited. An understanding of these limitations and of developments in material science is crucial prior to considering AM as an acceptable method for the fabrication of dental prostheses.

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Randomized controlled within-subject evaluation of digital and conventional workflows for the fabrication of lithium disilicate single crowns. Part II: CAD-CAM versus conventionallaboratory procedures

Sailer I, Benic GI, Fehmer V, Hämmerle CHF, Mühlemann S
J Prosthet Dent 2017;118:43-48

STATEMENT OF PROBLEM: Clinical studies are needed to evaluate the entire digital and conventional workflows in prosthetic dentistry.

PURPOSE: The purpose of the second part of this clinical study was to compare the laboratory production time for tooth-supported single crowns made with 4 different digital workflows and 1 conventional workflow and to compare these crowns clinically.

MATERIAL AND METHODS: For each of 10 participants, a monolithic crown was fabricated in lithium disilicate-reinforced glass ceramic (IPS e.max CAD). The computer-aided design and computer-aided manufacturing (CAD-CAM) systems were Lava C.O.S. CAD software and centralized CAM (group L), Cares CAD software and centralized CAM (group iT), Cerec Connect CAD software and lab side CAM (group CiL), and Cerec Connect CAD software with centralized CAM (group CiD). The conventional fabrication (group K) included a wax pattern of the crown and heat pressing according to the lost-wax technique (IPS e.max Press). The time for the fabrication of the casts and the crowns was recorded. Subsequently, the crowns were clinically evaluated and the corresponding treatment times were recorded. The Paired Wilcoxon test with the Bonferroni correction was applied to detect differences among treatment groups (α=.05).

RESULTS: The total mean (fflstandard deviation) active working time for the dental technician was 88 ffl6 minutes in group L, 74 ffl12 minutes in group iT, 74 ffl5 minutes in group CiL, 92 ffl8 minutes in group CiD, and 148 ffl11 minutes in group K. The dental technician spent significantly more working time for the conventional workflow than for the digital workflows (P<.001). No statistically significant differences were found between group L and group CiD or between group iT and group CiL. No statistical differences in time for the clinical evaluation were found among groups, indicating similar outcomes (P>.05).

CONCLUSIONS: Irrespective of the CAD-CAM system, the overall laboratory working time for a digital workflow was significantly shorter than for the conventional workflow, since the dental technician needed less active working time.

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The effect of a CAD/CAM-guided template on formation of the screw-access channel for fixed prostheses supported by lingually placed implants.

Lee DH, Li LJ, Mai HN, Kim KR, Lee KW
Int J Prosthodont 2017;30:113-115

PURPOSE: The aim of this study was to evaluate the effect of a computer-aided design/computer-assisted manufacturing (CAD/CAM) guide on drilling the screw-access channel for lingually placed implants.

MATERIALS AND METHODS: Screw-channel drilling guides were fabricated on lingually placed implant models using CAD/CAM technology. The screw channels were prepared with guided or freehand drilling by 20 dental graduates. The accuracy of each screw channel was assessed for drilling entry point, channel volume, and angulation ($\alpha = .05$).

RESULTS: The guided drilling group showed smaller deviations than the freehand drilling group, and prosthesis position influenced the guide effect ($P < .001$).

CONCLUSION: The CAD/CAM guide facilitated the screw channel preparation of cement-retained prostheses supported by lingually placed implants.

The International Journal of Prosthodontics
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Comparison of fixed dental prostheses with zirconia and metal frameworks: Five-year results of a randomized controlled clinical trial

Sailer I, Balmer M, Hüsler J, Hämmerle CHF, Känel S, Thoma DS
Int J Prosthodont 2017;30:426–428

PURPOSE: The aim of this study was to test whether posterior zirconia-ceramic (ZC) and metal-ceramic (MC) fixed dental prostheses(FDPs) exhibit similar survival and technical/biologic complication rates.

MATERIALS AND METHODS: A total of 58 patients in need of 76 posterior FDPs were randomly assigned to receive 40 ZC and 36 MC FDPs. The restorations were examined at baseline (cementation) and yearly for 5 years. Technical and biologic outcomes were compared. The independent treatment groups were compared with nonparametric Mann-Whitney test for metric variables and with Fisher exact test for categoric data.

RESULTS: A total of 52 patients with 40 ZC and 29 MC FDPs were examined at 5 years. No FDP failed during the 5 years; 2 ZC FDPs failed at 65.4 and 73.3 months. Debonding occurred at 3 ZC FDPs. Technical outcomes (modified US Public Health Service criteria) and general periodontal parameters did not show significant differences between ZC and MC FDPs.

CONCLUSION: ZC FDPs exhibited similar outcomes to MC FDPs based on 5-year survival estimates. The majority of technical and biologic outcome measures were not significantly different.

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Preferences related to the use of mobile apps as dental patient educational aids: A pilot study

Bohn CE, McQuistan MR, McKernan SC, Askelson NM
J Prosthodont. 2018;27(4):329-334. doi: 10.1111/jopr.12667

PURPOSE: Numerous patient education apps have been developed to explain dental treatment. The purpose of this study was to assess perceptions and preferences regarding the use of apps in dental settings.

MATERIALS AND METHODS: Four patient education apps describing fixed partial dentures were demonstrated to participants (N = 25). Questions about each app were asked using a semi-structured interview format to assess participants' opinions about each app's content, images, features, and use. Sessions were analyzed via note-based methods for thematic coding.

RESULTS: Participants believed that apps should be used in conjunction with a dentist's explanation about a procedure. They desired an app that could be tailored for scope of content. Participants favored esthetic images of teeth that did not show structural anatomy, such as tooth roots, and preferred interactive features.

CONCLUSIONS: Patient education apps may be a valuable tool to enhance patient-provider communication in dental settings. Participants exhibited varying preferences for different features among the apps and expressed the desire for an app that could be personalized to each patient. Additional research is needed to assess whether the use of apps improves oral health literacy and informed consent among patients.

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Shear bond strength of repair systems to new CAD/CAM restorative materials

Üstün Ö, Büyükhatipoğlu IK, Seçilmiş A
J Prosthodont. 2018;27(8):748-754. doi: 10.1111/jopr.12564

PURPOSE: To evaluate the bond strength of repair systems (Ceramic Repair, Clearfil Repair) to computer-aided design/computer-assisted machining (CAD/CAM) restorative materials (IPS e.max CAD, Vita Suprinity, Vita Enamic, Lava Ultimate).

MATERIALS AND METHODS: Thermally aged CAD/CAM restorative material specimens (5000 cycles between 5°C and 55°C) were randomly divided into two groups according to the repair system: Ceramic Repair (37% phosphoric acid + Monobond-S + Heliobond + Tetric N Ceram) or Clearfil Repair (40% phosphoric acid + mixture of Clearfil Porcelain Bond Activator and Clearfil SE Bond Primer + Clearfil SE Bond + Filtek Z250). The resin composite was light-cured on conditioned specimens. All specimens were stored in distilled water at 37°C for 24 hours and then additionally aged for 5000 thermal cycles. The shear bond strength test was performed using a universal testing machine (0.5 mm/min). Two-way ANOVA was used to detect significance differences according to the CAD/CAM material and composite repair system factors. Subgroup analyses were conducted using the least significant difference post-hoc test.

RESULTS: The results of two-way ANOVA indicated that bond strength values varied according to the restorative materials ($p < 0.05$). No significant differences were observed between the CAD/CAM restorative materials ($p > 0.05$), except in the Vita Suprinity group ($p < 0.05$). Moreover, no differences were observed between the repair systems.

CONCLUSIONS: Both the Clearfil and Ceramic repair systems used in the study allow for successful repairs.

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Clinical evaluation of indirect particle-filled composite resin CAD/CAM partial crowns after 24 months

Zimmermann M, Koller C, Reymus M, Mehl A, Hickel R
J Prosthodont. 2018;27(8):694-699. doi: 10.1111/jopr.12582.

PURPOSE: Resin-based CAD/CAM compound materials might be promising for single-tooth restorations. Insufficient clinical data are available for this new material class. The purpose of this study was to describe initial clinical in vivo results for indirect particle-filled composite resin CAD/CAM restorations after 24 months.

MATERIALS AND METHODS: Indirect particle-filled composite resin restorations were fabricated with a CAD/CAM method (CEREC Bluecam intraoral scanner, CEREC MCXL milling unit) by calibrated dental students. Forty-two partial crown restorations were seated adhesively in 30 patients with caries lesions or insufficient restorations (baseline). Strict inclusion criteria were defined for the patient collective. Follow-up evaluation comprised 40 restorations after 12 months and 33 restorations after 24 months. Evaluation criteria were modified FDI criteria with grades (1) to (5). Rating with FDI criteria (5) was defined as clinical failure. Statistical analysis was performed with Wilcoxon-Test ($p < 0.05$).

RESULTS: The success rate of indirect particle-filled composite resin CAD/CAM restorations after 12 months was 95.0% with two debondings observed. The cumulative success rate for indirect particle-filled composite resin CAD/CAM restorations after 24 months was 85.7% with two tooth fractures and one debonding. Statistically significant differences were found for baseline and 24-month follow-up evaluation for anatomic form and marginal adaptation criterion examined in respect to FDI criteria guidelines (Wilcoxon-Test, $p < 0.05$).

CONCLUSIONS: This study demonstrates particle-filled composite resin CAD/CAM restorations having a clinical success rate of 85.7% after 24 months. Adhesive bonding procedures need to be ensured carefully. A longer clinical evaluation period is necessary to draw further conclusions.

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Digital learning resources for prosthodontic education: The perspectives of a long-term dental educator regarding 4 key factors

Goodacre CJ
J Prosthodont 2018;27:791-797

Technological advances have led to the introduction of 3D education programs specifically designed for dentistry, leading to the author's use of these programs in the education of dental students. Based on this usage, this paper proposes there are 4 key factors that can enhance student education (spatial ability, interactivity, critical thinking, and clinical correlations with integration of multiple dental disciplines). These key factors can be incorporated into student learning through the use of 3D education programs in class. Lessons learned from using these programs include the importance of regular use in class as well as testing students both visually and textually on the content present in such programs. In this way, students will use the program and thereby enhance their 3D visualization skills while learning the required didactic information. Simply providing students with access to such programs without regular use in class and without testing the students on the content leads to these programs' lack of use. As a result, the students miss an opportunity to enhance their ability to visualize structures three dimensionally and manipulate them in their minds, a process known as spatial ability that is linked to success in the sciences.

Journal of Dentistry

10-year randomized trial (RCT) of zirconia-ceramic and metal-ceramic fixed dental prostheses

Sailer I, Balmer M, Hüsler J, Hämmerle CHF, Känel S, Thoma DS
J Dent 2018;76:32-39

OBJECTIVES: To monitor zirconia-ceramic and metal-ceramic posterior FDPs with respect to survival and technical/biological complication rates.

MATERIALS AND METHODS: Fifty-eight patients received 76 3- to 5-unit posterior FDPs. The sites were randomly assigned to 40 zirconia-based (ZC) and 36 metal-based (MC) FDPs. FDPs were examined at baseline (cementation), at 6 months, at 1 year and then yearly up to 10 years. Technical outcomes were assessed using modified United States Public Health Service (USPHS) criteria. Biologic outcomes included probing depth, plaque, bleeding on probing and tooth vitality. Statistical analysis was performed applying Kaplan-Meier (KM) estimation, log-rank, Mann-Whitney and Fisher exact test.

RESULTS: During the 10-year follow-up thirteen patients (17 FDPs) dropped out and 6 FDPs in 6 patients (5 ZC,1 MC) were considered catastrophic failures for technical and/or biological reasons. Forty-four patients with 53 FDPs (29 ZC, 24 MC) were available for examination. The median observation period was 10.3 years (ZC) and 10.0 years (MC). The 10-year KM survival estimate of ZC FDPs was 91.3% (95%CI:69.5;97.8) and 100% of MC FDPs. Minor chipping of the veneering ceramic and occlusal wear were found to a similar extent at ZC and MC FDPs. ZC FDPs demonstrated a significantly higher rate of framework fracture, de-bonding, major fractures of the veneering ceramic and poor marginal adaption. Biological outcomes were similar in both groups and between abutment and control teeth.

CONCLUSION: At 10 years, ZC and MC posterior FDPs resulted in similar outcomes for the majority of the outcome measures ($p > 0.05$).

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Rehabilitation of edentulous jaws with zirconia complete-arch fixed implant-supported prostheses: An up to 4-year retrospective clinical study

Tischler M, Patch C, Bidra AS
J Prosthet Dent 2018;120:204-209

STATEMENT OF PROBLEM: Limited data are available on the clinical outcomes of patients with edentulism treated with zirconiacomplete-arch fixed implant-supported prostheses (CAFIPs).

PURPOSE: The primary purpose of this retrospective clinical study was to study the failure rate of dental implants as well as the fracture rate of zirconia CAFIPs. The secondary purpose was to study the survival outcomes of patients with edentulism treated with zirconia CAFIPs as well as the rate of technical complications.

MATERIAL AND METHODS: This retrospective clinical study from private practice included 128 patients rehabilitated between January 1, 2013, and December 31, 2016, with 1072 implants supporting 191 zirconia CAFIPs for single-jaw as well as double-jaw rehabilitations. All zirconia prostheses were of 1-piece design and were veneered with feldspathic porcelain only at the gingival region and therefore considered as predominantly monolithic. Additionally, all prostheses were bonded to implant manufacturer's titanium cylinders that provided an intimate contact with the implants. The primary outcome measures were implant failure rate and prosthesis fracture rate. The secondary outcome measures were prosthodontic treatment survival rate and the incidence of technical complications with respect to monolithic zirconia CAFIPs. Cumulative survival rate (CSR) for implants and prostheses was calculated after a life-table survival analysis.

RESULTS: Of the analyzed samples over a 4-year period, at least 288 implants and 49 prostheses had a minimum of 4 years of follow-up. A total of 18 implant failures were noted (13 in maxilla, 5 in mandible), yielding a CSR of 97.6% for implants. One fracture of the zirconia prosthesis was recorded, yielding a CSR of 99.4% for the prostheses over the 4-year period. Another 3 prostheses required remaking because the supporting implants failed, and 1 prosthesis was remade because the lack of passive fit resulted in a CSR of 96.8% for the prosthodontic treatment itself. During the 4-year period, 1 zirconia prosthesis had a technical complication related to the debonding of titanium cylinders, and 2 prostheses had fractured screws, which were resolved successfully. No zirconia prostheses had chipping of the veneered gingival porcelain.

CONCLUSIONS: Findings from this retrospective clinical study from private practice showed that prosthodontic treatment of edentulous patients with a 1-piece, complete-arch fixed implant-supported zirconia prosthesis with veneered porcelain restricted to the gingival region had high survival rates for implants and prostheses. Minimal technical complications related to this type of treatment for edentulous jaws and no chipping of the veneered gingival porcelain were encountered.

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Precise reproduction of soft tissue structure around the pontic area using computer-aided design and manufacturing

Lee H, Paek J, Noh K, Kwon KR
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Reproducing soft tissue contours around a pontic area is important for the fabrication of an esthetic prosthesis, especially in the anterior area. A gingival model that precisely replicates the soft tissue structure around the pontic area can be easily obtained by taking a pick-up impression of an interim fixed dental prosthesis. After a working cast is fabricated using the customary technique, the pick-up model is superimposed onto the working model for the pontic area using computer-aided design and manufacturing (CAD/CAM). A definitive restoration using this technique would be well adapted to the pontic base, which is formed by the interim prosthesis.

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Effect of different surface treatments on bond strength of resin cement to a CAD/CAM restorative material

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J Prosthodont. 2019;28(1):71-78. doi: 10.1111/jopr.12574

PURPOSE: To investigate the effects of various surface treatment methods on the shear bond strength of self-adhesive resin cement to a novel CAD/CAM hybrid ceramic material.

MATERIALS AND METHODS: A novel hybrid ceramic restorative material (Vita Enamic) was used in this study. Sixty resin block specimens were prepared and separated into six groups for each surface treatment method (n = 10); group 1: control group, no treatment applied; group 2: sandblasted by 30 µm silicate-coated alumina particles (CoJet Sandblasting); group 3: 50 µm Al2 O3 sandblasting; group 4: 10% hydrofluoric acid; group 5: no surface treatment + universal adhesive (3M Single Bond Universal); group 6: 200 mJ, 10 Hz 2W Er,Cr:YSGG laser treatment. For each specimen, surface roughness measurements in noncontact mode were taken after the surface treatments using a portable surface texture-measuring machine. A self-adhesive resin cement (3M U200) was applied on every surface treated with the help of a cylindrical mold (2 × 4 mm) and was filled gradually. Shear bond strength was measured using a universal test machine, and one-way ANOVA and a Duncan test (p = 0.05) were used to analyze the data.

RESULTS: Mean values of the shear bond strength varied between 7.75 and 10.73 MPa. Bond strength values were enhanced by all surface treatment methods compared to the control group. The difference between group 5 and the control group (p < 0.05) was statistically significant, whereas there were no considerable differences between other treatment methods.

CONCLUSION: Surface treatments of hybrid ceramic resin blocks could enhance the bond strength to resin cement; however, using Single Bond Universal without surface treatment showed a higher bond strength value.

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Enhancing student learning of removable prosthodontics using the latest advancements in virtual 3D modeling

Mahrous A, Schneider GB
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When educating dental students or prosthodontic residents, a picture can be worth a thousand words. If that is so, then what could enhanced 3D modeling be worth relative to enhancing student learning? The answer is undoubtedly more than what a picture can provide. That is why the use of 3D models has become increasingly common with respect to patient care. The 3D modeling allows the patient to visualize more clearly the proposed treatments and outcomes; however, while 3D modeling has started to make an appearance in dental education, many of the current 3D modeling techniques do not offer the flexibility needed for dental education and enhanced student learning. At the University of Iowa, the use of 3D modeling software has enabled the creation of 3D models that can be altered or customized to be used in a more flexible way to teach students in the arts and complexities of removable partial denture (RPD) design and associated components. This educational technique article will: (1) demonstrate how these 3D models can be used to enhance student perception and learning regarding RPDs; and (2) will demonstrate using videos and web-based portals to show how the 3D RPD models were created and then used for educational purposes.

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In vitro evaluation of adhesion of candida albicans on CAD/CAM PMMA-based polymers

Murat S, Alp G, Alatalı C, Uzun M
J Prosthodont 2019;28:e873-e879

PURPOSE: To compare the amount of adherent Candida albicans to different CAD/CAM poly(methyl methacrylate) (PMMA)-based polymers and conventional heat-polymerized PMMA after long-term thermal cycling.

MATERIALS AND METHODS: The specimens were subjected to 10,000 thermal cycles (5-55°C) and divided into two groups, uncoated and pellicle-coated. Surface roughness and contact angles of the specimens were measured. The surface morphology was observed with scanning electron microscopy (SEM). An adhesion test was performed by incubating the disk specimens in C. albicans suspensions at 37°C for 2 hours, and the adherent cells were counted under an optical microscope. The data were analyzed statistically using a variance analysis and Tukey HSD post hoc comparison test. The correlation between measurements was tested using a Pearson correlation analysis ($\alpha = 0.05$).

RESULTS: CAD/CAM polymers generally showed statistically significant lowest Ra and contact angle values, whereas conventional PMMA showed the highest Ra and contact angle values in the uncoated group ($p < 0.05$). Pellicle coating essentially increased contact angle of all materials and reduced the differences in a number of Candida cells on the materials ($p < 0.05$). Candida adhesion was statistically significantly greatest on conventional PMMA when compared to CAD/CAM polymers. A strong positive correlation was found between the surface roughness of the specimens ($p < 0.05$) and the amount of adhered cells, whereas no correlation was found between hydrophobicity of the specimens and the amount of adhered cells ($p > 0.05$).

CONCLUSIONS: CAD/CAM PMMA-based polymers may be preferable to reduce Candida-associated denture stomatitis in long-term use.

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Three-dimensional endodontic guide for adhesive fiber post removal: A dental technique

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J Prosthet Dent 2019;121:387-390

This dental technique describes a protocol for adhesive fiber post removal using a prototyped endodontic guide. The removal of an adhesive fiber post is an important step for endodontic retreatment and the resolution of prosthetic problems. Computer-aided design and computer-aided manufacturing (CAD-CAM) technology was used to generate guides with prototyping and is a useful tool for fiber post removal.

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Influence of thermomechanical fatigue on the fracture strength of CAD-CAM-fabricated occlusal veneers

Al-Akhali M, Kern M, Elsayed A, Samran A, Chaar MS
J Prosthet Dent 2019;121:644-650

STATEMENT OF PROBLEM: With the development of new computer-aided design and computer-aided manufacturing (CAD-CAM) restorative dental materials, limited data regarding their survival rate and fracture strength are available when they are used as occlusal veneers. Therefore, these materials should be evaluated under conditions similar to those of the oral environment before being recommended for clinical use.

PURPOSE: To evaluate the influence of thermomechanical fatigue loading on the fracture strength of minimally invasive occlusal veneer restorations fabricated from different CAD-CAM materials and bonded to human maxillary premolars using self-etching bonding technique.

MATERIAL AND METHODS: Sixty-four CAD-CAM occlusal veneer restorations were fabricated from group LD (lithium disilicate [e.max CAD]), LS (zirconia-reinforced lithium silicate [Vita Suprinity]), PI (polymer-infiltrated ceramic [Vita Enamic]), and PM (polymethylmethacrylate [Telio CAD]). The occlusal veneers were luted to enamel (n=16) using a self-etching primer (Multilink Primer A/B) and a luting composite resin (Multilink Automix). Half of the specimens of each group (n=8) were randomly selected and subjected to thermomechanical fatigue loading in a masticatory simulator (1.2 million cycles at 98 N with 5°C-55°C thermocycling). All specimens were quasistatically loaded until fracture. The statistical analysis was made using the Kruskal-Wallis and Mann-Whitney U tests (α=.05).

RESULTS: According to the Kaplan-Meier analysis after the thermomechanical fatigue of the 4 groups, the cumulative survival rate was as follows: group LD, 50% group LS, 62.5% group PI, 37.5%; and group PM, 50%. Although some of the surviving specimens exhibited microcracking, their integrity or bonding to teeth was not affected. Thermomechanical fatigue significantly reduced the fracture strength of group PI (P=.047) and group PM (P=.025). Without thermomechanical fatigue, group PM showed significantly higher fracture strength than group LS (P=.015).

CONCLUSIONS: In general, thermomechanical fatigue decreased the survival rate and fracture strength in all test groups.

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