DEFINING DIGITAL DENTISTRY

A Survey of Recent Literature

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 the tireless effort of a volunteer task force. 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 2016. 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 48 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.

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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

STATEMENT OF PROBLEM: 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.

PURPOSE: 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.

MATERIAL AND METHODS: 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.

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

Chochlidakis K, Papaspyridakos P, Gemmiani A, Chen C, Feng J, 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.
Digital versus conventional impressions in fixed prosthodontics: A review

J Prosthodont 2016 Aug 2 PMID: 27483210

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.
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.
Evaluation of the absolute marginal discrepancy of zirconiabased 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 (α=.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).
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 ($\alpha=.05$).

**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) $\mu$m) was significantly smaller than for Ceramill (81(66) $\mu$m) ($P<.005$). 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.
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. 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. 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. 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). 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.
Accuracy of ceramic restorations made with two CAD/CAM systems

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

Ender A, Mehl A
J Prostheth 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 (α=.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 ±15.8 μm (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.
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.
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.
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.
Clinical evaluation of CAD/CAM metal-ceramic posterior crowns fabricated from intraoral digital impressions

Tamim H, Skjerven H, Ekfeldt A, Odont, Renold HJ

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

Ng J, Ruse D, Wyatt C
J Prosthet Dent 2014;112:555-560

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

Huang Z, Zhang L, Zhu J, Zhao Y, Zhang X
Article first published online: 14 SEP 2014, 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.
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.
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, α = 0.05).

RESULTS: Mean marginal (internal) discrepancies were: ITE 90 (92) μm, TRI 128 (106) μm, CBC 146 (84) μm, and COS 109 (93) μm. 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.
Digital evaluation of the accuracy of impression techniques and materials in angulated implants

Kurtulmus-Yılmaz S, Özcan O, Özcelik TB, Yagız 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.
3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impression


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


**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 ($\alpha = 0.05$).

**RESULTS:** Internal adaptation values were significantly affected by the impression technique ($p = 0.001$). Mean marginal gap was $76.33 \pm 65.32 \mu m$ for the crowns of the IDI group and $91.46 \pm 72.17 \mu m$ 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.
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.
Effect of imaging powder and CAD/CAM stone types on the marginal gap of zirconia crowns


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 physical 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.
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 silicone rubber 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.
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 impressions made 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 (α=.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.
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 (a=.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.
Three-dimensional evaluation of the repeatability of scanned conventional impressions of prepared teeth generated with white- and blue-light scanners

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

Arslan Y, Bankoglu Gungör M, Karakoca Nemli S, Kökdoğan Boyacı B, Aydın C
J Prosthodont 2016 Feb 5. PMID: 26848940

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

J Prosthodont 2016 Feb 8. PMID: 26855068

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-curious, 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 Definition). 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 Definition) 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.
In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions

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

**STATEMENT OF PROBLEM:** 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.

**PURPOSE:** 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 complete-arch 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.
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
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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 \(\mu\)m, 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 \(\pm\) 12.61 \(\mu\)m to -26.97 \(\pm\) 50.56 \(\mu\)m and from 0.16º \(\pm\) 0.04º to -0.43º \(\pm\) 0.1º, 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.
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.
Intraoral digital impression technique compared to conventional impression technique. A randomized clinical trial

Gjelvald B, Chrcanovic BR, Korduner EK, Collin-Bagewitz I, Kisch J

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

Su T, Sun J

STATEMENT OF PROBLEM: 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-occlusal edge (P3), and central-occlusal point (P4).

RESULTS: Mean marginal fit values of the digital group (64 ±16 mm) were significantly smaller than those of the conventional group (76 ±18 mm) (P<.05). The mean internal fit values of the digital group (111 ±34 mm) were significantly smaller than those of the conventional group (132 ±44 mm) (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.
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 were 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.
Using stereophotogrammetric technology for obtaining intraoral digital impressions of implants

Pradíes G, Ferreiro A, Özcan M, Giménez B, Martínez-Rus F

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

Patzelt SB, Lamprinos C, Stampf S, Att W

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.
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.
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.

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.

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

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.

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

J Prosthodont 2015 Dec 14. PMID: 26662261

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.
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: Pages 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 ≤ 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.
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 ΔF (r = −0.765, p < 0.0001), and ΔQ (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 ΔR (r = 0.369, p = 0.059) and ΔX (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 ΔF and ΔQ 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, ΔR and ΔX, 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 SIGNIFICANCE: 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.
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.
OBJECTIONS: 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 ± 20 μm) were significantly more than those measured from Cercon Digital Machine images (range = 52-80 μm, mean = 68 ± 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.

Quantification of incisal tooth wear in upper anterior teeth: Conventional vs new method using toolmakers microscope and a three-dimensional measuring technique
Association between the cariogenicity of a dental microcosm biofilm and its red fluorescence detected by Quantitative Light-induced Fluorescence-Digital (QLF-D)

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 SIGNIFICANCE: The QLF-D is able to assess the cariogenic levels of dental plaque based on the intensity of red fluorescence.
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 (ICC)s) 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.
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.

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 (ΔVHN) and lesion depth in the enamel.

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), ΔVHN (r = 0.65, p = 0.001), and lesion depth in the enamel (r = 0.82, p = 0.001) according to the maturation time.

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.

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

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.
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) at p < 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.
3D Computer aided treatment planning in endodontics

Bidra AS, Taylor TD, Agar JR

**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.
Shade matching assisted by digital photography and computer software

Schrapp L

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 (α = 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.
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 Prosthodont 2011;105:83-90

STATEMENT OF PROBLEM: A dark-colored prepared abutment tooth may negatively affect the esthetic outcome of a ceramic restoration if the tooth is restored using translucent ename-like ceramic materials.

PURPOSE: 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 (ΔE) were calculated. The data were analyzed with a 3-way ANOVA (tooth abutment color, ceramic thickness, and luting agent) and Tukey’s HSD test (α=.05), which evaluated within-group effects of the tooth abutment color to the ΔE at each ceramic thickness.

RESULTS: The ΔE 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 ΔE values relative to other variables tested. An increase in ceramic thickness resulted in a significant decrease in ΔE values (P<.01). The ΔE 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.
European dental students’ opinions about visual and digital tooth colour determination systems

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 ± 0.8 vs. 3.0 ± 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.
Dental shade matching using a digital camera

Bidra AS, Taylor TD, Agar JR

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 x 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.
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.
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.
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.
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.
Fabricating complete dentures with CAD/CAM and RP technologies

Bilgin MS, Erdem A, Aglarci OS, Dilber E
J Prosthodont 2015 Jun 1. PMID: 26032438

Two technological 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.
The use of digital impressions to fabricate tooth-supported partial removable dental prostheses: A clinical report

Mansour M, Sanchez E, Machado C
J Prosthodont 2015 Sep 15. PMID: 26371612

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.
Part-digitizing system of impression and interocclusal record for complete denture fabrication

Matsuda T, Goto T, Yagi K, Kashiwabara T, Ichikawa T
J Prosthodont 2015 Nov 30

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.
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.
Innovative approach for interim facial prosthesis using digital technology

Yoshioka F, Ozawa S, Hyodo I, Tanaka Y

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.
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

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.
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 computer-guided 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 computer-guided 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 (α=.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.
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

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 1400N 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).
Two-body wear rate of CAD/CAM resin blocks and their enamel antagonists

Stawarczyk B, Özcan M, Trottmann A, Schmutz F, Roos M, Hammerle 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 (α=.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 IEP. 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.
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 Jan 5. PMID: 25557585

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.
Enhancing fracture and wear resistance of dentures/overdentures utilizing digital technology: A case series report

Afify A, Haney S
J Prosthodont 2016 Feb 24. PMID: 26916680

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 has been implemented.
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 2016 Aug 2. PMID: 27483086

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.
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, Hammerle C

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 (1200 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 (a=.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; O-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.
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±0.40 mm in the x-direction (lateral), 0.73±0.63 mm in the y-direction (anterior-posterior) and 0.55±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.