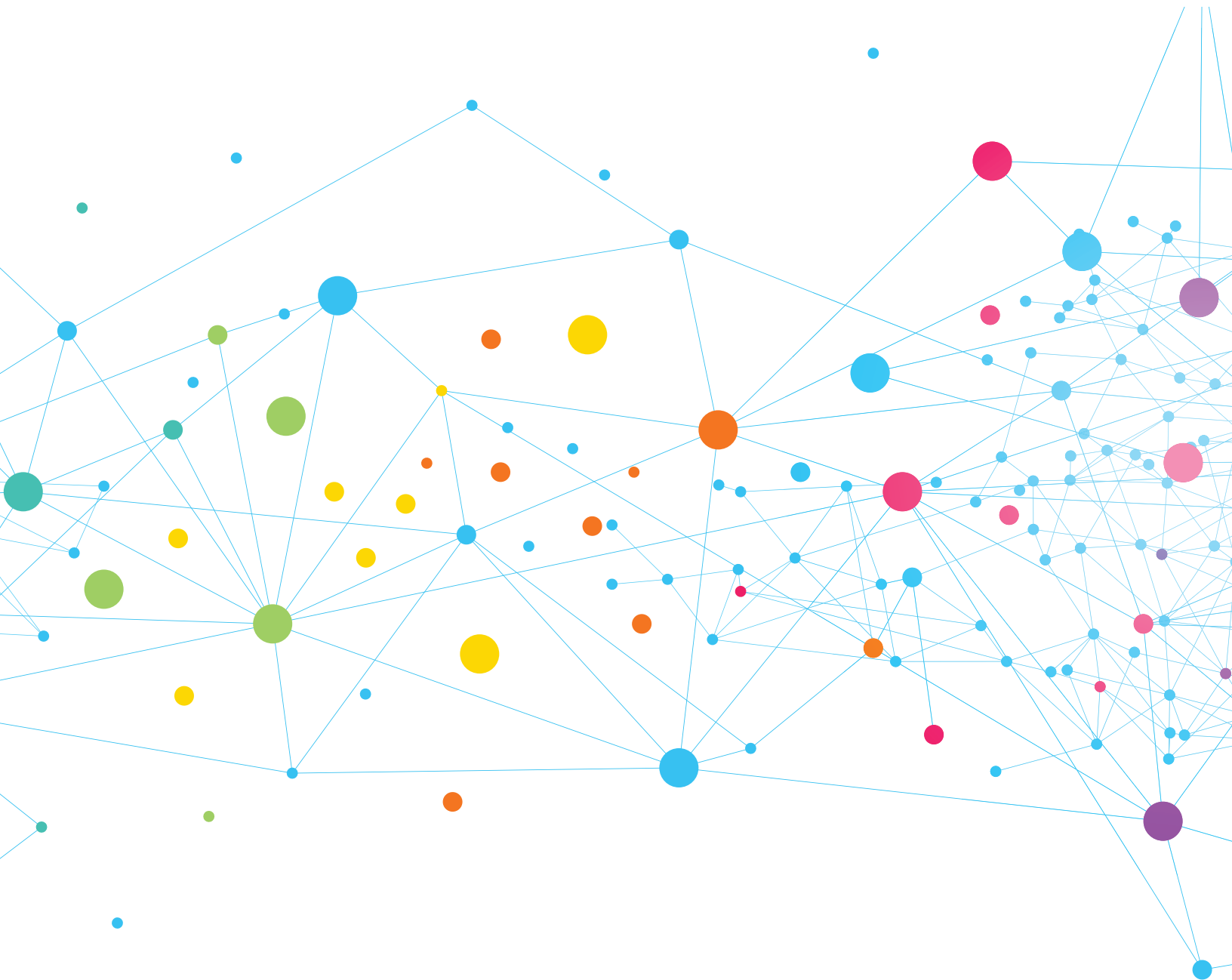


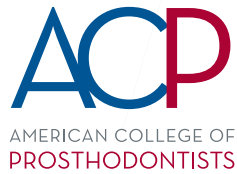
DEFINING DIGITAL DENTISTRY

# A Survey of Recent Literature

**ACP**  
AMERICAN COLLEGE OF  
PROSTHODONTISTS



# Introduction & Acknowledgements



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

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

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# A Survey of Recent Literature

## Table of Contents

4-9	<b>REVIEWS - SYSTEMATIC REVIEWS</b>
10-69	<b>ACCURACY - ADAPTATION</b>
70-82	<b>WORKFLOWS &amp; EFFICIENCY</b>
83-97	<b>ASSESSMENT &amp; DIAGNOSIS</b>
98-108	<b>COLOR ASSESSMENT - MATCHING</b>
109-120	<b>REMOVABLE</b>
121-129	<b>MAXILLOFACIAL</b>
130-139	<b>GUIDED PLANNING &amp; SURGERY</b>
140-162	<b>MISCELLANEOUS - OTHER</b>

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

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

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

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

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

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

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

## Marginal adaptation of ceramic crowns: a systematic review

Contrepois M, Soenen A, Bartala M, Laviolle 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, Geminiani 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

*Ahlholm P, Sipilä K, Vallittu P, Jakonen M, Kotiranta U  
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 zirconia-based ceramic copings

Martínez-Rus F, Suárez MJ, Rivera B, Pradés 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 ( $\alpha=0.05$ ).

**RESULTS:** The mean marginal openings were  $29.98 \pm 3.97 \mu\text{m}$  for the In-Ceram Zirconia group,  $12.24 \pm 3.08 \mu\text{m}$  for the In-Ceram YZ group,  $13.15 \pm 3.01 \mu\text{m}$  for the Cercon group, and  $8.67 \pm 3.96 \mu\text{m}$  for the Procera group. Significant differences were found among the 4 systems ( $P < 0.05$ ).

**CONCLUSIONS:** The marginal accuracy achieved for the 4 zirconia-based ceramic crown systems analyzed was within the range of clinical acceptance ( $120 \mu\text{m}$ ).

## 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 Girschbach).

**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)  $\mu\text{m}$ ) was significantly smaller than for Ceramill (81(66)  $\mu\text{m}$ ) ( $P<.005$ ). 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.

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

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

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

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

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

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

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

## Accuracy of ceramic restorations made with two CAD/CAM systems

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

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

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

**MATERIAL AND METHODS:** Forty zirconia-based and lithium disilicate crowns, 20 each, were fabricated with the Cerec inLab and Everest CAD/CAM systems on a specially designed stainless steel die to ensure the standardization of specimen shape and dimensions. The vertical marginal fit for all tested crowns was evaluated by using a digital microscope at  $\times 100$  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 Prosthet Dent* 2013;109:121-128

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

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

**MATERIAL AND METHODS:** A steel reference dentate model was fabricated and measured with a reference scanner (digital reference model). Conventional impressions were made from the reference model, poured with Type IV dental stone, scanned with the reference scanner, and exported as digital models. Additionally, digital impressions of the reference model were made and the digital models were exported. Precision was measured by superimposing the digital models within each group. Superimposing the digital models on the digital reference model assessed the trueness of each impression method. Statistical significance was assessed with an independent sample t test ( $\alpha=0.05$ ).

**RESULTS:** The reference scanner delivered high accuracy over the entire dental arch with a precision of  $1.6 \pm 0.6 \mu\text{m}$  and a trueness of  $5.3 \pm 1.1 \mu\text{m}$ . Conventional impressions showed significantly higher precision ( $12.5 \pm 2.5 \mu\text{m}$ ) and trueness values ( $20.4 \pm 2.2 \mu\text{m}$ ) with small deviations in the second molar region ( $P < 0.001$ ). Digital impressions were significantly less accurate with a precision of  $32.4 \pm 9.6 \mu\text{m}$  and a trueness of  $58.6 \pm 15.8 \mu\text{m}$  ( $P < 0.001$ ). 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.

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

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

The purpose of this investigation was to measure the accuracy of digital impressions (DIs) compared to conventional impressions (CIs). Using the iTero system, a master cast was scanned to produce stereolithography dies. As a control group, silicone impressions were taken and poured using stone. The resulting stereolithography and stone dies were scanned and overlaid on the scanned reference image of the master cast. The mean ( $\pm$  standard deviation) dimensional difference to the master cast was  $23.9 (\pm 17.6) \mu\text{m}$  for DIs and  $17.6 (\pm 45.6) \mu\text{m}$  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  $0.037 \pm 0.017$  mm and  $0.269 \pm 0.114$  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  $\mu\text{m}$ . 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, Rønold HJ  
*Int J Prosthodont* 2014;27:331-337. doi: 10.11607/ijp.3607

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

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

**RESULTS:** No adjustments were needed for any of the interproximal contact points. Adjustments of occlusion and articulation contacts were needed in 20% of the restorations. Clinical evaluation of the marginal integrity showed satisfactory results according to the CDA criteria. The 50 silicone replicas showed a median precementation space of 46  $\mu\text{m}$  at the marginal measurement location, 94  $\mu\text{m}$  at the midaxial location, and 185  $\mu\text{m}$  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;112:555-260

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

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

**MATERIAL AND METHODS:** The maxillary right second premolar was prepared for a ceramic crown in a typodont. The typodont was then digitized with a laboratory scanner, and the digital file was used to mill a replica of the maxillary arch from a monolithic block of yttria-stabilized zirconia to serve as the master model. Digital impressions of the prepared maxillary right second premolar were recorded with a scanning unit. Scan files were exported as .STL files and sent by e-mail to a dental laboratory. The files were input into a digital design workflow for digital articulation, digital waxing, and design of the definitive crown. Fifteen crowns were produced by milling computer-aided designed lithium disilicate glass ceramic blocks with a 5-axis milling. Fifteen lithium disilicate glass ceramic crowns were produced with a conventional impression and a laboratory fabrication method. The original zirconia die was removed from the zirconia master model to evaluate the crown margins. Circumferential marginal gap measurements were made at 8 measurement locations: mesial, 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  $\pm$ SD vertical gap measurement for the digitally made crowns was  $48 \pm 25 \mu\text{m}$ , which was significantly smaller than that for the conventionally made crowns ( $74 \pm 47 \mu\text{m}$ ).

**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 30 $\times$  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.

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

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

- BACKGROUND:** Little is known about the accuracy of physical dental casts that are based on three-dimensional (3D) data from an intraoral scanner (IOS). Thus, the authors conducted a study to evaluate the accuracy of full-arch stereolithographic (SLA) and milled casts obtained from scans of three IOSs.
- METHODS:** The authors digitized a polyurethane model using a laboratory reference scanner and three IOSs. They sent the scans (n = five scans per IOS) to the manufacturers to produce five physical dental casts and scanned the casts with the reference scanner. Using 3D evaluation software, the authors superimposed the data sets and compared them.
- RESULTS:** The mean trueness values of Lava Chairside Oral Scanner C.O.S. (3M ESPE, St. Paul, Minn.), CEREC AC with Bluecam (Sirona, Bensheim, Germany) and iTero (Align Technology, San Jose, Calif.) casts were 67.50 micrometers (95 percent confidence interval [CI], 63.43-71.56), 75.80  $\mu\text{m}$  (95 percent CI, 71.74-79.87) and 98.23  $\mu\text{m}$  (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  $\mu\text{m}$  (95 percent CI, 2.76-24.79), 21.62  $\mu\text{m}$  (95 percent CI, 10.60-32.63) and 48.83  $\mu\text{m}$  (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 ( $n = 5$ ,  $\alpha = 0.05$ ).

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

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

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

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

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

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

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

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

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

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

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

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

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

**MATERIAL AND METHODS:** A dentoforn 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  $\pm 0.00898$  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 ( $0.048 \text{ mm} \pm 0.009$  and  $0.040 \text{ mm} \pm 0.009$ ) 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 ( $0.088 \text{ mm} \pm 0.024$  and  $0.076 \text{ mm} \pm 0.023$ ), C: digital impression/IPS e.max Press ( $0.089 \text{ mm} \pm 0.020$  and  $0.075 \text{ mm} \pm 0.015$ ) and D: digital impression/IPS e.max CAD ( $0.084 \text{ mm} \pm 0.021$  and  $0.074 \text{ mm} \pm 0.026$ ). 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

*Pradies G, Zarauz C, Valverde A, Ferreira A, Martínez-Rus F  
J Dent 2015;43:201-208*

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

**METHODS:** Twenty-five participants with 30 posterior teeth with a prosthetic demand were selected for the study. Two crowns were made for each preparation. One crown was fabricated from an intraoral digital impression system (IDI group) and the other crown was fabricated from a conventional two-step silicone impression (CI group). To replicate the interface between the crown and the preparation, each crown was cemented on its corresponding clinical preparation with ultra-flow silicone. Each crown was embedded in acrylic resin to stabilise the registered interface and then cut in 2 mm thick slices in a buco-lingual orientation. The internal gap was determined as the vertical distance from the internal surface of the crown to the prepared tooth surface at four points (marginal gap, axial gap, crest gap, and occlusal fossa gap) using stereomicroscopy with a magnification of 40 $\times$ . 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 ffl 65.32  $\mu\text{m}$  for the crowns of the IDI group and 91.46 ffl 72.17  $\mu\text{m}$  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  $\mu\text{m}$ , 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

*Alhazzawi TF, Al-Samadani KH, Lemons J, Liu PR, Essig ME, Bartolucci AA, Janowski GM.*

*J Am Dent Assoc 2015 Feb;146:111-120. doi: 10.1016/j.adaj.2014.10.006.*

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

**METHODS:** A melamine tooth was prepared and scanned using a laboratory 3-shape scanner to mill a polyurethane die, which was duplicated into different stones (Jade, Lean, CEREC) and titanium. Each die was sprayed with imaging powders (NP, IPS, Optispray, Vita) to form 15 groups. Ten of each combination of stone/titanium and imaging powders were used to mill crowns. A light-bodied impression material was injected into the intaglio surface of each crown and placed on the corresponding die. Each crown was removed, and the monophasic material was injected to form a monophasic 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  $\mu\text{m}$ ). 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 siloxanether material of a typodont master model, and conventional casts were cast from dental stone. Digital impressions were obtained with a digital scanner, and digital stereolithographic models were printed. The typodont and fabricated casts were digitized with a structured light scanner and saved in surface tessellation language (STL) format. All STL records were superimposed via a best-fit method. The digital impression and cast fabrication method was compared with the conventional impression and cast fabrication method for discrepancy, accuracy, and reproducibility. The Levene test was used to determine equality of variances, and a 1-way ANOVA was conducted to assess the overall statistical significance of differences among the groups ( $n=5$ ,  $\alpha=.05$ ).

**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 ( $\alpha=0.05$ ).

**RESULTS:** One-way ANOVA revealed that the internal gap obtained from the Lava/press group (0.211 mm,  $\pm$ SD 0.041) was significantly greater than that obtained from the other groups ( $P<0.001$ ), while no significant differences were found among PVS/press (0.111 mm  $\pm$ SD 0.047), PVS/CAD/CAM (0.116 mm  $\pm$ SD 0.02), and Lava/CAD/CAM (0.145 mm  $\pm$ 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 ( $\alpha=0.05$ ).

**RESULTS:** The average ( $\pm$ SD) gap for the conventional impression group was 112.3 ( $\pm$ 35.3)  $\mu$ m. The digital impression groups had similar average gap sizes; the Lava group was 89.8 ( $\pm$ 25.4)  $\mu$ m, and the iTero group was 89.6 ( $\pm$ 30.1)  $\mu$ m. No statistically significant difference was found in the effects among impression techniques ( $P=0.185$ ).

**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

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

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

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

**MATERIAL AND METHODS:** Impressions of the canine, premolar, and molar abutment teeth were made and repeatedly scanned with each scanner type to obtain 5 sets of 3D data for each tooth. Point clouds were compared, and error sizes per tooth and scanner type were measured (n=10). One-way ANOVA with Tukey honest significant differences multiple comparison and independent t tests were performed to evaluate repeatability ( $\alpha=0.05$ ).

**RESULTS:** Repeatability (mean  $\pm$ SD) of the white- and blue-light scanners for canine, premolar, and molar teeth was statistically significant (means:  $P=0.001$ ,  $P<0.001$ ,  $P<0.001$ ;  $\pm$ SD:  $P<0.001$ ,  $P<0.001$ ,  $P=0.003$ ). Means of discrepancies with the white-light scanner ( $P<0.001$ ) 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 ( $P<0.001$ ). Corresponding SDs of discrepancies with the white-light scanner ( $P<0.001$ ) 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 ( $P=0.73$ ).

**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 Güngör M, Karakoca Nemli S, Kökdogan 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

Shembesh M, Ali A, Finkelman M, Weber HP, Zandparsa R  
*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-carious, unrestored human mandibular left first premolar and first molar teeth (teeth #19 and 21), prepared for a three-unit all-ceramic FDP. Impressions of the reference model were obtained using four impression systems (n = 10), group 1 (PVS impression scan), group 2 (stone cast scan), group 3 (Cadent iTero), and group 4 (Lava True 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  $81.4 \mu\text{m}$  (6.8), Cadent iTero scan  $62.4 \mu\text{m}$  (5.0), master cast scan  $50.2 \mu\text{m}$  (6.1), and Lava True definition scan  $26.6 \mu\text{m}$  (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  $120 \mu\text{m}$  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 ( $120 \mu\text{m}$ ). 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 Prosthet Dent* 2016;115:313-320

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

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

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

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

**CONCLUSIONS:** Conventional and digital impression methods differ significantly in the 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, Pradies G  
J Prosthodont 2016 Mar 2. PMID: 26934046*

**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  $\mu\text{m}$ , 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  $5.38 \pm 12.61 \mu\text{m}$  to  $-26.97 \pm 50.56 \mu\text{m}$  and from  $0.16^\circ \pm 0.04^\circ$  to  $-0.43^\circ \pm 0.1^\circ$ , 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.

## Precision of dental implant digitization using intraoral scanners

Flügge T, Att W, Metzger MC, Nelson K  
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**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

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

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

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

**RESULTS:** The mean total procedure times for digital and conventional impression technique were  $14:33 \pm 5:27$  and  $20:42 \pm 5:42$ , respectively ( $p < 0.0001$ ). Mean impression times were  $7:33 \pm 3:37$  and  $11:33 \pm 1:56$ , respectively ( $p < 0.0001$ ). Mean VAS scores for the dentist's assessment of difficulty (0 to 100; very difficult = 100) were  $24.00 \pm 18.02$  and  $48.02 \pm 21.21$ , respectively ( $p < 0.0001$ ). Mean VAS scores for the patients' assessment of discomfort (0 to 100; very discomforting = 100) was  $6.50 \pm 5.87$  and  $44.86 \pm 27.13$ , 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.

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

Kocaağaoğlu H, Kılınc HI, Albayrak H, Kara M  
*J Prosthet Dent* 2016;116:368-374

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

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

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

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

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

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

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

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

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

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

**RESULTS:** Mean marginal fit values of the digital group (64  $\pm$  116  $\mu$ m) were significantly smaller than those of the conventional group (76  $\pm$  118  $\mu$ m) ( $P < .05$ ). The mean internal fit values of the digital group (111  $\pm$  134  $\mu$ m) were significantly smaller than those of the conventional group (132  $\pm$  144  $\mu$ m) ( $P < .05$ ).

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

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

Kocaağaoğlu H, Kılınc HI, Albayrak H, Kara M  
*J Prosthet Dent* 2016;116:368-374

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

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

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

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

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



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

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

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

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

**MATERIAL AND METHODS:** A master die was fabricated to simulate a dental preparation. The die was measured with a coordinate measuring machine (CMM) to obtain an accurate digital CAD reference model (CRM). The master die was then scanned 10 times with 3 structured light scanners, 2 laser scanners, and 1 contact scanner. The resulting laboratory scan data (LSD) were converted to a stereolithography (STL) format. The discrepancies between measurements were compared 3-dimensionally and at 3 selected areas of a virtual sagittal cut using CAD software. The Kruskal-Wallis 1-way analysis of variance was first performed to compare scanners and then to group data according to scanner type. The Spearman rank correlation coefficient was used to test the association between resolution and all other variables ( $\alpha=0.05$ ).

**RESULTS:** For all 6 scanners, the mean resolution value was 133.9 (SD 93.9) points/mm<sup>2</sup>. The value for trueness was 38.8 (SD 6.2)  $\mu$ m and for precision 45.5 (SD 4.8)  $\mu$ m. Trueness values were 20.3  $\mu$ m (SD 32.7) at the axial surfaces, 46.6  $\mu$ m (SD 25.9) at the margin of the preparation, and 55.8  $\mu$ m (SD 29.3) at the center of the occlusal groove. The ZENO Scan was the most accurate and precise of the 6 scanners for most of the variables measured.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Freire Y, Gonzalo E, Lopez-Suarez C, Suarez MJ  
*J Prosthodont* 2017 Feb 2. doi: 10.1111/jopr.12590. [Epub ahead of print]

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

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

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

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

## Effect of split-file digital workflow on crown margin adaptation

Sheridan RR, Verrett R, Haney S, Schoolfield J  
*J Prosthodont* 2017 Jun 9. doi: 10.1111/jopr.12606. [Epub ahead of print]

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

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

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

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

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

Gold SA, Ferracane JL, da Costa J

*J Prosthodont* 2017 May 17. doi: 10.1111/jopr.12638. [Epub ahead of print]

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

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

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

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

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



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

Mostafa NZ, Ruse ND, Ford NL, Carvalho RM, Wyatt CCL  
*J Prosthodont* 2017 Aug 21. doi: 10.1111/jopr.12656. [Epub ahead of print]

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

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

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

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

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

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

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

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

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

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

## Marginal gap of milled versus cast gold restorations

*Johnson R, Verrett R, Haney S, Mansueto M, Challa S  
J Prosthodont 2017;26:56-63*

**PURPOSE:** This in vitro study evaluated and compared the vertical marginal gap of cast and milled full coverage gold copings using two margin designs (chamfer and chamfer bevel) before and after fitting adjustments.

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

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

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

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

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

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

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

**MATERIAL AND METHODS:** Thirty extracted human maxillary premolar teeth without caries or defects were used. The teeth were prepared for zirconia crowns and randomly divided into 3 groups. Zirconia copings were designed at a thickness of 0.5 mm with 30° of simulated die spacer starting 1 mm from the margin of preparations. They were produced using computer-aided design-computer-aided manufacture (CAD-CAM) protocol with a conventional impression (group Cn) and 2 different production protocols with digital impressions (group C) and group Tr. The marginal, axial, and occlusal discrepancies of these copings were measured using the silicone replica technique with stereomicroscopy at x50 magnification, and the data were analyzed with 1-way ANOVAs ( $\alpha=0.05$ ).

**RESULTS:** The mean marginal discrepancy values were 85.6  $\mu\text{m}$  for group Cn, 58.7  $\mu\text{m}$  for group C, and 47.7  $\mu\text{m}$  for the Tr group. Significant differences were found among the production protocols in marginal, axial, and occlusal discrepancies ( $P<0.05$ ). Copings fabricated with the aid of digital impressions had significantly fewer marginal discrepancies than those of group Cn ( $P<0.05$ ). Group Tr exhibited the lowest marginal discrepancy, whereas groups Cn and C demonstrated similar axial adaptations ( $P>0.05$ ), and group Tr revealed the lowest axial discrepancy ( $P<0.05$ ). With regard to the occlusal discrepancy evaluation, group Tr had the lowest discrepancy. However, no significant differences were found between groups C and Cn ( $P>0.05$ ).

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

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

Li H, Lyu P, Wang Y, Sun Y  
*J Prosthet Dent* 2017;117:93-101

**STATEMENT OF PROBLEM:** Limited information is available regarding the influence of object translucency on the scanning accuracy of a powder-free intraoral scanner.

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

**MATERIAL AND METHODS:** Six slice specimens (12·10 mm) and 6 offset copings (1.00-mm thickness) were made from different translucent homogeneous ceramic blocks (CEREC Blocs, SO-M to S5-M, highest to lowest translucency). The primary sintered zirconia offset coping was produced in the same way as the control. Optical parameters related to the translucency of each slice were measured with a spectrophotometer. Three-dimensional (3D) datasets of the surface morphology of offset copings were obtained by using the intraoral scanner. The same white wax resin bases were used for registration. Quantitative parameters of scanning trueness and precision were measured. One-way ANOVA was used to analyze the values of each parameter among the 6 ceramic blocks. Bivariate correlation was used to analyze the relationships between each parameter of scanning accuracy and translucency ( $\alpha=0.05$ ).

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

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

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

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

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

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

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

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

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

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

Lee JJ, Jeong ID, Park JY, Jeon JH, Kim JH, Kim WC  
*J Prosthet Dent* 2017;117:253-259

**STATEMENT OF PROBLEM:** Scanners are frequently used in the fabrication of dental prostheses. However, the accuracy of these scanners is variable, and little information is available.

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

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

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

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

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

Zeltner M, Sailer I, Mühlemann S, Özcan M, Hämmerle CH, Benic GI  
*J Prosthet Dent* 2017;117:354-362

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

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

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

**RESULTS:** Discrepancymarginal was  $83.6 \pm 51.1 \mu\text{m}$  for the Cerec infinident,  $90.4 \pm 66.1 \mu\text{m}$  for the conventional,  $94.3 \pm 58.3 \mu\text{m}$  for the Lava,  $127.8 \pm 58.3 \mu\text{m}$  for the iTero, and  $141.5 \pm 106.2 \mu\text{m}$  for the Cerec inLab workflow. The differences between the treatment modalities were not statistically significant ( $P>.05$ ). Discrepancysoulder was  $82.2 \pm 42.4 \mu\text{m}$  for the Cerec infinident,  $97.2 \pm 63.8 \mu\text{m}$  for the conventional,  $103.4 \pm 52.0 \mu\text{m}$  for the Lava,  $133.5 \pm 73.0 \mu\text{m}$  for the iTero, and  $140.0 \pm 86.6 \mu\text{m}$  for the Cerec inLab workflow. Only the differences between the Cerec infinident and the Cerec inLab were statistically significant ( $P=.036$ ). The conventionally fabricated crowns revealed significantly lower values in Discrepancycusp and Discrepancyocclusal than all the crowns fabricated with digital workflows ( $P<.05$ ).

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



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

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

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

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

**MATERIAL AND METHODS:** Three-unit implant-supported FDP frameworks were made using the CAD-CAM (n=10) and overcasting (n=10) methods. The frameworks were waxed to simulate a mandibular first premolar (PM region) to first molar (M region) FDP using overcast mini-abutment cylinders. The wax patterns were overcast (overcast experimental group) or scanned to obtain the frameworks (CAD-CAM control group). All frameworks were fabricated from cobalt-chromium (CoCr) alloy. The marginal fit was analyzed according to the single-screw test protocol, obtaining an average value for each region (M and PM) and each framework. The frameworks were tightened for the photoelastic model with standardized 10-Ncm torque. Stress was measured by quantitative photoelastic analysis. The results were submitted to the Student t test, 2-way ANOVA, and Pearson correlation test ( $\alpha=0.05$ ).

**RESULTS:** The framework fabrication method (FM) and evaluation site (ES; M and PM regions) did not affect the marginal fit values ( $P=0.559$  for FM and  $P=0.065$  for ES) and stress ( $P=0.685$  for FM and  $P=0.468$  for ES) in the implant-supported system. Positive correlations between marginal fit and stress were observed (CAD-CAM:  $r=0.922$ ;  $P<0.001$ ; overcast:  $r=0.908$ ;  $P<0.001$ ).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**RESULTS:** The type of CAD-CAM used affected the marginal fit of the monolithic restoration. The mean (fflSD) highest marginal discrepancy was recorded in group TZI at  $39.3 \pm 2.3 \mu\text{m}$ , while the least mean marginal discrepancy was recorded in group IZ ( $22.8 \pm 8.9 \mu\text{m}$ ). The Bonferroni post hoc test showed that group TZI was significantly different from all other groups tested ( $P<.05$ ).

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

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

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

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

**MATERIAL AND METHODS:** Ten silicone impressions were made for a prepared canine tooth. Each die received 2 lithium disilicate (IPS e.max) copings, 1 from milled wax blocks and 1 from additive wax. The replica technique was used to measure the fit by scanning electron microscopy at  $\times 80$  magnification. Collected data were analyzed using the paired Student t test for the marginal and internal fit. For the occlusal fit, the difference in scores did not follow a normal distribution, and the Wilcoxon signed rank test was used ( $\alpha=0.05$ ).

**RESULTS:** The mean marginal, axial, and occlusal fit showed no significant differences when the 2 CAD-CAM manufacturing processes were compared ( $P>0.05$ ). For the marginal fit, the mean ( $\pm$ SD) values were  $105.1 \mu\text{m} \pm 39.6$  with the milled process and  $126.2 \mu\text{m} \pm 25.2$  for the additive process. The mean values were  $98.1 \mu\text{m} \pm 26.1$  for the axial fit in the milled process and  $106.8 \mu\text{m} \pm 21.2$  in the additive process. For the occlusal fit, median values (interquartile interval) were  $199.0 \mu\text{m}$  (141.5 to 269.9) for subtractive manufacturing and  $257.2 \mu\text{m}$  (171.6 to 266.0) for micro-SLA manufacturing.

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

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

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

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

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

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

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

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

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

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

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

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

**MATERIAL AND METHODS:** A master abutment of a premolar mandibular tooth preparation with 4-mm height and a 0.6-mm deep 120-degree chamfer finish line with a 12-degree angle of convergence was replicated in die stone and scanned. Thirty-six cobalt-chromium alloy copings were produced using 3 different production techniques. Twelve copings were produced by laser-sintering, 12 by milling, and 12 by milled wax/lost wax. The surface microstructure of 2 copings in each group was analyzed using interferometry. The remaining 10 copings in each group were used to evaluate marginal and internal fit by using an impression material replica method, and retention was evaluated by using a uniaxial tensile force pull-off test. The copings from each test group were cemented with zinc phosphate cement onto resin abutments. Statistical analyses of differences in marginal and internal fit were performed using 1-way ANOVA and the Mann-Whitney U test. Differences in surface topography were analyzed with the Kruskal-Wallis and Mann-Whitney U tests for nonparametric data. Differences in retentive values were analyzed using the Mann-Whitney U test for nonparametric data (all  $\alpha=0.05$ ).

**RESULTS:** Differences in surface microstructure were seen. The laser-sintered copings showed increased surface roughness compared with milled and milled wax/lost wax copings. Differences in marginal and internal fit were noted. Laser-sintered showed significantly smaller spaces between coping and abutment than milled wax/lost wax copings ( $P=0.003$ ). At the margins, laser-sintered copings showed significantly smaller spaces than either the milled wax/lost wax group ( $P=0.002$ ) or the milled group ( $P=0.002$ ). At the chamfer, laser-sintered copings showed significantly smaller spaces than milled wax/lost wax copings ( $P=0.005$ ). At the center of the axial walls, laser-sintered copings showed significantly smaller spaces than those in the milled wax/lost wax ( $P=0.004$ ) and milled copings ( $P=0.005$ ). No significant differences were noted between milled and milled wax/lost wax copings ( $P>0.05$ ). No significant differences were detected regarding retentive forces in the pull-off tests ( $P>0.05$ ).

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



# A comparative study of additive and subtractive manufacturing for dental restorations

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

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

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

**MATERIAL AND METHODS:** The inlay (distal occlusal cavity) shape was fabricated using 3-dimensional image (reference data) software. Specimens were fabricated using 4 different methods (each n=10, total N=40), including 2 additive manufacturing methods, stereolithography apparatus and selective laser sintering; and 2 subtractive methods, wax and zirconia milling. Fabricated specimens were scanned using a dental scanner and then compared by overlapping reference data. The results were statistically analyzed using a 1-way analysis of variance ( $\alpha=0.05$ ). Additionally, the surface morphology of 1 randomly (the first of each specimen) selected specimen from each group was evaluated using a digital microscope.

**RESULTS:** The results of the overlap analysis of the dental restorations indicated that the root mean square (RMS) deviation observed in the restorations fabricated using the additive manufacturing methods were significantly different from those fabricated using the subtractive methods ( $P<0.05$ ). However, no significant differences were found between restorations fabricated using stereolithography apparatus and selective laser sintering, the additive manufacturing methods ( $P=0.466$ ). Similarly, no significant differences were found between wax and zirconia, the subtractive methods ( $P=0.986$ ). The observed RMS values were  $106 \mu\text{m}$  for stereolithography apparatus,  $113 \mu\text{m}$  for selective laser sintering,  $116 \mu\text{m}$  for wax, and  $119 \mu\text{m}$  for zirconia. Microscopic evaluation of the surface revealed a fine linear gap between the layers of restorations fabricated using stereolithography apparatus and a grooved hole with inconsistent weak scratches when fabricated using selective laser sintering. In the wax and zirconia restorations, possible traces of milling bur passes were observed.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**RESULTS:** Statistically significant differences were found between the 2 impression systems for both mean trueness ( $P=.010$ ) and mean precision ( $P=.007$ ). Conventional impressions had higher accuracy with a mean trueness of  $17.0 \pm 6.6 \mu\text{m}$  and mean precision of  $16.9 \pm 5.8 \mu\text{m}$  than optical impressions with a mean trueness of  $46.2 \pm 11.4 \mu\text{m}$  and mean precision of  $61.1 \pm 4.9 \mu\text{m}$ .

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

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

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

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

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

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

**CONCLUSIONS:** CAD/CAM techniques improve marginal fit.

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

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

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

**METHODS:** 70 consecutive patients with a total of 86 glass-ceramic/zirconia crowns were treated by a single clinician using standardized clinical and laboratory protocols. A complete digital workflow was adopted for the purpose except for the veneering procedure for the glass-ceramic crowns. Occlusal adjustments were made before the ceramic glazing procedure. Before cementation, all abutments 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

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

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

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

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

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

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

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

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

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

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

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

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

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



## 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.

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

*Peñarrocha-Oltra D, Agustín-Panadero R, Pradies G, Gomar-Vercher S,  
Peñarrocha-Diago M  
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  $\mu\text{m}$  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.

# 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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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



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

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

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

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

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

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

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

## Digital workflow for a dental prosthesis that considers lateral mandibular relation

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

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

## 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  $p \leq 0.05$ .

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

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

## 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  $\Delta R$  and  $\Delta X$  measure reflected light, whereas QLF variables  $\Delta F$  and  $\Delta Q$  measure fluorescence.

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

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

**CLINICAL 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  $\Delta F$  and  $\Delta Q$  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  $\Delta F$  ( $p = 0.002$ ) (mean 22.60 - F/P and 28.80 - Rest.) and  $\Delta Q$  ( $p = 0.012$ ) (mean 230.49 - F/P and 348.30 - Rest.).

**CONCLUSIONS:**  $\Delta F$  and  $\Delta Q$  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.

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

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

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

**METHODS:** Fifty participants (25 males and 25 females, mean age =  $25 \pm 4$  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  $\mu\text{m}$ , mean = 130 ffl 20  $\mu\text{m}$ ) were significantly more than those measured from Cercon Digital Machine images (range = 52-80  $\mu\text{m}$ , mean = 68 ffl 23  $\mu\text{m}$ ) 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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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



## 3D Computer aided treatment planning in endodontics

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

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

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

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

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

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

## 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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## 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.

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

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

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

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

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

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

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

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

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

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

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

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

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



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

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

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

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

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

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

## Performance of five commercially available tooth color-measuring devices

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

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

**MATERIALS AND METHODS:** In an in vitro study, standards (A1, A2, A3, A3.5, and A4 shade tabs of Vita Lumin) were measured five times with five electronic devices (ShadeScan, Easyshade, Ikam, IdentaColor II, and ShadeEye) by two operators. In an in vivo study, the right upper central incisors of 25 dental students were measured with the same electronic devices by a single operator. Vita shade tab codes were expressed as CIE (International Commission on Illumination) L\*a\*b\* values and in terms of the precision and accuracy of ΔE color differences. The Mann-Whitney statistical test was used to analyze the differences between the two operators in the in vitro study, and the Kruskal-Wallis one-way analysis of variance on ranks with the post-hoc Tukey test was used to analyze the accuracy and precision of electronic devices.

**RESULTS:** No statistically significant difference was found between the different operators in the in vitro study. The obtained precision was Easyshade > ShadeScan □ Ikam > IdentaColor II > ShadeEye. The obtained accuracy was Easyshade > ShadeScan □ Ikam > ShadeEye > IdentaColor II. In the in vivo study, the Easyshade and the Ikam were the most precise, and the ShadeEye and the IdentaColor II were more precise than the ShadeScan. With respect to accuracy, there was no statistical difference between the ShadeScan, Ikam, and the Easyshade. The IdentaColor II was considered inaccurate ( $\Delta E_a = 3.4$ ).

**CONCLUSIONS:** In the clinical setting, the Easyshade and Ikam systems were the most reliable. The other devices tested were more reliable in vitro than in vivo.

# Shade matching assisted by digital photography and computer software

Schropp L  
*J Prosthodont* 2009;18:235-241

**PURPOSE:** To evaluate the efficacy of digital photographs and graphic computer software for color matching compared to conventional visual matching.

**MATERIAL AND METHODS:** The shade of a tab from a shade guide (Vita 3D-Master Guide) placed in a phantom head was matched to a second guide of the same type by nine observers. This was done for twelve selected shade tabs (tests). The shade-matching procedure was performed visually in a simulated clinic environment and with digital photographs, and the time spent for both procedures was recorded. An alternative arrangement of the shade tabs was used in the digital photographs. In addition, a graphic software program was used for color analysis. Hue, chroma, and lightness values of the test tab and all tabs of the second guide were derived from the digital photographs. According to the CIE L\*C\*h\* color system, the color differences between the test tab and tabs of the second guide were calculated. The shade guide tab that deviated least from the test tab was determined to be the match. Shade matching performance by means of graphic software was compared with the two visual methods and tested by Chi-square tests ( $\alpha = 0.05$ ).

**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.

## Reliability and accuracy of four dental shade-matching devices

Kim-Pusateri S, Brewer JD, Davis EL, Wee AG  
*J Prosthet Dent* 2009;101:193-199

**STATEMENT OF PROBLEM:** There are several electronic shade-matching instruments available for clinical use, but the reliability and accuracy of these instruments have not been thoroughly investigated.

**PURPOSE:** The purpose of this in vitro study was to evaluate the reliability and accuracy of 4 dental shade-matching instruments in a standardized environment.

**MATERIAL AND METHODS:** Four shade-matching devices were tested: SpectroShade, ShadeVision, VITA Easyshade, and ShadeScan. Color measurements were made of 3 commercial shade guides (Vitapan Classical, Vitapan 3D-Master, and Chromascop). Shade tabs were placed in the middle of a gingival matrix (Shofu GUMY) with shade tabs of the same nominal shade from additional shade guides placed on both sides. Measurements were made of the central region of the shade tab positioned inside a black box. For the reliability assessment, each shade tab from each of the 3 shade guide types was measured 10 times. For the accuracy assessment, each shade tab from 10 guides of each of the 3 types evaluated was measured once. Differences in reliability and accuracy were evaluated using the Standard Normal z test (2 sided) ( $\alpha=.05$ ) with Bonferroni correction.

**RESULTS:** Reliability of devices was as follows: ShadeVision, 99.0%; SpectroShade, 96.9%; VITA Easyshade, 96.4%; and ShadeScan, 87.4%. A significant difference in reliability was found between ShadeVision and ShadeScan ( $P=.008$ ). All other comparisons showed similar reliability. Accuracy of devices was as follows: VITA Easyshade, 92.6%; ShadeVision, 84.8%; SpectroShade, 80.2%; and ShadeScan, 66.8%. Significant differences in accuracy were found between all device pairs ( $P<.001$ ) for all comparisons except for SpectroShade versus ShadeVision ( $P=.033$ ).

**CONCLUSIONS:** Most devices had similar high reliability (over 96%), indicating predictable shade values from repeated measurements. However, there was more variability in accuracy among devices (67-93%), and differences in accuracy were seen with most device comparisons.

## Dental color matching instruments and systems. Review of clinical and research aspects

*Chu SJ, Trushkowsky RD, Paravina RD  
J Dent 2010;38:e2-e16*

**ABSTRACT:** To review current status of hand held systems for tooth color matching in vivo and corresponding research. “Medline” database from 1981 to 2010 were searched electronically with key words tooth, teeth, color and dentistry. Spectrophotometers, colorimeters and imaging systems are useful and relevant tools for tooth color measurement and analysis, and for quality control of color reproduction. Different measurement devices either measure the complete tooth surface providing a “color map” or an “average” color of the limited area [3-5mm] on the tooth surface. These instruments are useful tools in color analysis for direct or indirect restorations, communication for indirect restorations, reproduction and verification of shade. Whenever possible, both instrumental and visual color matching method should be used, as they complement each other and can lead towards predictable esthetic outcome.

**KEYWORDS:** Tooth; Teeth; Color; Color measurement; Colorimeters; Spectrophotometers; Digital camera

## Four color-measuring devices compared with a spectrophotometric reference system

*Lehmann KM, Igiel C, Schmidtman I, Scheller H  
J Dent 2010;38:e65-e70*

**ABSTRACT:** The objective of this study was to compare the L\*C\*h° color coordinates of dental color-measuring devices with those of a spectrophotometric reference system. The International Commission on Illumination (CIE) L\*C\*h° color coordinates of ceramic samples, matching the colors of the VITA Linearguide, were recorded using four color-measuring devices (VITA Easyshade (A), VITA Easyshade compact (B), Degudent Shadepilot (C), X-Rite Shadevision (D)) and a spectrophotometric reference system under standardized test conditions. The intraclass correlation coefficients, regression lines with coefficients of determination, and mean deviations of the dental color-measuring devices from the spectrophotometric reference system were calculated. All of the devices had high intraclass correlation coefficients, between 0.979 and 1.000. Nearly all measurements, except the hue values of devices A, B, and D, showed coefficients of determination close to 1.0 over the range of measurements for L\*C\*h° color coordinates. Similarly, all of the devices had coefficients of determination near the optimum value of 1.0. Devices C and D produced regression line slopes near the optimum value of 1.0 and intercepts close to the optimum value of zero. Only the L\* coordinate measurements of devices A and B and the h° coordinate measurements of device B differed not significantly from the spectrophotometric reference values. The electronic dental color-measuring devices tested showed excellent repeatability, but some devices showed substantial deviations in color coordinate values from the spectrophotometric reference system. Devices C and D showed higher precision than devices A and B.

**KEYWORDS:** Color; Shade-measuring devices; Repeatability; Color parameters; CIE

# Effect of abutment tooth color, cement color, and ceramic thickness on the resulting optical color of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown

Chaiyabutr Y, Kois JC, Lebeau D, Nunokawa G  
*J Prosthet Dent* 2011;105:83-90

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

The purpose of this study was to evaluate the cumulative effect that the tooth abutment color, cement color, and ceramic thickness have on the resulting optical color of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown.

**MATERIAL AND METHODS:** A CAD/CAM glass-ceramic lithium disilicate-reinforced monolithic crown (IPS e.max CAD LT) was fabricated. Three possible crown restoration variables were tested in vitro. The procedure examined 4 prepared abutment tooth colors (light, medium light, medium dark, and dark), 2 cement (Variolink II) colors (translucent and opaque), and 4 ceramic thickness values (1.0 mm, 1.5 mm, 2.0 mm, and 2.5 mm). The color of each combination was measured using a spectrophotometer, and the average values of the color difference ( $\Delta E$ ) were calculated. The data were analyzed with a 3-way ANOVA (tooth abutment color, ceramic thickness, and luting agent) and Tukey's HSD test ( $\alpha=0.05$ ), which evaluated within-group effects of the tooth abutment color to the  $\Delta E$  at each ceramic thickness.

**RESULTS:** The  $\Delta E$  values of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown were significantly influenced by the tooth abutment color ( $P<0.001$ ), cement color ( $P<0.001$ ), and ceramic thickness ( $P<0.001$ ). Significant interactions were present among these 3 variables ( $P<0.001$ ). A dark-colored abutment tooth demonstrated the greatest  $\Delta E$  values relative to other variables tested. An increase in ceramic thickness resulted in a significant decrease in  $\Delta E$  values ( $P<0.01$ ). The  $\Delta E$  values were slightly decreased when the crowns were cemented using the opaque cement.

**CONCLUSIONS:** This study demonstrated that underlying tooth abutment color, cement color, and ceramic thickness all influence the resulting optical color of CAD/CAM glass-ceramic lithium disilicate-reinforced restorations.

## European dental students' opinions about visual and digital tooth colour determination systems

*Dozic A, Kharbanda AK, Kamell H, Brand HS  
J Dent 2011;39:e23-e28*

**OBJECTIVES:** The aim of the study was to investigate students' opinion about visual and digital tooth colour determination education at different European dental schools.

**METHODS:** A cross-sectional web-based survey was created, containing nine dichotomous, multiple choice and 5-point Likert scale questions. The questionnaire was distributed amongst students of 40 European dental schools. Seven hundred and ninety-nine completed questionnaires from students of 15 dental schools were analysed statistically.

**RESULTS:** Vitapan Classical and Vitapan 3D-Master are the most frequently used visual determination systems at European dental schools. Most students responded with "neutral" regarding whether they find it easy to identify the colour of teeth with a visual determination system (range 2.8-3.6). A minority of the dental students had received education in digital imaging systems (2-47%). The Easysshade was the most frequently mentioned digital system. The majority of the students who did not receive education on digital systems would like to see this topic added to the curriculum (77-100%). The dental students who had worked with both methods found it significantly easier to determine tooth colour with a digital system than with a visual system (mean score 3.5 ffl 0.8 vs. 3.0 ffl 0.8).

**CONCLUSIONS:** Tooth colour determination programmes show a considerable variation across European dental schools. Based upon the outcomes of this study, students prefer digital imaging systems over visual systems, and like to have (more) education about digital tooth colour imaging.



## Dental shade matching using a digital camera

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

**OBJECTIVES:** Digital cameras could be substitutes for contact-type instruments in shade selection and overcome their drawbacks. The images taken show morphology and color texture of teeth. A new method was proposed to compare the color of shade tabs taken by a digital camera using appropriate color features.

**METHODS:** Vita 3D-MASTER shade guide and Canon EOS 1100D digital camera were employed. Shade tab images were compared in two reference strategies. The color of tooth surface was presented by a content manually cropped out of the image. The content was divided into  $10 \cdot 2$  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 Commission Internationale de l'Éclairage (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,  $\Delta E$ ,  $\Delta L$  and  $\Delta b$  from the alcohol-containing mouthrinse showed statistically significant differences when compared to the other groups. The  $\Delta E$  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 R<sup>2</sup> 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.

# Evaluation of a novel computer color matching system based on the improved back-propagation neural network model

Wei J, Peng M, Li Q, Wang Y

*J Prosthodont* 2016 Nov 9. doi: 10.1111/jopr.12561. [Epub ahead of print]

**PURPOSE:** To explore the feasibility of a novel computer color-matching (CCM) system based on the improved back-propagation neural network (BPNN) model by comparing it with the traditional visual method.

**MATERIAL AND METHODS:** Forty-three metal-ceramic specimens were fabricated by proportionally mixing porcelain powders. Thirty-nine specimens were randomly selected to train the BPNN model, while the remaining four specimens were used to test and calibrate the model. A CCM system based on the improved BPNN model was constructed using MATLAB software. A comparison of the novel CCM system and the traditional visual method was conducted by evaluating the color reproduction results of 10 maxillary central incisors. Metal-ceramic specimens were fabricated using two color reproduction approaches. Color distributions ( $L^*$ ,  $a^*$ , and  $b^*$ ) of the target teeth and of the corresponding metal-ceramic specimens were measured using a spectroradiometer. Color differences ( $\Delta E$ ) and color distributions ( $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$ ) between the teeth and their corresponding specimens were calculated.

**RESULTS:** The average  $\Delta E$  value of the CCM system was  $1.89 \pm 0.75$ , which was lower than that of the visual approach ( $3.54 \pm 1.11$ ,  $p < 0.01$ ). With respect to color distributions, substantial differences were found between the two color-matching systems, except for  $\Delta L^*$  ( $p > 0.05$ ).

**CONCLUSION:** The novel CCM system produced greater accuracy in color reproduction within the given color space than the traditional visual approach.

## CAD/CAM fabricated complete dentures: concepts and clinical methods of obtaining required morphological data

*Goodacre CJ, Garbacea A, Naylor WP, Daher T, Marchack CB, Lowry J  
J Prosthet Dent 2012;107:34-46*

The clinical impression procedures described in this article provide a method of recording the morphology of the intaglio and cameo surfaces of complete denture bases and also identify muscular and phonetic locations for the prosthetic teeth. When the CAD/CAM technology for fabricating complete dentures becomes commercially available, it will be possible to scan the denture base morphology and tooth positions recorded with this technique and import those data into a virtual tooth arrangement program where teeth can be articulated and then export the data to a milling device for the fabrication of the complete dentures. A prototype 3-D tooth arrangement program is described in this article that serves as an example of the type of program than can be used to arrange prosthetic teeth virtually as part of the overall CAD/CAM fabrication of complete dentures.

## 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.

## 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.

## Comparison of treatment outcomes in digital and conventional complete removable dental prosthesis fabrications in a predoctoral setting

*Kattadiyil MT, Jekki R, Goodacre CJ, Baba NZ  
J Prosthet Dent 2015;114:818-825*

**STATEMENT OF PROBLEM:** Scientific evidence is lacking regarding the clinical effectiveness of digital complete removable dental prostheses (CRDP).

**PURPOSE:** This prospective clinical study was conducted to compare clinical treatment outcomes, patient satisfaction, and dental student preferences for digitally and conventionally processed CRDP in a predoctoral setting.

**MATERIAL AND METHODS:** This clinical study rated and compared CRDP fabricated by predoctoral students, using a 2-appointment digital prosthesis fabrication process as opposed to the conventional 5-appointment process. Fifteen completely edentulous patients were treated in the predoctoral clinic at Loma Linda University School of Dentistry. Fifteen predoctoral (third- and fourth-year) dental students fabricated 2 sets of maxillary and mandibular CRDP for each patient. Each patient received 1 conventional set and 1 digital (AvaDent) set of CRDP. Faculty and patient ratings, patient and student preferences, and perceptions of the conventional versus digital prostheses were recorded and analyzed. The average treatment time for the fabrication of each type of prostheses was analyzed.

**RESULTS:** Significantly higher average scores were observed for digital dentures than for conventional dentures according to criteria evaluated by faculty ( $P=.007$ ). Patients reported significantly higher overall average satisfaction scores with digital dentures ( $P=.001$ ). Patients preferred the digital dentures ( $P<.01$ ). Significantly higher scores were observed for the retention of the digital maxillary complete denture ( $P=.001$ ) compared with that for the digital mandibular and conventional complete dentures. Students preferred digital prostheses compared with conventional prostheses ( $P<.05$ ). The conventional process required significantly more clinical time for each patient than with the digital process of fabrication ( $P<.01$ ).

**CONCLUSIONS:** The digital process proved to be an equally effective and more time-efficient option than the conventional process of prosthesis fabrication in the predoctoral program. The digital denture process was preferred and effectively used by predoctoral dental students under faculty supervision.

## A comparison of two digital techniques for the fabrication of complete removable dental prostheses: A pilot clinical study

Schwindling FS, Stober T  
*J Prosthet Dent* 2016;116:756-763

**STATEMENT OF PROBLEM:** The introduction of digital techniques might improve the quality and cost-effectiveness of treatment with complete removable dental prostheses (CDs).

**PURPOSE:** The purpose of this pilot clinical trial was to study and compare the clinical feasibility, complications during fabrication, and quality of 2 types of digitally designed CDs.

**MATERIAL AND METHODS:** Five participants were recruited into this preliminary clinical trial. For each participant, 2 pairs of digital CDs were designed. Prosthesis bases were fabricated by using identical data, either by milling from polymethyl methacrylate blanks or by injection molding. The treatment involved 4 clinical appointments. Polyvinyl siloxane impressions were made with custom trays and were subsequently digitalized. After evaluating esthetics and function with trial dentures, the CD bases were fabricated. To evaluate the workflow and quality of the prostheses, the clinical outcome was measured on 6-point scales ranging from poor (grade 6) to excellent (grade 1). For both prosthesis types, the following aspects were examined: fit, retention, esthetics, phonetics, maxillomandibular relation, and occlusion.

**RESULTS:** Both types of digital CDs could be fabricated without major complications. Only a few minor complications occurred during the fabrication process, predominantly esthetic issues. No pronounced difference was found between the prostheses concerning functional aspects. The definitive esthetic outcome was rated as very good.

**CONCLUSIONS:** The CDs fabricated using digital technology met the clinical requirements. However, more research is needed to confirm the results of this investigation.

## Design of complete dentures by adopting CAD developed for fixed prostheses

Li Y, Han W, Cao J, Lv Y, Zhang Y, Han Y, Shen Y, Ma Z, Liu H  
*J Prosthodont* 2016 Nov 21. doi: 10.1111/jopr.12554. [Epub ahead of print]

The demand for complete dentures is expected to increase worldwide, but complete dentures are mainly designed and fabricated manually involving a broad series of clinical and laboratory procedures. Therefore, the quality of complete dentures largely depends on the skills of the dentist and technician, leading to difficulty in quality control. Computer-aided design and manufacturing (CAD/CAM) has been used to design and fabricate various dental restorations including dental inlays, veneers, crowns, partial crowns, and fixed partial dentures (FPDs). It has been envisioned that the application of CAD/CAM technology could reduce intensive clinical/laboratory work for the fabrication of complete dentures; however, CAD/CAM is seldom used to fabricate complete dentures due to the lack of suitable CAD software to design virtual complete dentures although the CAM techniques are in a much advanced stage. Here we report the successful design of virtual complete dentures using CAD software of 3Shape Dental System 2012, which was developed for designing fixed prostheses instead of complete dentures. Our results demonstrated that complete dentures could be successfully designed by the combination of two modeling processes, single coping and full anatomical FPD, available in the 3Shape Dental System 2012.

# Preliminary clinical application of removable partial denture frameworks fabricated using computer-aided design and rapid prototyping techniques

Ye H, Ning J, Li M, Niu L, Yang J, Sun Y, Zhou Y  
*Int J Prosthodont* 2017;30:348-353

**PURPOSE:** The aim of this study was to explore the application of computer-aided design and rapid prototyping (CAD/RP) for removable partial denture (RPD) frameworks and evaluate the fitness of the technique for clinical application.

**MATERIALS AND METHODS:** Three-dimensional (3D) images of dentition defects were obtained using a lab scanner. The RPD frameworks were designed using commercial dental software and manufactured using selective laser melting (SLM). A total of 15 cases of RPD prostheses were selected, wherein each patient received two types of RPD frameworks, prepared by CAD/RP and investment casting. Primary evaluation of the CAD/RP framework was performed by visual inspection. The gap between the occlusal rest and the relevant rest seat was then replaced using silicone, and the specimens were observed and measured. Paired t test was used to compare the average thickness and distributed thickness between the CAD/RP and investment casting frameworks. Analysis of variance test was used to compare the difference in thickness among different zones.

**RESULTS:** The RPD framework was designed and directly manufactured using the SLM technique. CAD/RP frameworks may meet the clinical requirements with satisfactory retention and stability and no undesired rotation. Although the average gap between the occlusal rest and the corresponding rest seat of the CAD/RP frameworks was slightly larger than that of the investment casting frameworks ( $P < .05$ ), it was acceptable for clinical application.

**CONCLUSION:** RPD frameworks can be designed and fabricated directly using digital techniques with acceptable results in clinical application.

## Use of intraoral scanning and 3-dimensional printing in the fabrication of a removable partial denture for a patient with limited mouth opening

Wu J, Li Y, Zhang Y  
*J Am Dent Assoc* 2017;148:338-341

**BACKGROUND AND OVERVIEW:** When treating patients with severely limited mouth openings, it is difficult for the dentist to obtain an impression and fabricate a removable partial denture (RPD) by using traditional methods. Intraoral scanning, computer-aided design, and 3-dimensional (3D) printing have provided alternative methods for fabricating dental prostheses.

**CASE DESCRIPTION:** The authors present a case in which they aimed to improve the efficiency and quality of fabricating an RPD framework by integrating the technologies of intraoral scanning, computer-aided design, and 3D printing. Initially, the authors reconstructed the digital cast with multiple intraoral scans. Subsequently, the authors designed the virtual RPD framework. On the basis of the virtual framework, the titanium alloy framework was fabricated by means of a 3D printing process, and the authors fitted the final RPD to the patient.

**CONCLUSIONS AND PRACTICAL IMPLICATIONS:** Unlike the traditional method, this integrated system has the potential to design a custom-made dental prosthesis and directly make an RPD framework with complicated patterns.

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**KEYWORDS:** 3-dimensional printing; Intraoral scanning; computer-aided design; limited mouth opening; removable partial denture

## CAD/CAM-fabricated nonmetal clasp denture: In vitro pilot study

*Takahashi Y, Hamanaka I, Isshi K  
Int J Prosthodont 2017;30:277-279*

**PURPOSE:** The purpose of this study was to fabricate a prototype nonmetal clasp denture using computer-aided design/computer-assisted manufacture (CAD/CAM) technology.

**MATERIALS AND METHODS:** A partially edentulous mandibular working cast was scanned using an optical scanner. A sectional denture separated by two parts was designed on the scanned cast. These parts were milled and combined, and adhered using an adhesive luting agent.

**RESULTS:** The completed denture was delivered on the working cast and provided an excellent level of fitness.

**CONCLUSION:** A prototype nonmetal clasp denture could be fabricated using CAD/CAM technology.

## Evaluation of Currently Available CAD/ CAM Denture Systems

*Steinmassl PA, Klauzner F, Steinmassl O, Dumfahrt H, Grunert I  
Int J Prosthodont 2017;30:116-122*

**PURPOSE:** The introduction of computer-aided design/computer-assisted manufacture (CAD/CAM) technology into removable denture prosthodontics enables denture adaptation in fewer patient visits, an advantage that appeals to dentists and patients. Since manufacturers follow very different approaches, an evaluation of the different clinical CAD/CAM complete denture fabrication protocols is desirable. The aim of this article is to assess and evaluate the different clinical fabrication protocols of currently available CAD/CAM denture systems to provide decision support for dental practitioners.

**MATERIALS AND METHODS:** The information for the present article was gathered by questionnaires from (in alphabetical order) Global Dental Science, Merz Dental, Wieland Dental + Technik, Ivoclar Vivadent, VITA Zahnfabrik, and Whole You, and complemented with results from the authors' clinical experience.

**RESULTS:** Wieland Digital Denture involves four patient visits. Both AvaDent digital dentures and Whole You Nexteeth enable denture fabrication in three (including a try-in session) or two (without try-in) visits. Baltic Denture System stipulates complete denture fabrication in two visits, and VITA VIONIC material system is an open system enabling choice between different treatment protocols. It can be combined with several open scanners, CAD software options, and milling machines.

**CONCLUSION:** The available CAD/CAM denture fabrication systems provide a variety of advantages, and the decision on a system should depend on the dentist's prosthodontic expertise, patient throughput rate, and requirements regarding denture individualization.



## 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  
J Prosthodont 2015 Aug 21. PMID: 26295755*

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.

## Digital capture, design, and manufacturing of a facial prosthesis: Clinical report on a pediatric patient

*Grant GT, Aita-Holmes C, Liacouras P, Garnes J, Wilson WO Jr  
J Prosthet Dent 2015;114:138-141*

A digitally captured, designed, and fabricated facial prosthesis is presented as an alternative to customary maxillofacial prosthodontics fabrication techniques, where a facial moulage and patient cooperation may be difficult.

## Reconstruction of an Extensive Midfacial Defect Using Additive Manufacturing Techniques

*Fernandes N, van den Heever J, Hoogendijk C, Botha S, Booysen G, Els J  
J Prosthodont 2016;25:589-594*

**ABSTRACT:** Malignant peripheral nerve sheath tumors are extremely rare tumors arising in peripheral nerves. Only 17 cases involving the trigeminal nerve have ever been reported. These tumors have a very poor prognosis and very high rates of recurrence and metastases. Their recommended treatment involves complete tumor resection followed by radiation. This can be problematic in the head and neck region. We present a clinical case involving a 33-year-old female patient presenting with a slow-growing, exophytic mass of the anterior maxilla. Incisional biopsy and subsequent histological examination revealed a diagnosis of a malignant peripheral nerve sheath tumor. Surgical resection involved a complete maxillectomy, rhinectomy, and resection of the upper lip and aspects of the left and right cheeks. Reconstruction of the subsequent defect incorporated the placement of four zygomatic oncology implants to aid in retention of a facial prosthesis. These implants, however, were subsequently lost; and an anatomical model of the hard tissues was manufactured via 3D printing. This model was used to design and manufacture a titanium frame (customized implant) for the patient. The frame was then fixated and secured intraoperatively with 21 cortical screws. A maxillary denture and silicone facial prosthesis were also made to fit onto this frame. This is the first known case where additive manufacturing, via the use of rapid prototyping and 3D printing, was employed to manufacture a facial prosthesis.

**KEYWORDS:** 3D printing; Rapid prototyping; facial prosthesis; malignant peripheral nerve sheath tumors

# Geometric evaluation of the effect of prosthetic rehabilitation on the facial appearance of mandibulectomy patients: A preliminary study

*Aswehlee AM, Elbashti ME, Hattori M, Sumita YI, Taniguchi H  
Int J Prosthodont 2017;30:455-457*

**PURPOSE:** The purpose of this study was to geometrically evaluate the effect of prosthetic rehabilitation on the facial appearance of mandibulectomy patients.

**MATERIALS AND METHODS:** Facial scans (with and without prostheses) were performed for 16 mandibulectomy patients using a noncontact three-dimensional (3D) digitizer, and 3D images were reconstructed with the corresponding software. The 3D datasets were geometrically evaluated and compared using 3D evaluation software.

**RESULTS:** The mean difference in absolute 3D deviations for full face scans was 382.2  $\mu\text{m}$ .

**CONCLUSION:** This method may be useful in evaluating the effect of conventional prostheses on the facial appearance of individuals with mandibulectomy defects.

## Fabricating a maxillary obturator using an intraoral digital impression: A case history report

*Park JH, Lee KS, Lee JY, Shin SW  
Int J Prosthodont 2017;30:266-268*

Digital impressions can be a useful option that reduces patient discomfort and simplifies clinical procedures such as accurate impression recordings. In this report, a patient with a partial maxillectomy was managed with a metal frame fabricated from a digital impression through an intraoral scanner. The final impression employed the altered cast technique for the fabrication of the obturator.

## CAD/CAM-assisted auricular prosthesis fabrication for a quick, precise, and more retentive outcome: A clinical report

Yadav S, Narayan AI, Choudhry A, Balakrishnan D  
*J Prosthodont* 2017 Jan 24. doi: 10.1111/jopr.12589. [Epub ahead of print]

Auricular defects comprise a large proportion of maxillofacial deformities. Most patients with acquired deformities have psychosocial ineptness and seek cosmetic rehabilitation. Although minor defects can be corrected surgically, extensive deformities are difficult to reconstruct with plastic surgery. Contrary to that, prosthetic restoration can provide excellent esthetic results. The conventional methods of maxillofacial prosthesis fabrication are time consuming and the outcome depends on the technician's skill. The advent of CAD/CAM technology in the field of dentistry has brought enormous improvement in the quality of health care provided. In the past decade, several methods have been described employing CAD/CAM techniques for the cosmetic rehabilitation of auricular defects. This clinical report details the integration of multiple digital technologies of CT scanning, computer aided design, and rapid prototyping to construct an ear prosthesis with limited number of appointments.

# Generation and evaluation of 3D digital casts of maxillary defects based on multisource data registration: A pilot clinical study

Ye H, Ma Q, Hou Y, Li M, Zhou Y

*J Prosthet Dent* 2017 Apr 25. pii: S0022-3913(17)30079-3. doi: 10.1016/j.

*prosdent.2017.01.014. [Epub ahead of print]*

**STATEMENT OF PROBLEM:**

Digital techniques are not clinically applied for 1-piece maxillary prostheses containing an obturator and removable partial denture retained by the remaining teeth because of the difficulty in obtaining sufficiently accurate 3-dimensional (3D) images.

**PURPOSE:** The purpose of this pilot clinical study was to generate 3D digital casts of maxillary defects, including the defective region and the maxillary dentition, based on multisource data registration and to evaluate their effectiveness.

**MATERIAL AND METHODS:** Twelve participants with maxillary defects were selected. The maxillofacial region was scanned with spiral computer tomography (CT), and the maxillary arch and palate were scanned using an intraoral optical scanner. The 3D images from the CT and intraoral scanner were registered and merged to form a 3D digital cast of the maxillary defect containing the anatomic structures needed for the maxillary prosthesis. This included the defect cavity, maxillary dentition, and palate. Traditional silicone impressions were also made, and stone casts were poured. The accuracy of the digital cast in comparison with that of the stone cast was evaluated by measuring the distance between 4 anatomic landmarks. Differences and consistencies were assessed using paired Student t tests and the intraclass correlation coefficient (ICC). In 3 participants, physical resin casts were produced by rapid prototyping from digital casts. Based on the resin casts, maxillary prostheses were fabricated by using conventional methods and then evaluated in the participants to assess the clinical applicability of the digital casts.

**RESULTS:** Digital casts of the maxillary defects were generated and contained all the anatomic details needed for the maxillary prosthesis. Comparing the digital and stone casts, a paired Student t test indicated that differences in the linear distances between landmarks were not statistically significant ( $P > .05$ ). High ICC values (0.977 to 0.998) for the interlandmark distances further indicated the high degree of consistency between the digital and stone casts. The maxillary prostheses showed good clinical effectiveness, indicating that the corresponding digital casts met the requirements for clinical application.

**CONCLUSIONS:** Based on multisource data from spiral CT and the intraoral scanner, 3D digital casts of maxillary defects were generated using the registration technique. These casts were consistent with conventional stone casts in terms of accuracy and were suitable for clinical use.



## Digital design and fabrication of surgical obturators based only on preoperative computed tomography data

*Rodney J, Chicchon I  
Int J Prosthodont 2017;30:111-112*

This article describes the digital fabrication of a surgical obturator (SO) using only computed tomography (CT) data from the tumor area. This procedure is a departure from the traditional method of making an impression and obtaining a patient cast prior to surgery to allow for SO fabrication. The present approach allows for a virtual resection based on the patient's CT image; the SO is digitally designed with animation software and fabricated by 3D printing. The SO is relined with a denture reliner at the time of surgery to complete the obturation of the maxillectomy defect.

## The combination of digital surface scanners and cone beam computed tomography technology for guided implant surgery using 3Shape Implant Studio Software: A case history report

Lanis A, del Canto OA  
*Int J Prosthodont* 2015;28:169-178

The incorporation of virtual engineering into dentistry and the digitization of information are providing new perspectives and innovative alternatives for dental treatment modalities. The use of digital surface scanners with surgical planning software allows for the combination of the radiographic, prosthetic, surgical, and laboratory fields under a common virtual scenario, permitting complete digital treatment planning. In this article, the authors present a clinical case in which a guided implant surgery was performed based on a complete digital surgical plan combining the information from a cone beam computed tomography scan and the virtual simulation obtained from the 3Shape TRIOS intraoral surface scanner. The information was imported to and combined in the 3Shape Implant Studio software for guided implant surgery planning. A surgical guide was obtained by a 3D printer, and the surgical procedure was done using the Biohorizons Guided Surgery Kit and its protocol.

## 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 ( $\alpha=0.01$ ). 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 ( $P>0.01$ ). Although not statistically significant ( $P>0.01$ ), 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.

## Digital approach to planning computer-guided surgery and immediate provisionalization in a partially edentulous patient

*Arunyanak SP, Harris BT, Grant GT, Morton D, Lin WS  
J Prosthet Dent 2016;116:8-14*

This report describes a digital approach for computer-guided surgery and immediate provisionalization in a partially edentulous patient. With diagnostic data obtained from cone-beam computed tomography and intraoral digital diagnostic scans, a digital pathway of virtual diagnostic waxing, a virtual prosthetically driven surgical plan, a computer-aided design and computer-aided manufacturing (CAD/CAM) surgical template, and implant-supported screw-retained interim restorations were realized with various open-architecture CAD/CAM systems. The optional CAD/CAM diagnostic casts with planned implant placement were also additively manufactured to facilitate preoperative inspection of the surgical template and customization of the CAD/CAM-fabricated interim restorations.

## Combining guided alveolar ridge reduction and guided implant placement for all-on-4 surgery: A clinical report

*Faeghi Nejad M, Proussaefs P, Lozada J  
J Prosthet Dent 2016;115:662-667*

Immediate restoration with the all-on-4 concept has become an established treatment option. The technique involves alveoloplasty before implant placement to provide space for the prosthetic components and to provide a platform on which dental implants can be placed in clinical situations where a knife-edge alveolar ridge is present. Guided implant surgery involves the fabrication of a guide by using data from cone-beam computed tomography (CBCT) and implant surgery performed without flap reflection. In the presented technique, a printed cast based on a CBCT is used to fabricate a guide for both alveolar ridge reduction and guided implant surgery. The alveolar ridge reduction and implant surgery are virtually simulated in the laboratory to provide space for the restorative components and to avoid critical anatomic landmarks (mental nerve or perforation of the lingual mandibular plate). The described surgical guide enables guided alveolar ridge reduction and guided implant placement where the implant placement performed in the laboratory can be duplicated clinically during implant surgery.

## Impact of Surgical Template on the Accuracy of Implant Placement

*Xu LW, You J, Zhang JX, Liu YF, Peng W  
J Prosthodont 2016;25:641-646*

**PURPOSE:** To achieve functional and esthetic results, implants must be placed accurately; however, little information is available regarding the effect of surgical templates on the accuracy of implant placement. Thus, the aim of this study was to measure the deviation between actual and planned implant positions, and determine the deviation caused by the surgical template.

**MATERIALS AND METHODS:** Jaws from 16 patients were scanned using cone beam computed tomography (CBCT). For our study, 53 implants were planned in a virtual 3D environment, of which 35 were inserted in the mandible and 18 in the maxilla. A stereolithographic (SLA) surgical template was created. A CBCT scan of the surgical template fitted on a plaster model was performed, and the images obtained were matched to virtual implant plan images that contained the planned implant position. The actual implant position was acquired from the registration position of the surgical template. Deviation between actual and planned implant positions was analyzed.

**RESULTS:** Mean central deviation at the hex and apex was 0.456 mm and 0.515 mm, respectively. Mean value of horizontal deviation at the hex was 0.193 mm, horizontal deviation at the apex was 0.277 mm, vertical deviation at the hex was 0.388 mm, vertical deviation at the apex was 0.390 mm, and angular deviation was 0.621°.

**CONCLUSION:** Our study results revealed a significant deviation between actual and planned implant positions caused by the surgical template.

## In-office fabrication of dental implant surgical guides using desktop stereolithographic printing and implant treatment planning software: A clinical report

*Whitley D III, Eidson SR, Rudek I, Bencharit S  
J Prosthet Dent 2017;118:256-263*

Guided surgery is accepted as the most accurate way to place an implant and predictably relate the implant to its definitive prosthesis, although few clinicians use it. However, recent developments in high-quality desktop 3-dimensional stereolithographic printers have led to the in-office fabrication of stereolithographic surgical guides at reduced cost. This clinical report demonstrates a protocol for using a cost-effective, in-office rapid prototyping technique to fabricate a surgical guide for dental implant placement.

## Creation of a 3-dimensional virtual dental patient for computer-guided surgery and CAD-CAM interim complete removable and fixed dental prostheses: A clinical report

*Harris BT, Montero D, Grant GT, Morton D, Llop DR, Lin WS  
J Prosthet Dent 2017;117:197-204*

This clinical report proposes a digital workflow using 2-dimensional (2D) digital photographs, a 3D extraoral facial scan, and cone beam computed tomography (CBCT) volumetric data to create a 3D virtual patient with craniofacial hard tissue, remaining dentition (including surrounding intraoral soft tissue), and the realistic appearance of facial soft tissue at an exaggerated smile under static conditions. The 3D virtual patient was used to assist the virtual diagnostic tooth arrangement process, providing patient with a pleasing preoperative virtual smile design that harmonized with facial features. The 3D virtual patient was also used to gain patient's pretreatment approval (as a communication tool), design a prosthetically driven surgical plan for computer-guided implant surgery, and fabricate the computer-aided design and computer-aided manufacturing (CAD-CAM) interim prostheses.



## Facially generated and cephalometric guided 3D digital design for complete mouth implant rehabilitation: A clinical report

*Coachman C, Calamita MA, Coachman FG, Coachman RG, Sesma N  
J Prosthet Dent 2017;117:577-586*

Harmony among the teeth, lips, and facial components is the goal of prosthodontic treatment, whether performed by conventional or digital workflow methods. This clinical report describes a facial approach to planning computer-guided surgery and immediate computer-aided designed and computer-aided manufactured (CAD-CAM) interim complete-arch fixed dental prostheses on immediately placed dental implants with a digital workflow. A single clinical appointment for data collection included dentofacial documentation with photographs and videos. On these photographs, facial reference lines were drawn to create a smile frame. This digital smile design and sagittal cephalometric analysis were merged with 3-dimensional scanned casts and a cone beam computed tomographic file in virtual planning software, thus guiding virtual waxing and implant positioning. Computer-guided implant surgery and CAD-CAM interim dental prostheses allowed esthetic and functional rehabilitation in a predictable manner and integrated with the patient's face.

## Reliability of a CAD/CAM surgical guide for implant placement: An in vitro comparison of surgeons' experience levels and implant sites

*Park SJ, Leesungbok R, Cui T, Lee SW, Ahn SJ  
Int J Prosthodont 2017;30:367-169*

**PURPOSE:** This in vitro study evaluated the reliability of a surgical guide with regard to different levels of operator surgical experience and implant site.

**MATERIALS AND METHODS:** A stereolithographic surgical guide for epoxy resin mandibles with three edentulous molar sites was produced using a computer-aided design/computer-assisted manufacture (CAD/CAM) system. Two surgeons with and two surgeons without implant surgery experience placed implants in a model either using or not using the CAD/CAM surgical guide. Four groups were created: inexperienced surgeon without the guide (group 1); experienced surgeon without the guide (group 2); inexperienced surgeon with the guide (group 3); and experienced surgeon with the guide (group 4). Planned implants and placed implants were superimposed using digital software, and deviation parameters were calculated.

**RESULTS:** There were no significant differences in any of the deviation parameters between the groups when using the surgical guide. With respect to the implant sites, there were no significant differences among the groups in any parameter.

**CONCLUSION:** Use of the CAD/CAM surgical guide reduced discrepancies among operators performing implant surgery regardless of their level of experience. Whether or not the guide was used, differences in the anterior-posterior implant site in the molar area did not affect the accuracy of implant placement.

## Computer-guided implant planning using a preexisting removable partial dental prosthesis

*Kim JE, Shim JS  
J Prosthet Dent 2017;117:13-17*

Converting a conventional removable partial dental prosthesis (RPDP) into an implant-assisted removable partial dental prosthesis (IARPD) may be facilitated by using data from the intaglio surface of the RPDP for proper implant placement. This procedure can be done by connecting the data from the intaglio surface of the RPDP to the residual ridge data of the cone beam computed tomography scan with implant planning software. However, although a misplaced implant under an RPDP can cause various complications, as yet, no technique has connected the information on a patient's existing RPDP to the implant planning software. This article presents computer-guided implant planning, using a patient's existing RPDP.

## Novel-design ultra-thin CAD/CAM composite resin and ceramic occlusal veneers for the treatment of severe dental erosion

Schlichting LH, Maia HP, Baratieri LN, Magne P  
*J Prosthet Dent* 2011;105:217-226

**STATEMENT OF PROBLEM:** Ultra-thin bonded posterior occlusal veneers represent a conservative alternative to traditional inlays and complete coverage crowns for the treatment of severe erosive lesions. There is a lack of data regarding selection of the most appropriate material and its influence on fatigue resistance, which may affect restoration longevity.

**PURPOSE:** The purpose of this study was to assess the influence of CAD/CAM restorative material (ceramic vs. composite resin) on fatigue resistance of ultra-thin occlusal veneers.

**MATERIAL AND METHODS:** A standardized nonretentive tooth preparation (simulating advanced occlusal erosion) was applied to 40 extracted molars including removal of occlusal enamel, and immediate dentin sealing (Optibond FL). All teeth were restored with a 0.6 mm-thick occlusal veneer (Cerec3 chairside CAD/CAM system). Reinforced ceramics (Empress CAD and e.max CAD) and composite resins (Paradigm MZ100 and XR (experimental blocks)) were used to mill the restorations (n=10). The intaglio surfaces were HF-etched and silanated (reinforced ceramics) or airborne-particle abraded and silanated (composite resins). Preparations were airborne-particle abraded and etched before restoration insertion. All restorations were adhesively luted with preheated Filtek Z100. Cyclic isometric loading was applied at 5 Hz, beginning with a load of 200N (x5,000), followed by stages of 400, 600, 800, 1000, 1200 and 1,400N at a maximum of 30,000 cycles each. The number of cycles at initial failure (first cracks) was recorded. Specimens were loaded until catastrophic failure (lost restoration fragment) or to a maximum of 185,000 cycles. Groups were compared using the life table survival analysis ( $\alpha=.008$ , 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).

## Effect of surface conditioning with airborne-particle abrasion on the tensile strength of polymeric CAD/CAM crowns luted with self-adhesive and conventional resin cements

Stawarczyk B, Basler T, Ender A, Roos M, Ozcan M, Hämmerle C  
*J Prosthet Dent* 2012;107:94-101

**STATEMENT OF PROBLEM:** Adhesively bonded, industrially polymerized resins have been suggested as definitive restorative materials. It is claimed that such resins present similar mechanical properties to glass ceramic.

**PURPOSE:** The purpose of this study was to assess the tensile strength of polymeric crowns after conditioning with 2 different protocols: luted with self-adhesive or with conventional resin cements to dental abutments.

**MATERIAL AND METHODS:** Human teeth were prepared for crowns and divided into 13 groups (N=312, n=24 per group). Polymeric crowns were CAD/CAM fabricated and divided into 3 groups depending on different surface conditioning methods: A) No treatment, B) airborne-particle abrasion with 50  $\mu\text{m}$  alumina, and C) airborne-particle abrasion with 110  $\mu\text{m}$  alumina. Thereafter, the crowns were luted on dentin abutments with the following cements: 1) RXU (RelyX Unicem, self-adhesive), 2) GCM (G-Cem, self-adhesive), 3) ACG (artCem GI, conventional), and 4) VAR (Variolink II, conventional). Glass ceramic crowns milled and cemented with dual-polymerized resin cement (Variolink II) served as the control group. The tensile strength was measured initially (n=12) and after aging by mechanical thermocycling loading (1 200 000 cycles, 49 N, 5°C to 50°C) (n=12). The tensile strength (MPa) of all crowns was determined by the pull-off test (Zwick/Roell Z010; Ulm, Germany, 1mm/min). Subsequently, the failure types were classified. Data were analyzed with 2-way and 1-way ANOVA followed by a post hoc Scheffé test and t test ( $\alpha=0.05$ ).

**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  $\mu\text{m}$  (initial: 2.8 MPa; after aging: 1 MPa) than 50  $\mu\text{m}$  alumina (initial: 1.4 MPa; after aging: 0 MPa). No significant effect was found between 50 and 110  $\mu\text{m}$  particle size alumina in combination with the other 2 cements. After aging, the tensile strength of the crowns luted with GCM (50  $\mu\text{m}$ : 0 MPa and 110  $\mu\text{m}$ : 1 MPa) and ACG (50  $\mu\text{m}$ : 1 MPa and 110  $\mu\text{m}$ : 1.2 MPa) was significantly lower than those luted with RXU (50  $\mu\text{m}$ : 1.9 MPa and 110  $\mu\text{m}$ : 2 MPa). All airborne particle abraded polymeric CAD/CAM crowns (initial: 1.4-2.8; 0-2 MPa) showed significantly lower tensile strength values than the control group (initial: 7.3 MPa; after aging: 6.4 MPa). Although with all polymeric specimens, failure type was adhesive between the cement and the crowns, the control group showed exclusively cohesive failures within the ceramic.

**CONCLUSIONS:** Airborne-particle abrasion before cementation of polymeric CAD/CAM crowns minimally improved the tensile strength. Both the failure types and the tensile strength values of adhesively luted glass ceramic crowns showed superior results to adhesively cemented polymeric ones. Although the tensile strength results were low, crowns cemented with RXU showed, after aging, the highest tensile strength of all other tested groups.

## Two-body wear rate of CAD/CAM resin blocks and their enamel antagonists

Stawarczyk B, Özcan M, Trottman A, Schmutz F, Roos M, Hämmerle C  
*J Prosthet Dent* 2013;109:325-332

**STATEMENT OF PROBLEM:** Computer-aided design and computer-aided manufacturing (CAD/CAM) resins exhibit good mechanical properties and can be used as long-term restorations. The wear rate of such resins and their enamel antagonists is unknown.

**PURPOSE:** The purpose of this study was to test and compare the 2-body wear rate of CAD/CAM resin blocks.

**MATERIAL AND METHODS:** Wear specimens (N=42, n=6) were made from 5 CAD/CAM resins: ZENO PMMA (ZP), artBloc Temp (AT), Telio CAD (TC), Blanc High-class (HC), CAD-Temp (CT); 1 manually polymerized resin: Integral esthetic press (negative control group, IEP); and 1 glass-ceramic: VITA Mark II (positive control group, VM2). The specimens for the wear resistance were aged in a thermomechanical loading machine (49 N, 1.67 Hz, 5/50°C) with human enamel antagonists. The material loss of all specimens before, during, and after aging was evaluated with a 3DS profilometer. The measured material loss data of all tested groups were statistically evaluated with linear mixed model analysis ( $\alpha=0.05$ ).

**RESULTS:** Manually polymerized resin showed significantly higher material wear ( $P<.001$ ) than all other tested groups. Glass-ceramic showed significantly lower wear values ( $P<.001$ ) than CAD/CAM resins ZP, AT, HC, CT, and IES. CAD/CAM resin TC was not significantly different from the positive control group. Glass-ceramic showed the highest enamel wear values ( $P<.001$ ) of all tested resins. No differences were found in the enamel wear among all resins. The glass-ceramic group showed damage in the form of cracks on the worn enamel surface in 50% of specimens.

**CONCLUSIONS:** CAD/CAM resins showed lower wear rates than those conventionally polymerized. Only one CAD/CAM resin, TC, presented material wear values comparable with glass-ceramic. The tested glass-ceramic developed cracks in the enamel antagonist and showed the highest enamel wear values of all other tested groups.

## The digital one-abutment/one-time concept. A clinical report

*Bever F, Groesser J, Schweiger J, Hey J, Güth JF, Stimmelmayer 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.

# Translucency of esthetic dental restorative CAD/CAM materials and composite resins with respect to thickness and surface roughness

Awad D, Stawarczyk B, Liebermann A, Ilie N  
*J Prosthet Dent* 2015;113:534-540

**STATEMENT OF PROBLEM:** Little information is available about the translucency of monolithic CAD/CAM materials.

**PURPOSE:** The purpose of this study was to evaluate the translucency of restorative CAD/CAM materials and direct composite resins with respect to thickness and surface roughness.

**MATERIALS AND METHODS:** In total, 240 disk-shaped specimens (12×14×1 mm and 12×14×2 mm) of 3 different CAD/CAM glass ceramics (CELTRA Duo, IPS e.max CAD, IPS Empress CAD), a fine-structure feldspathic ceramic (VITA Mark II), a hybrid ceramic (VITA Enamic), a resin nanoceramic composite resin (LAVA Ultimate), an experimental (CAD/CAM nanohybrid composite resin), 2 interim materials (Telio CAD; VITA CAD-Temp), and 3 direct composite resins (Tetric EvoCeram; Filtek Supreme XTE; Tetric EvoCeram Bulk Fill) were fabricated (n=10). After 3 different surface pretreatments (polished, rough SiC P1200, or SiC P500), absolute translucency and surface roughness were measured using spectrophotometry and tactile profilometry. The influence of material type, thickness, and roughness on absolute translucency was analyzed using a multivariate analysis, 1-way ANOVA, and the Tukey HSD post hoc test (P<.05). Pearson correlations and statistical hypothesis tests were used to assess the results (P<.05).

**RESULTS:** The effect of all tested parameters was significant among the materials (P<.05). The greatest influence on the measured translucency was thickness (partial eta squared  $\eta^2=.988$ ), closely followed by material (.982), and the pretreatment method (.835). The surface roughness was strongly influenced by the pretreatment method (.975) and type of material (.941).

**CONCLUSION:** Thickness and surface roughness are major factors affecting the absolute translucency of adhesively luted restorations.



## 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 different surface treatments on bond strength of resin cement to a CAD/CAM restorative material

Barutçigil K, Barutçigil Ç, Kul E, Özarıslan MM, Buyukkaplan US  
*J Prosthodont* 2016 Nov 23. doi: 10.1111/jopr.12574. [Epub ahead of print]

**PURPOSE:** To investigate the effects of various surface treatment methods on the shear bond strength of self-adhesive resin cement to a novel CAD/CAM hybrid ceramic material.

**MATERIALS AND METHODS:** A novel hybrid ceramic restorative material (Vita Enamic) was used in this study. Sixty resin block specimens were prepared and separated into six groups for each surface treatment method (n = 10); group 1: control group, no treatment applied; group 2: sandblasted by 30 µm silicate-coated alumina particles (CoJet Sandblasting); group 3: 50 µm Al<sub>2</sub>O<sub>3</sub> sandblasting; group 4: 10% hydrofluoric acid; group 5: no surface treatment + universal adhesive (3M Single Bond Universal); group 6: 200 mJ, 10 Hz 2W Er,Cr:YSGG laser treatment. For each specimen, surface roughness measurements in noncontact mode were taken after the surface treatments using a portable surface texture-measuring machine. A self-adhesive resin cement (3M U200) was applied on every surface treated with the help of a cylindrical mold (2 × 4 mm) and was filled gradually. Shear bond strength was measured using a universal test machine, and one-way ANOVA and a Duncan test (p = 0.05) were used to analyze the data.

**RESULTS:** Mean values of the shear bond strength varied between 7.75 and 10.73 MPa. Bond strength values were enhanced by all surface treatment methods compared to the control group. The difference between group 5 and the control group (p < 0.05) was statistically significant, whereas there were no considerable differences between other treatment methods.

**CONCLUSION:** Surface treatments of hybrid ceramic resin blocks could enhance the bond strength to resin cement; however, using Single Bond Universal without surface treatment showed a higher bond strength value.

## A pilot study to assess the feasibility and accuracy of using haptic technology to occlude digital dental models

Wu W, Cen Y, Hong Y, Keeling A, Khambay B  
*J Dent* 2016;46:54-60

**OBJECTIVES:** The use of haptic technology as an adjunct to clinical teaching is well documented in medicine and dentistry. However its application in clinical patient care is less well documented. The aim of this pilot study was to determine the feasibility and accuracy of using a haptic device to determine the occlusion of virtual dental models.

**METHODS:** The non-occluded digital models of 20 pre-treatment individuals were chosen from the database of Faculty of Dentistry, The University of Hong Kong. Following minimal training with the haptic device (Geomagic®Touch™), the upper model was occluded with the lower model until a stable occlusion was achieved. Seven landmarks were placed on each of the corners of the original and haptically aligned upper model bases. The absolute distance between the landmarks was calculated. Intra- and inter-operator errors were assessed.

**RESULTS:** The absolute distance between the 7 landmarks for each original and corresponding haptically aligned model was 0.54 ffl 0.40 mm in the x-direction (lateral), 0.73 ffl 0.63 mm in the y-direction (anterior-posterior) and 0.55 ffl 0.48 mm in the z-direction (inferior-superior).

**CONCLUSION:** Based on initial collision detection to prevent interpenetration of the upper and lower digital model surfaces, and contact form resistance during contact, it is possible to use a haptic device to occlude digital study models.

**CLINICAL SIGNIFICANCE:** The use of 3D digital study models is routine, but new problems arise, such as the lack of “touch” in a virtual environment. Occluding study models requires the sense of touch. For the first time, using haptic technology, it is possible to occlude digital study models in a virtual environment.

## A new method for assessing the accuracy of full arch impressions in patients

*Kuhr F, Schmidt A, Rehmann P, Wöstmann B  
J Dent 2016;55:68-74*

**OBJECTIVE:** To evaluate a new method of measuring the real deviation (trueness) of full arch impressions intraorally and to investigate the trueness of digital full arch impressions in comparison to a conventional impression procedure in clinical use.

**METHODS:** Four metal spheres were fixed with composite using a metal application aid to the lower teeth of 50 test subjects as reference structures. One conventional impression (Impregum Penta Soft) with subsequent type-IV gypsum model casting (CI) and three different digital impressions were performed in the lower jaw of each test person with the following intraoral scanners: Sirona CEREC Omnicam (OC), 3M True Definition (TD), Heraeus Cara TRIOS (cT). The digital and conventional (gypsum) models were analyzed relative to the spheres. Linear distance and angle measurements between the spheres, as well as digital superimpositions of the spheres with the reference data set were executed.

**RESULTS:** With regard to the distance measurements, CI showed the smallest deviations followed by intraoral scanners TD, cT and OC. A digital superimposition procedure yielded the same order for the outcomes: CI ( $15\pm 4\mu\text{m}$ ), TD ( $23\pm 9\mu\text{m}$ ), cT ( $37\pm 14\mu\text{m}$ ), OC ( $214\pm 38\mu\text{m}$ ). Angle measurements revealed the smallest deviation for TD ( $0.06^\circ\pm 0.07^\circ$ ) followed by CI ( $0.07^\circ\pm 0.07^\circ$ ), cT ( $0.13^\circ\pm 0.15^\circ$ ) and OC ( $0.28^\circ\pm 0.21^\circ$ ).

**CONCLUSION:** The new measuring method is suitable for measuring the dimensional accuracy of full arch impressions intraorally. CI is still significantly more accurate than full arch scans with intraoral scanners in clinical use.

**CLINICAL SIGNIFICANCE:** Conventional full arch impressions with polyether impression materials are still more accurate than full arch digital impressions. Digital impression systems using powder application and active wavefront sampling technology achieve the most accurate results in comparison to other intraoral scanning systems (DRKS-ID: DRKS00009360, German Clinical Trials Register).

## Shear bond strength of repair systems to new CAD/CAM restorative materials

Üstün Ö, Büyükhatipoğlu IK, Seçilmiş A

*J Prosthodont* 2016 Nov 23. doi: 10.1111/jopr.12564. [Epub ahead of print]

**PURPOSE:** To evaluate the bond strength of repair systems (Ceramic Repair, Clearfil Repair) to computer-aided design/computer-assisted machining (CAD/CAM) restorative materials (IPS e.max CAD, Vita Suprinity, Vita Enamic, Lava Ultimate).

**MATERIALS AND METHODS:** Thermally aged CAD/CAM restorative material specimens (5000 cycles between 5°C and 55°C) were randomly divided into two groups according to the repair system: Ceramic Repair (37% phosphoric acid + Monobond-S + Heliobond + Tetric N Ceram) or Clearfil Repair (40% phosphoric acid + mixture of Clearfil Porcelain Bond Activator and Clearfil SE Bond Primer + Clearfil SE Bond + Filtek Z250). The resin composite was light-cured on conditioned specimens. All specimens were stored in distilled water at 37°C for 24 hours and then additionally aged for 5000 thermal cycles. The shear bond strength test was performed using a universal testing machine (0.5 mm/min). Two-way ANOVA was used to detect significance differences according to the CAD/CAM material and composite repair system factors. Subgroup analyses were conducted using the least significant difference post-hoc test.

**RESULTS:** The results of two-way ANOVA indicated that bond strength values varied according to the restorative materials ( $p < 0.05$ ). No significant differences were observed between the CAD/CAM restorative materials ( $p > 0.05$ ), except in the Vita Suprinity group ( $p < 0.05$ ). Moreover, no differences were observed between the repair systems.

**CONCLUSIONS:** Both the Clearfil and Ceramic repair systems used in the study allow for successful repairs.

# Parallel randomized controlled clinical trial in patients with temporomandibular disorders treated with a CAD/CAM versus a conventional stabilization splint

*Pho Duc JM, Hüning SV, Grossi ML  
Int J Prosthodont 2016;29:340-350*

**PURPOSE:** This parallel randomized controlled trial (RCT) compared the efficacy of a computer-aided design/computer-assisted manufacture (CAD/CAM) splint versus a conventional stabilization splint in patients with temporomandibular disorders (TMD).

**MATERIALS AND METHODS:** A sample of 48 age-matched TMD patients from the Ludwig Maximilian University Prosthodontic Department in Munich, Germany, were randomly allocated into groups 1 (CAD/CAM splint) and 2 (conventional splint). The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) was used for TMD Axis I (groups I, II, and III) and Axis II (chronic pain grade [CPG]) diagnoses. Numeric scales (TMD/NS, 10 cm) were used to measure headaches, face pain, jaw joint pain, jaw joint noises, mastication pain, neck pain, face tension, limitation of mouth opening, complaints during mastication, and teeth sensitivity at baseline and then monthly for 9 months ( $T_1$  to  $T_{10}$ ). Optical axiography was used to measure right and left condyle movements (mm) at baseline, 3 months, and 6 months ( $T_1$ ,  $T_4$ , and  $T_7$ ).

**RESULTS:** A total of 32 patients (drop-out rate = 33%; 68.75% women; 28.51 ffl 7.13 years old), 16 per group, completed the study. RDC/TMD Axis I showed the following diagnoses: 93.75% muscle disorders, 37.75% disc displacement with reduction, 3.12% disc displacement without reduction, and 56.25% arthralgia. There was a significant reduction in 10 out of 13 items of the TMD/NS in the CAD/CAM splint versus 8 out of 13 in the conventional splint. However, no significant improvement in mandibular movements (ie, increase in range of motion and reduction in asymmetry between right and left condyles) was observed.

**CONCLUSION:** Both treatments were equally efficacious and no difference was found between them.

## Implant ball attachment fabricated with CAD/CAM to overcome an unfavorable clinical situation: A case report

*Shim JS, Lim JH, Shin JH, Ryu JJ, Lee JY, Shin SW  
Int J Prosthodont 2016;29:611-613*

**ABSTRACT:** The most common complication of implant ball attachments is loss of retention via structural wear. Hence, parallel placement of implants was identified as a prerequisite for long-term success. In this case, although severe angulation was formed between implants due to severe alveolar bone resorption, parallel ball attachments on the implants could be fabricated using computer-aided design/computer-assisted manufacture. This procedure can be a solution when implants are placed with angulation and offers additional advantages such as long-term stability.



## Complete-mouth rehabilitation using a 3D printing technique and the CAD/CAM double scanning method: A clinical report

*Joo HS, Park SW, Yun KD, Lim HP  
J Prosthet Dent 2016;116:3-7*

According to evolving computer-aided design/computer-aided manufacturing (CAD/CAM) technology, ceramic materials such as zirconia can be used to create fixed dental prostheses for partial removable dental prostheses. Since 3D printing technology was introduced a few years ago, dental applications of this technique have gradually increased. This clinical report presents a complete-mouth rehabilitation using 3D printing and the CAD/CAM double-scanning method.

## Comparison of 64-detector-multislice and cone beam computed Tomographies in the evaluation of linear measurements in the alveolar ridge

*Pena de Andrade JG, Valerio CS, de Oliveira Monteiro MA, de Carvalho Machado V, Manzi FR*

*Int J Prosthodont 2016;29:132-134*

**ABSTRACT:** This study compared the accuracy of linear measurements of the alveolar ridge in images obtained using 64-detector-multislice computed tomography (CT) and cone beam CT (CBCT). Eight sites were selected corresponding to the regions of molars, premolars, canines, and incisors in six dry human jaws. After the completion of multislice CT and CBCT, the jaws were sectioned into specific regions. Results showed there was no statistically significant difference between the measurements obtained from the CT images and those obtained from dry jaws (actual measurements) for all the evaluated sites (molars, premolars, and anterior teeth). There was also no statistically significant difference between the measurements obtained by the two CT methods.

## Preferences related to the use of mobile apps as dental patient educational aids: A pilot study

Bohn CE, McQuistan MR, McKernan SC, Askelson NM  
*J Prosthodont.* 2017 Sep 5. doi: 10.1111/jopr.12667. [Epub ahead of print]

**PURPOSE:** Numerous patient education apps have been developed to explain dental treatment. The purpose of this study was to assess perceptions and preferences regarding the use of apps in dental settings.

**MATERIALS AND METHODS:** Four patient education apps describing fixed partial dentures were demonstrated to participants (N = 25). Questions about each app were asked using a semi-structured interview format to assess participants' opinions about each app's content, images, features, and use. Sessions were analyzed via note-based methods for thematic coding.

**RESULTS:** Participants believed that apps should be used in conjunction with a dentist's explanation about a procedure. They desired an app that could be tailored for scope of content. Participants favored esthetic images of teeth that did not show structural anatomy, such as tooth roots, and preferred interactive features.

**CONCLUSIONS:** Patient education apps may be a valuable tool to enhance patient-provider communication in dental settings. Participants exhibited varying preferences for different features among the apps and expressed the desire for an app that could be personalized to each patient. Additional research is needed to assess whether the use of apps improves oral health literacy and informed consent among patients.

## Precise reproduction of soft tissue structure around the pontic area using computer-aided design and manufacturing

Lee H, Paek J, Noh K, Kwon KR

*J Prosthodont* 2017 Aug 21. doi: 10.1111/jopr.12593. [Epub ahead of print]

Reproducing soft tissue contours around a pontic area is important for the fabrication of an esthetic prosthesis, especially in the anterior area. A gingival model that precisely replicates the soft tissue structure around the pontic area can be easily obtained by taking a pick-up impression of an interim fixed dental prosthesis. After a working cast is fabricated using the customary technique, the pick-up model is superimposed onto the working model for the pontic area using computer-aided design and manufacturing (CAD/CAM). A definitive restoration using this technique would be well adapted to the pontic base, which is formed by the interim prosthesis.

# Clinical evaluation of indirect particle-filled composite resin CAD/CAM partial crowns after 24 months

Zimmermann M, Koller C, Reymus M, Mehl A, Hickel R  
*J Prosthodont* 2017 Apr 19. doi: 10.1111/jopr.12582. [Epub ahead of print]

**PURPOSE:** Resin-based CAD/CAM compound materials might be promising for single-tooth restorations. Insufficient clinical data are available for this new material class. The purpose of this study was to describe initial clinical in vivo results for indirect particle-filled composite resin CAD/CAM restorations after 24 months.

**MATERIALS AND METHODS:** Indirect particle-filled composite resin restorations were fabricated with a CAD/CAM method (CEREC Bluecam intraoral scanner, CEREC MCXL milling unit) by calibrated dental students. Forty-two partial crown restorations were seated adhesively in 30 patients with caries lesions or insufficient restorations (baseline). Strict inclusion criteria were defined for the patient collective. Follow-up evaluation comprised 40 restorations after 12 months and 33 restorations after 24 months. Evaluation criteria were modified FDI criteria with grades (1) to (5). Rating with FDI criteria (5) was defined as clinical failure. Statistical analysis was performed with Wilcoxon-Test ( $p < 0.05$ ).

**RESULTS:** The success rate of indirect particle-filled composite resin CAD/CAM restorations after 12 months was 95.0% with two debondings observed. The cumulative success rate for indirect particle-filled composite resin CAD/CAM restorations after 24 months was 85.7% with two tooth fractures and one debonding. Statistically significant differences were found for baseline and 24-month follow-up evaluation for anatomic form and marginal adaptation criterion examined in respect to FDI criteria guidelines (Wilcoxon-Test,  $p < 0.05$ ).

**CONCLUSIONS:** This study demonstrates particle-filled composite resin CAD/CAM restorations having a clinical success rate of 85.7% after 24 months. Adhesive bonding procedures need to be ensured carefully. A longer clinical evaluation period is necessary to draw further conclusions.

## Biomechanical behavior of endodontically treated premolars using different preparation designs and CAD/CAM materials

Lise DP, Ende AV, De Munck J, Suzuki TYU, Vieira LCC, Van Meerbeek B  
*J Dent* 2017;59:54-61

**OBJECTIVES:** To evaluate the effect of restoration design ('2.5-mm deep endocrown', '5-mm deep endocrown' or '5-mm deep post&crowns') and CAD/CAM material type (composite or lithium disilicate glass-ceramic) on the load-to-failure of endodontically treated premolars in absence of any ferrule.

**METHODS:** The crowns of 48 single-rooted premolars were cut and the roots were endodontically treated. Teeth were randomly divided into six groups (n=8); teeth in each group were restored using one of the two tested materials with standardized CAD/CAM fabricated endocrowns (with either 2.5-mm or 5-mm deep intra-radicular extension) or conventional crowns (5-mm deep post&crowns). After cementation using luting composite, the specimens were immersed in distilled water and subjected to 1,200,000 chewing cycles with a load of 50N applied parallel to the long axis of the tooth (0°). After cyclic loading, a compressive load was applied at 45° to the tooth's long axis using a universal testing machine until failure. Load-to-failure was recorded (N) and the specimens were examined under a stereomicroscope with 3.5x magnification to determine the mode of failure.

**RESULTS:** All specimens survived the 1,200,000 chewing cycles. A significant interaction between restoration design and CAD/CAM material was found using two-way ANOVA. In the '2.5-mm deep endocrown' groups, the composite achieved a significantly higher load-to-failure than the lithium disilicate glass-ceramic, while no differences between materials were found in the '5-mm deep endocrown' and '5-mm deep post&crowns' groups. More unfavorable failures (root fractures) were observed for higher load-to-failure values.

**CONCLUSIONS:** Only following a '2.5-mm deep endocrown' design, composite appeared more favorable than lithium disilicate glass-ceramic as crown material; this may be explained by their difference in elastic modulus.

**CLINICAL SIGNIFICANCE:** Shallow endocrown preparations on premolars present less surface for adhesive luting and a difference in crown material becomes apparent in terms of load-to-failure. The use of a more flexible composite crown material appeared then a better option.

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

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

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

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

**RESULTS:** Parafunctional habits were reported by all patients. All participants exhibited tooth wear  $\geq 140 \mu\text{m}$  in depth and extending to  $\geq 280 \mu\text{m}$  in at least one tooth. Maxillary central incisors were the most commonly and severely affected teeth.

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

## Additive manufacturing techniques in prosthodontics: where do we currently stand? A critical review.

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

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

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

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

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



## The effect of a CAD/CAM-guided template on formation of the screw-access channel for fixed prostheses supported by lingually placed implants.

Lee DH, Li LJ, Mai HN, Kim KR, Lee KW  
*Int J Prosthodont* 2017;30:113-115

**PURPOSE:** The aim of this study was to evaluate the effect of a computer-aided design/ computer-assisted manufacturing (CAD/CAM) guide on drilling the screw-access channel for lingually placed implants.

**MATERIALS AND METHODS:** Screw-channel drilling guides were fabricated on lingually placed implant models using CAD/CAM technology. The screw channels were prepared with guided or freehand drilling by 20 dental graduates. The accuracy of each screw channel was assessed for drilling entry point, channel volume, and angulation ( $\alpha = .05$ ).

**RESULTS:** The guided drilling group showed smaller deviations than the freehand drilling group, and prosthesis position influenced the guide effect ( $P < .001$ ).

**CONCLUSION:** The CAD/CAM guide facilitated the screw channel preparation of cement-retained prostheses supported by lingually placed implants.

## Build angle: does it influence the accuracy of 3D-printed dental restorations using digital light-processing technology?

Osman RB, Alharbi N, Wismeijer D  
*Int J Prosthodont* 2017;30:182-188

**PURPOSE:** The aim of this study was to evaluate the effect of the build orientation/build angle on the dimensional accuracy of full-coverage dental restorations manufactured using digital light-processing technology (DLP-AM).

**MATERIALS AND METHODS:** A full dental crown was digitally designed and 3D-printed using DLP-AM. Nine build angles were used: 90, 120, 135, 150, 180, 210, 225, 240, and 270 degrees. The specimens were digitally scanned using a high-resolution optical surface scanner (IScan D104i, Imetric). Dimensional accuracy was evaluated using the digital subtraction technique. The 3D digital files of the scanned printed crowns (test model) were exported in standard tessellation language (STL) format and superimposed on the STL file of the designed crown [reference model] using Geomagic Studio 2014 (3D Systems). The root mean square estimate (RMSE) values were evaluated, and the deviation patterns on the color maps were further assessed.

**RESULTS:** The build angle influenced the dimensional accuracy of 3D-printed restorations. The lowest RMSE was recorded for the 135-degree and 210-degree build angles. However, the overall deviation pattern on the color map was more favorable with the 135-degree build angle in contrast with the 210-degree build angle where the deviation was observed around the critical marginal area.

**CONCLUSIONS:** Within the limitations of this study, the recommended build angle using the current DLP system was 135 degrees. Among the selected build angles, it offers the highest dimensional accuracy and the most favorable deviation pattern. It also offers a self-supporting crown geometry throughout the building process.

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