Review Article

COMPUTER ASSISTED VS CONVENTIONAL FIXED PROSTHESIS: A REVIEW

Norouzi H,[1] Nokar S[2]

1. *Department of Prosthodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, IRAN.*
2. *Associate Professor, Department of Prosthodontics, Dental Research Center, Tehran, Tehran University of Medical Sciences, IRAN.*

Abstract

Computers have had a meaningful impact on the dental office and dental practice leading to significant changes in communication, financial accounting, and administrative functions. C continuous development in dental processing ensures new opportunities in the field of fixed prosthodontics in a complete virtual environment without any physical model situations. The aim was to compare fully digitalized workflows to conventional and/or mixed analog-digital workflows for the treatment with tooth borne or implant-supported fixed reconstructions. Traditionally, the standard treatment approach is conventional impression technique. The application of intraoral digital scanner and CAD-CAM technologies has to be considered a valid alternative to conventional impression and prostheses fabrication procedures. The CAD-CAM overcomes to the main physical limitations of conventional impression technique including the dimensional changes of impression materials, the expansion of dental stone and hand made errors. So, the aim of the current research was to determine dimensional accuracy of intraoral and laboratory scanners using the PubMed and Medline database English literature by the terms "affecting factors", "accuracy", digital impressions". Compared to a conventional impression, intraoral digital scanning can save time and steps for dentists and technicians. Steps eliminated at the dental office include tray selection, material dispensing, material setting, material disinfection, and impression packaging and shipping. Steps eliminated at the lab include plaster pouring, die cutting, trimming, articulation, and extraoral scanning.

Key words: CAD-CAM prosthodontics, Dental implant, Digital impression, Dimensional accuracy, Intraoral scanners, Laboratory scanners, Precision.

Introduction

Computerized systems have more recently generated increasing diversity of application for the delivery of patient treatment. Digital impression systems play deniable role on accuracy of dental implant impression. Three-dimensional scanning of an oral cavity in Orthodontics and restorative dentistry is required for an accurate mapping which sequels in the elimination of long procedures. However, based on the researches, there are several factors such as impression technique, splinting the impression coping, surface treatment of impression copings, the depth and angulation of implants, and the connection type and length which effect accuracy of conventional implant impressions. Computer-Aided Design/Computer- Aided Manufacturing (CAD-CAM) is a new technique using a digital impression intraoral to fabricate the master model, design and final restoration.[1] This method improves physical limitations such as the dimensional changes of impression materials, the expansion of dental stone and technician provided errors on during restoration fabrication, which decreases cost and processing time.[2] The application of intraoral digital scanner and CAD-CAM technologies has to be considered a valid alternative to conventional impression and prostheses fabrication procedures.[3] Digital impression has acceptable precision in detecting the finishing line and implant position detection. That is due to the use of dedicated impression transfers called scan bodies, whose surfaces are universally known and saved in digital libraries.[4] So, the main purpose of this study research was to comparison conventional and cad cam technique to making fixed prosthesis using of intraoral and laboratory scanners using the PubMed and Medline database English literature by the terms "CAD-CAM prosthesis", "accuracy", digital implant impressions", "CAD-CAM prosthesis", "intraoral scanning systems", "Marginal discrepancy". Many clinical and laboratory procedures are related to achieving passive fit; this includes impression techniques, definitive cast production, and prosthesis fabrication.[5] The general accuracy of prosthetic frameworks depends on the success of the individual steps of the production process, from implant alignment, impression technique and material, framework design and fabrication to the experience of the clinician and technician. The term accuracy refers to the precision and trueness of a system, device or technique.

Material and Methods

The keywords used for the literature search for this review was peer-reviewed articles following key-words: affecting factors × accuracy × CAD CAM prosthesis × digital implant impressions. Among them, the papers were fit the criteria selected and available full-text articles read. Related articles were also scrutinized. Hand search was also driven. The search was carried out using Biological Abstracts, Chemical Abstracts, and the data bank of the PubMed and Medline database updated to 2017. The references found in the search were then studied in detail.

CAD/CAM technologies

Use of the CAD-CAM technologies to manufacture prosthetic frameworks on dental implants is noticeably increasing. This method requires that the position of the implants within the dental arch be acquired and displayed in a virtual model.[6] As the current technologies do not facilitate recording the implant itself, a scan body is positioned on the implant and optically scanned. The scan is acquired intra orally or extra orally using a stone cast poured from a conventional implant impression using implant impression posts.[6] To date several CAD-CAM Systems produced such as Cerec 3. Vita CEREC Mark II (Vita Zahnfabrik) Dicor MGC (Dentsply, L. D. Caulk Division) Procera AllCeram. (Nobel Biocare, Goteborg, Sweden), Celay (Mikrona, Spreitenbach, Switzerland). The ones mostly used at present are: CEREC system 3 (Sirona), Lava system (3M), Procera system (Nobel Biocare), Everest system (KAVO). Cercon system (Degudent, Densply International Company), hereafter described, was used for the resolution of the clinical cases here exposed. CAD-CAM systems are available in 3 different production approaches, depending on their location: chairside, dental laboratory, or centralized milling center. In the first approach, the digitalization instrument is an intraoral camera, which substitutes for a conventional impression. The milling procedures can be undertaken in a dental office when the restorative material is resin, nanoceramic resin, or lithium disilicate blocks, but when the restorative material is presintered zirconia, dental laboratory equipment must be used. In the second approach, a definitive cast is fabricated from a conventional impression and is transferred to the laboratory.[7] Three-dimensional data are produced from the definitive die with a scanner, and the data are processed with design software and sent to the milling machine. In the third approach, data sets produced in the dental laboratory are sent to the production center for fabrication with the CAD-CAM device, and the restorations are returned to the dental laboratory.[7] When CAD-CAM technology is used to make all-ceramic restorations, the fit can be set for each abutment tooth with software that customizes the marginal gap for the clinical situation.[7] The ability of CAD/CAM technology to implement the predetermined fit depends on the accuracy of the entire system including the scanning device, milling material, and milling unit. It also relies on exact dimensional prediction to compensate for sintering shrinkage. The CAD-CAM technique is an economical and reproducible method which has been demonstrated to improve marginal fit.[7] Most used dental CAD system is listed in table.

CAD System	Manufacturer	File output
3Shape	3Shape	Propietary/STL
ARTI / Modelliere	Zirkonzahn	STL
CeraMill	Amann Girbach	STL
Cercon Eye/Art	Dentsply	Propietary
Cerec	Sirona	Propietary
Delcam	Delcam	STL
Dental Wings	Dental Wings	STL
E4D	Planmeca	Propietary/STL
Exocad	Exocad	STL
InLab	Sirona	Propietary/STL
Procera	Nobel Biocare	Propietary/STL

Figure 1: Mostly used CAD system

Cercon

The Cercon System is usually referred to as a CAM system which have no a CAD component. The system scans the wax pattern and mills a zirconia bridge coping from presintered zirconia blanks. Then coping sintered in the Cercon heat furnace at 1350°C for 6-8 hours. A leucite-free and low-fusing Cercon Ceram S veneering porcelain is commonly applied to provide the esthetic contour. Based on the literature the marginal discrepancy for Cercon all-ceramic crowns and fixed partial dentures was 25-30 µm.

Lava

This system introduced in 2002, which includes a laser optical system which can scan the digital information of the multiple abutment margins and edentulous ridge. The Lava CAD software automatically finds the margin and suggests a pontic. It is reported framework is designed larger to compensate for sintering shrinkage. Using this system, the semisintered zirconia block can properly size and then select for milling. Milled frameworks then undergo sintering to attain their final dimensions, density, and strength. The system has numerous shades to color the framework for maximum esthetics.

CEREC

CEREC using an optical scan a couple charged device camera, and a 3D digital image can use for prepared tooth scan. The restoration is then designed and milled. With the newer CEREC 3D, the operator can take multiple images for clinicians to prepare multiple teeth in the same quadrant and create a virtual cast for the entire quadrant. The designed restoration can have transmitted to a remote milling unit for fabrication. One of the advantages of this system is that the software can virtually seat the restoration back into the virtual cast to provide the adjacent contact while designing the next restoration.[8]

Procera

Procera/All Ceram was introduced earlier than systems above. Procera uses an innovative concept for generating its alumina and zirconia copings. This system scans 3D images of the master dies that are sent to the processing center via modem. The processing center then generates enlarged dies designed to compensate for the shrinkage of the ceramic material. Copings are manufactured by dry pressing high-purity alumina powder against the enlarged dies. The complete procedure for Procera coping fabrication is very sensitive because the degree of die enlargement must precisely match the shrinkage produced by sintering the alumina or zirconia.[9]

Benefits of intraoral scanning systems

Several advantages introduced by digital intraoral scanning which briefly discussed here. Intraoral scanning systems have satisfactory quality by quick and easy scanning procedure. Also, they don't need to prepare an impression tray or remix the impression. Some intraoral scanning systems now produce true-color models, which allows for the improvement of the capture of elements such as dental structures and gingival texture. This enables, for instance, the analysis of color changes in teeth and gingiva, which is not possible with a plaster model. Some systems also permit selective tooth shade measurements.[10] Intraoral scan systems are expensive. The current prices mean that the cost–benefit ratio is not yet feasible for many patients.[11] The possibilities of digital impression-taking using intraoral optical impression systems today extend far beyond single-tooth restorations. Depending on the system, the user is offered a comprehensive range of application s that includes the prosthetic reconstruction of implants and the design of orthodontic appliances.[12]

Factors affecting accuracy of digital implant impressions

An increasing number of dentists are using intraoral scanners in their daily practice as an alternative to conventional physical impression taking.[10] For short-span tooth or implant-based reconstructions within the same quadrant the risk of producing errors in the digitizing process is considered low, as the scan sensor captures a relatively large surface in relation to the total area required.[11] Several in-vitro studies have shown high levels of accuracy using different intraoral scanners.[13] Digital impression techniques at the implant level have become available and have played an important role in the development of a fully digital workflow for implant restorations.[5] Digital impressions could offer some advantages over traditional implant impression procedures with elastomeric impression materials, such as reduced risks of distortion during impression and cast fabrication, improved patient comfort and acceptance (especially in patients with a strong gag reflex), and lower costs resulting from the direct data output as a complete digital workflow. On effect of implant divergence on the accuracy of definitive casts created from traditional and digital implant-level impressions Lin *et al*[5] reported the digital method created less accurate definitive casts compared to the conventional pathway with the tested two-implant scenarios. Also, Chew *et al* revealed the 3D accuracy of implant impressions varied according to the impression technique and implant level. The tissue level implant system had comparable mean linear and absolute angular distortions to the bone level implant but exhibited the smallest standard deviations.[13] Van der Meer *et al*[14] compared the in vitro accuracy of the Cerec AC Bluecam, LAVA C.O.S., and iTero intraoral scanners and concluded that LAVA C.O.S. provided the most consistent and accurate scans. Also, researchers investigated the accuracy of various intraoral scanners and the effects of operator experience, implant angulation, and depth.[15] The scanners tested were LAVA C.O.S., iTero, 3D Progress (MHT) and ZFX Intrascan (Zimmer Dental). Accuracy consists of precision and trueness. Precision describes how close repeated measurements are to each other.[10] Scanner with higher precision has correlated to a more repeatable and consistent scan. Trueness describes how far the measurement deviates from the actual dimensions of the measured object. Scanners with high trueness indicates that the scanner delivers a result that is close or equal to the actual dimensions of the object being scanned.[10] It is reported to complete arch treatments conventional impressions were significantly more accurate than digital impressions.[10] Also the precision of intraoral scanners decreased with an increasing distance between the scan bodies.[16] Factors negatively influence restoration outcomes are including distortion of impressions or models, volumetric changes in the manipulation of impression materials and stone models, abrasion or fracture of the models shipment of cases. Digital impressions are not susceptible to changes in accuracy once they are recorded and electronic transmission of the files to dental laboratories is completed efficiently with no loss of accuracy.

Accuracy between digital and conventional impression

Marginal and internal fitness are essential criteria for the success of FDPs. A high level of impression accuracy is important to assist the fabrication of a precise restoration.[11] The all-ceramic crowns manufactured from digital impressions demonstrated narrower marginal gaps than the ones from conventional impressions. This outcome was mainly explained by the working procedure difference: in the conventional group, silicone impressions and plaster models were made, whereas in the digital group, the crowns were designed and manufactured directly from the scanning data without needing to fabricate an intermediate model.[11] In a study, Anh *et al* revealed the iTero® and Trios® systems showed no statistically significant difference in precision among models with differing degrees of tooth irregularity. However, there were statistically significant differences in the precision of the 2 scanners when the starting points of scanning were different. The iTero® scanner (mean deviation, 29.84 ± 12.08 mm) proved to be less precise than the Trios® scanner (22.17 ± 4.47 mm). The precision of 3D images differed according to the degree of tooth irregularity, scanning sequence, and scanner type. However, from a clinical standpoint, both scanners were highly accurate regardless of the degree of tooth irregularity.[17] Therefore, the accuracy of most clinical intraoral scanners could be considered very high. Lower precision from direct scanning can be caused by many factors, such as limited scanner operation because of the intraoral structure, a limitation of the incident angle of the scanning laser light, the presence of saliva, and increase in hand tremor due to difficulty in handling the equipment. So, it is considered that further experimental studies measuring accuracy by directly scanning arches possessing irregular tooth arrangements, such as in this study, would have significance.[17] Seelbach *et al*[11] compared the accuracy of full ceramic crowns obtained from intraoral scans using Lava COS, CEREC AC, and iTero systems with two different conventional impression techniques. The mean margin fit of crowns was 48 ± 25 µm for Lava COS, 30 ± 17 µm for CEREC AC, 41 ± 16 µm for iTero, 33 ± 19 µm for single-step putty wash technique and 60 ± 30 microns for the two-step putty wash technique. The mean internal fit was 29 ± 7 µm for Lava COS, 88 ± 20 µm for CEREC AC, 50 ± 2 µm for iTero, 36 ± 5 µm for single-step putty wash technique, and 35 ± 7 for two-step putty wash technique. No significant difference observed in the margin fit or internal adaptation of the crowns using any of the techniques. Brawek *et al*[18] also compared the fit of Lava DVS crowns fabricated using digital impressions from the Lava COS system and Vita Rapid Layering Technique crowns using digital impressions with CEREC AC system. Fourteen patients requiring a posterior crown had two crowns fabricated using each digital impression technique. A replica technique was used to measure clinical crown adaptation and fit for both crowns on each preparation. The Lava COS crowns had a significantly better mean marginal fit compared to the CEREC crowns however the difference in fit may not be clinically relevant since both were well below the accepted threshold of 120 µm. Accuracy also depends on how well the scanner is manufactured. Larger 3D scanner manufacturers typically have better production facilities and tools and can automate parts of the assembly steps including outgoing quality inspection. They can thereby reduce product variability to lower levels than those achievable through human manufacturing operations alone. Larger manufacturers are also usually financially stable and are thus most likely to remain in business and provide long term support.[18]

Marginal discrepancy

Marginal discrepancy can be defined as the vertical distance from the finish line of the preparation to the cervical margin of the restoration. This is an important component of fixed restorations, as a large marginal opening may lead to more plaque accumulation, micro leakage, recurrent caries, and periodontal disease.[19] Historically, high noble cast restorations have shown smaller marginal discrepancies than base metal alloy, metal ceramic or ceramic restorations. Some studies have reported marginal gaps smaller than 10 µm for high-palladium-content alloys and for gold-platinum-palladium alloys, whereas other studies have found marginal discrepancies between 18 and 46 µm.[6] Marginal openings from 50 to 120 µm are considered clinically acceptable in terms of longevity. Miss fitting framework will generate stress on the implants which may have a biological effect on the bone-implant interface.[14] Also prosthetic complications as screw loosening or fracture may be related to ill-fitting framework fit. A finite element analysis study has also shown that passive fit will distribute masticatory forces more evenly over the implants.[14] As the impression procedure is at the origin of the workflow, the data collected during this phase is important as errors introduced in this phase will reverberate in the rest of the workflow. An intra-oral scanner could overcome some of the errors associated with traditional impression taking and cast production as digital output data can be fed directly into a digital workflow. The assessment of the accuracy of traditional impression materials has primarily been performed using linear or 3D measurements. In comparison to metal-ceramic restorations, the tooth reduction is generally more for all-ceramic restorations due to the need for uniform 1mm wide rounded shoulder or wide chamfer margin design. To allow for an even thickness for adequate strength, the tooth must be prepared more proximally and lingually than for conventional metal-ceramic restorations. The shoulder should be rounded internally to reduce stresses within the tooth and ceramic but should have a 90° angle at the external cavosurface margin.[6] If the shoulder preparation has a sharp axiogingival internal line angle, as in a conventional metal-ceramic preparation, the scanning device may not be able to capture the area of the axiogingival internal line angle accurately.[6] Increasing the convergence angle (taper) of tooth preparations has been reported to improve the internal and marginal adaptation of zirconia-based crowns.[6] This reduction in strength is likely due to small flaws that are created during the milling process. Marginal chipping is still a concern for some ceramics, as this directly affects marginal accuracy and fit. The design of frameworks for layered all-ceramic crowns is typically a coping of uniform thickness over the preparation. However, chipping of the layering ceramic in unsupported areas such as the marginal ridges can occur in load bearing regions of the mouth. There is still debate about whether the design of layered all-ceramic restorations should mimic the guidelines for metal-ceramic frameworks.[6]

Clinical production of crown

The design of a crown with a CAD system is an interesting operation in that it clearly shows the superiority of the CAD-CAM approach over medical imaging techniques such as magnetic resonance imaging or scanners. Three-dimensional medical imaging does not go beyond the development in space of an observed image.[19] Early researchers explaining that such a rep re sensation was of limited interest, and that the power of a medical application for CAD-CAM would be in its ability to design a piece that would replace what was being observed. In dental CAD-CAM, there is a big difference between the initial object (the preparation) and the final object (the prosthesis). It is possible to go beyond the stage of a mere reproduction because prosthetic rules can be integrated in the software.[19] Special software is provided by the manufacturers for the design of various kinds of dental restorations. With such software, crown and fixed partial dentures (FPD) frameworks can be constructed on the one hand; on the other hand, some systems also offer the opportunity to design full anatomical crowns, partial crowns, inlays, inlay retained FPDs, as well as adhesive FPDs and telescopic primary crowns.[20] The software of CAD/CAM systems presently available on the market is being continuously improved. The latest construction possibilities are continuously available to the user by means of updates. The data of the construction can be stored in various data formats.[19] The systems available on the market are differentiated mostly in their construction software. While many systems emphasise an indication spectrum that is as broad as possible, other manufacturers place emphasis on intuitive use and user-friendliness. With the use of digital intraoral impression systems, the complete elimination of a physical model based on a conventional impression is technically possible. Additionally, a master cast can be fabricated using three-dimensional printing systems with a similarly high accuracy. The digital information from the intraoral scanner can be sent to the printing facility without the risk of losing any accuracy. Thus, the number of manual steps and some physical shortcomings such as distortion of the impression material may be reduced in the fabrication workflow. Different digital intraoral impressions do not show higher accuracy and precision compared to highly accurate conventional impression systems in-vitro, as recently reported. However, the elimination of processing steps within the digital workflow may provide greater reliability.

Design of the crown

The use of CAD-CAM technology can not only shape restorations by milling, but also allows for quality control of the dental devices by designing optimal shapes based on material characteristics by CAD; thus, preventing degradations such as residual strain due to the effects of processing, and ultimately providing reproducible processing. When milling a prefabricated ceramic block, the quality of which has been confirmed beforehand by the manufacturer, there are almost no internal defects in the milled products, whereas conventional powder build-up and baked porcelain products usually contain internal porosity. According to clinical and in vitro studies using finite element and fractographic analyses, the primary causes of failure reported for all-ceramic FPDs differed from those reported for the metalceramic FPDs. Fractures of ceramic FPDs tended to occur in the connector areas because of the concentrated stress. Therefore, the design of the connector, particularly the dimensions, must be made independently depending on the type of ceramic material used for the framework. CAD better guarantees the durability and reduces the risk of fracture. Processing data can be saved and followed up during the functional period for the device. Even if evidence is required to predict the prognosis of restorations during the functional period, these features detailed here have not been available with the conventional production systems in general use. Therefore, quality control of dental restorative and prosthetic devices using CAD/CAM technology will be a factor with increasing importance in the future with an aging society because such restorative and prosthetic devices will need to function for longer periods as part of the body.

Repeatability between digital and conventional impressions

The quality of repeatability to some extent reflects the authenticity and stability of a scanning device. Intraoral digital scanning is performed in a process where the scanner is held via a clinician. The digital impression repeatability should meet a satisfactory level to increase the impression quality.[21] In this regard, 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.[22] Two factors influence the accuracy: trueness, which describes the deviation of the impression geometry from the original geometry, and precision, which describes the deviation between repeated impressions rather than to the original geometry.[23] Precision reflects the degree of deviation between impressions within a test group. The current reference standard for a complete-arch intraoral impression is the conventional impression made with rigid impression trays and elastomeric impression material. Numerous impression constituents and methods have been examined in vitro and show a high level of accuracy. The trueness of conventional impressions is usually tested through measuring the alteration in linear distance among an original master model and a gypsum cast derived from the impression.[24] Because of limitation of this method via intraoral, researchers used indirect approach and verify the impression trueness through determining the fit of the definitive restoration based on that impression.[25] The accuracy of digital impression for various clinical applications is controversial despite numerous researches revealed digital and conventional impressions produce restorations of equal quality.[26] The accuracy of digital casts is best evaluated by superimposing the impression on the original .

Other factors

A major factor lab should consider is the number of indications that the scanner supports, e.g. long span bridges, Customized Abutments, accurate Implant Bars and Removable Partial Dentures. Too many low-end non-upgradable scanners will only support the very basic indications and thus limit the lab and represent a weak investment long-term. The scanner's supported indications cannot be viewed on their own. The CAD software running with the scanner will need to support them as well.[26]

Conclusion

Currently, there is no common standard for measuring and validating the accuracy of dental scanners. Most scanner manufacturers do not even disclose how they measure their accuracy claims. The science of high accuracy measurement - metrology- applies reference objects with accuracies much higher than the scanner. These objects can only be manufactured by specialized accredited companies or metrology laboratories.

References

1. Gargari M, Ottria L, Morelli V, Benli M, Ceruso FM. Conservative zirconia-ceramic bridge in front teeth. Case report. Oral and Implantol 2015;7(4):93-98.
2. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dent Mater J 2009;28(1):44-56.
3. Ali AO. Accuracy of Digital Impressions Achieved from Five Different Digital Impression Systems. Dentistry. Omics International 2015;5(5):1-6.
4. Diamanti MV, Del Curto B, Barlattani A, Bollero P, Ottria L, Pedeferri M. Mechanical characterization of

an innovative dental implant system. J Applied Biomater Biomech 2009;7(1):23-28.
5. Lin WS, Harris BT, Elathamna EN, Abdel-Azim T, Morton D. Effect of implant divergence on the accuracy of definitive casts created from traditional and digital implant-level impressions: an in vitro comparative study. Int J Oral Maxillofac Implants 2015;30:102–109.
6. Beuer F, Stimmelmayr M, Gueth JF, Edelhoff D, Nsumsnn M. In vitro performance of full-contour zirconia single crowns. Dent Materials 2012;28(4):449–456.
7. Rosentritt M, Behr M, Kolbeck C, Handel G. Marginal integrity of CAD/CAM fixed partial dentures. Eur J Dent. 2007;1(1):25-30.
8. Estafan D, Dussetschleger F, Agosta C, Reich S. Scanning electron microscope evaluation of CEREC II and CEREC III inlays. Gen Dent 2003;51(5):450-454.
9. Posselt A, Kerschbaum T. Longevity of 2,328 chairside Cerec inlays and onlays. Int J Comput Dent 2003;6(3):231-248.
10. Ender A, Attin T, Mehl A. In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. J Prosthet Dent 2016;115(3):313-320.
11. Seelbach P, Brueckel C, Wöstmann B. Accuracy of digital and conventional impression techniques and workflow. Clin Oral Investig 2013;17(7):1759–1764.
12. Patzelt SB, Emmanouilidi A, Stampf S, Strub JR, Att W. Accuracy of full-arch scans using intraoral scanners. Clin Oral Investig 2014;18(6):1687–1694.
13. Katsoulis J, Mericske-Stern R, Rotkina L, Zbaren C, Enkling N, Blatz MB. Precision of fit of implant-supported screw-retained 10-unit computer-aided-designed and computer- aided- manufactured frameworks made from zirconium dioxide and titanium: an in vitro study. Clin Oral Implants Res 2014;25(2):165–174.
14. van der Meer WJ, Andriessen FS, Wismeijer D, Ren Y. Application of intraoral dental scanners in the digital workflow of implantology. PLoS One 2012;7(8):e43312.
15. Gimenez B, Ozcan M, Martinez-Rus F, Pradies G. Accuracy of a digital impression system based on active wavefront sampling technology for implants considering operator experience, implant angulation, and depth. Clin Implant Dent Relat Res 2015;17(suppl1):e54–e64.
16. Flügge TV, Att W, Metzger MC, Nelson K. Precision of dental implant digitization using intraoral scanners. Int J Prosthodont 2016;29(3):277-83.
17. Anh J, Park JM, Chun YS, Kim M, Kim M. A comparison of the precision of three-dimensional images acquired by 2 digital intraoral scanners: effects of tooth irregularity and scanning direction. Korean J Orthod 2016;46(1):3-12.
18. Brawek PK, Wolfart S, Endres L, Kirsten A, Reich S. The clinical accuracy of single crowns exclusively fabricated by digital workflow - the comparison of two systems. Clin Oral Investig 2013;17(9):2119-25.
19. Kohorst P, Brinkmann H, Dittmer MP, Borchers L, Stiesch M. Influence of the veneering process on the marginal fit of zirconia fixed dental prostheses. J Oral Rehabil 2010;37(4):283-91.
20. Sjögren G, Molin M, van Dijken JW. A 10-year prospective evaluation of CAD/CAM-manufactured (Cerec) ceramic inlays cemented with a chemically cured or dual-cured resin composite. Int J Prosthodont 2004;17(2):241-246.
21. Galhano GA, Pellizzer EP, Mazaro JV. Optical impression systems for CAD-CAM restorations. J Craniofac Surg 2012;23(6):e575-e579
22. Akyalcin S, Cozad BE, English JD, Colville CD, Laman S. Diagnostic accuracy of impression-free digital models. Am J Orthod Dentofacial Orthop 2013;144(6):916-22.
23. Chandran DT, Jagger DC, Jagger RG, Barbour ME. Two- and three-dimensional accuracy of dental impression materials: effects of storage time and moisture contamination. Biomed Mater Eng 2010;20(5):243-9.
24. Haim M, Luthardt RG, Rudolph H, Koch R, Walter MH, Quaas S. Randomized controlled clinical study on the accuracy of two-stage putty-and-wash impression materials. Int J Prosthodont 2009;22(3):296-302.
25. Almeida e Silva JS, Erdelt K, Edelhoff D, Araújo É, Stimmelmayr M, Vieira LC *et al*. Marginal and internal fit of four-unit zirconia fixed dental prostheses based on digital and conventional impression techniques. Clin Oral Investig 2014;18(2):515-23.
26. An S, Kim S, Choi H, Lee JH, Moon HS. Evaluating the marginal fit of zirconia copings with digital impressions with an intraoral digital scanner. J Prosthet Dent 2014;112(5):1171-5.

Corresponding Author

Dr. Saied Nokar
Associate Professor,
Department of Prosthodontics,
Dental Research Center,
Tehran University of Medical Sciences,
Tehran, IRAN
Email id: snir2500@yahoo.com