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Digital Versus Conventional Impressions for Fixed Prosthodontics: A Review

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Abstract

With the application of computer-aided design and computer-aided manufacturing (CAD/CAM), the notion of intra-oral digital imprints was proposed in the early 1980s. Dentists have paid close attention to it, and it has been employed to fabricate dental prostheses in several situations. Fabrication of dental prothesis using digital intra-oral impressions have shown in few published studies that it has demonstrated significant advantages over traditional impressions. This review discusses the comparison between conventional and digital impression techniques regarding the following: Accuracy, patient acceptance and operator acceptance. Also, it discusses different categories and principals of digital impression techniques.

Keywords: CAD/CAM, Digital Impression, Conventional Impression

Introduction

An accurate cast is required for the fabrication of a single crown or partial fixed prosthesis which can be achieved by either conventional or digital impression techniques. Evaluation of the level of quality of fixed restorations could be achieved by 2 main clinical factors: internal and marginal fit [1-3]. Measurement of accuracy fit has been found to be one of the most critical elements in determining clinical success [1,4]. However, some studies limited their assessment to the marginal accuracy. Measurements of distinct points of sectioned tooth crown assemblies was found to be very helpful in evaluating the internal fit of crowns and FPDS [5,6].

One of the most crucial criterions for evaluating clinical success of fixed restorations is the marginal fit [1,4,7]. An acceptable marginal discrepancy ranged from 34 to 119 um [8]. Deficiency of marginal fit can lead to dissolving of the luting cement and plaque retention, secondary caries, retention loss of the restoration, periodontal and pulpal inflammation.

The internal fit is also considered as a criterion for success of crowns as it influenced the seating of the crown and consequently on the marginal fit. It has been shown that 25 um thick die spacer can increase the restoration's retention and improve the crown's seating by 25% [9]. Also, because of the higher distortion of the porcelain into the cement layer, increasing cement thickness has been demonstrated to reduce the fracture resistance of ceramic restorations. Improper internal fit can lead to reduced fracture toughness, missing rotation stability, loss of axial retention [10].

Conventional impression is still the most common method for duplicating intraoral anatomy and transferring this information to a dental laboratory for indirect dental restoration manufacturing. The most often utilized conventional impression materials for generating definitive impressions in fixed prosthodontics are polyether (PE) and polyvinyl siloxane (PVS). These materials have a high degree of precision and dimensional stability, as well as a long history of use in fixed prosthodontics [11-15]. Material distortion and affect accuracy could be a result of Temperature fluctuations, time between impression forming and pouring, gypsum product surface wettability, and disinfection methods are all factors to consider [15,16]. Also, Laboratory procedures for prosthesis manufacture, such as waxing, investing, casting, or pressing, might cause dimensional errors and influence the final restoration's fit. In addition to using a die hardener and die spacer [17,18].

Digital impression and crown fabrication techniques have been developed as new innovations. Accurately fitted milled restorations can be achieved now by Advances in computer-aided design and computer-aided manufacturing (CAD-CAM) technology together with various intraoral scanning (IS) systems were developed and are currently in use today therefore: the utilization of a digital workflow for prosthesis production is becoming more common. Restorations have been made using CAD/CAM technology especially ceramic crowns and fixed prothesis, since 1980s [19]. When compared to traditional impressions, digital impressions are gaining in popularity and acceptance among practitioners. Digitization of entire quadrants and jaws, as well as extra scanning and alignment of antagonistic teeth are now doable by most of the digital systems. Improved patient and operator acceptance, as well as possible cost and time savings are from the potential benefits of the IS process. Elimination of laboratory production processes that may cause mismatch, reduced transit time between clinic and dental laboratory, and reduced patient discomfort are only a few of the advantages it has over traditional approaches [20-24]..However, it has been shown that conventional impressions are having high level of detail accuracy are now in use. Taking into consideration that extra-oral scanning for a plaster cast made from conventional silicone impression is accurate, although the deformation of the impression materials and plaster is making the process of conventional impression hard to reproduce [25].

CAD/CAM Systems

Three primary components make up CAD/CAM systems: (1) a data acquisition unit that collects data from the prepared tooth in the oral cavity and converts it to virtual impressions (an optical impression is created directly or indirectly at this point); (2) software for designing virtual restorations and adjusting all milling parameters; and (3) a computerized milling device that fabricates the restoration from various restorative materials [25]. The first two parts of the system play roles in the CAD phase, while the third is responsible for the CAM phase. CAD/CAM systems can be categorized into 2 systems based on their capacity to share digital data: open and closed [26]. Closed systems offer all the 3 parts of the CAD/CAM systems including: data acquisition, software, and the milling machine. But there isn't any interoperability between the various systems. Other CAD/CAM systems' original data is adopted by open systems.

Many limitations have been found in intraoral digital impression. Some systems need powder spraying on the tooth surface which may be accompanied by inhomogeneous powder thickness, also scanner displacement may affect the scanning accuracy.

This article reviews the properties of the most currently used intra-oral digital and focuses on categories, principals, and operation. we mainly discuss the difference between conventional and digital intra-oral impressions.

Digital Impressions

Different Types of Scanners

There are two available types of scanners intra-oral optical scanners and laboratory scanners. Intra-oral optical scanners could be single image or video camera and laboratory scanners could be optical scanners or mechanical scanners. In addition, scanners could be divided into contact scanners in which there is physical contact of the probe with the object being copied eg: procera and non- contact scanners in which there is not any physical contact only depending on radiation, ultrasound and light which are based on multiple different concepts [27].

Different Concepts

Different available concepts including active wave front sampling, triangulation, parallel confocal and stereophotogrammetry [28].

Active wave front sampling in which there is rotation around the optical axis by a single off- axis aperture. As a result, the picture of a target point will appear to spin on the image plane. In fact, only a single image is recorded on the image plane at each aperture point, preventing any overlapping issues. Triangulation is a method in which knowing the positions and angles of two points of view that the detector can produce so that the position of a point of a triangle can be estimated. Parallel confocal is including up and down movement of light which leads to picture acquisition from various depths, both focused and defocused from selected depths so that the tooth image is rebuilt from a series of photos taken at various focal lengths and aperture settings. Stereophotogrammetry is a technique that estimates all co-ordinates by algorithmic study of X, Y, and Z relying on passive light projection [28].

Any camera mainly depending on projection of light whether active or passive. Active light can be projected from the camera as white, red, and blue structured light. while passive light is using only ambient lightening illuminating intraoral tissue relying on the texture of the object [29].

Single image cameras are recording individual images of the dentition about 3 teeth in single image and assemble overlapping images into 3-D virtual image eg: Trios (3 shape), i-Tero (Align Technology), PlanScan (Plan-meca), CS 3500 (Carestream Dental LLC), and i-Tero (Align Technology). Video cameras are recording video “filming” eg: True Definition scanner (the most recent version of the Lava Chairside Oral Scanner, COS), Apollo DI (Sirona), and OmniCam (Sirona) technologies are all available [30].

Laboratory optical scanners are using projection of measuring light scanner under definite angle and record all the required data through digital sensor, while mechanical scanners are reading master cast mechanically utilising a ruby ball line by line on contact probe to get 3D measurements [31].

Scanning protocol could be pre-operative scanning which incorporates existing anatomical contours and occlusal planes into the final restoration or post-operative scanning in which the preparation is scanned, and CAD is derived from selected data points and may be combined with internal library of tooth anatomic designs. Scanning path could be one way or s-sweep, a certain path should be followed to increase accuracy. The scanner should be placed at the center of the acquisition area with proper fluid control, centralized tooth should be maintained, and the distance should be 5-30 mm depending on the scanner [31].

Types, Operating Characteristics and Principales

The main currently available intra-oral digital impression techniques include CEREC, Lava C. O. S. System, iTero, E4D, and TRIOS. The difference between them is in the working principal, the necessity of powder coat spraying, light source, output file format and operative process.

CEREC System

The CEREC 1 system (Sirona, Bensheim, Germany) was the first intra-oral digital imprint system to hit the market in 1987. This technology is based on the “triangulation of light” principle, which focuses the intersection of three linear light beams on a specific location in three-dimensional space. The accuracy of scans is reduced by the effect of uneven light dispersion through certain surfaces. Production of uniform light dispersion could be obtained by the use of a titanium dioxide powder coating that is opaque which helps to improve scan accuracy [32].

CEREC's fourth-generation device, known as CEREC AC Bluecam, is now the most reliable. The light source for the images is a type of visible blue light emitted by an LED blue diode. The CEREC AC Bluecam can take a quadrant image in under a minute and the opposing image in a matter of seconds. While the most recent CEREC system, CEREC AC omnicam, was released in 2012. The omnicam imaging approach is a sort of continuous imaging in which a 3D model is created by the capture of data in a series of steps, Bluecam imaging, on the other hand, is a single image acquisition. Omnicam can be used for imaging full arch, quadrant, or even a single tooth. Omnicam is characterized by Scanning without powder and exact 3D photos with natural color. Scanning larger areas are done easier using powder free feature which is offered by omnicam. During digital scanning, the dentist is requested to hold the scanner and direct the camera toward the scanned area. The camera tip should be a few millimetres away from the tooth surface or should just brush up against it. Notable depth of field can be expressed by a seamless scanning protocol which includes sliding the to produce the successive data into a 3D model, gently move the camera head over the teeth in a single direction [33].

After completion of scanning, the preparation can be viewed on a computer monitor from any angle. There is an availability for cutting the to draw the finish line directly on the die image, use a virtual die on the effective model. An idealized restoration design is created using a CAD system called "Bigeneric" which will help the dentist to make variety of adjustments using several on-screen tools. As long as designing of the restoration have been finished, mounting of a block of ceramic or composite material in the milling equipment with the desired shade to begin the physical repair [33]. Another option is also available for fabrication of restoration is by transferring the data to the dental laboratory by CEREC Connect. Single crowns, veneers, inlays, inlays, and implant supported FPDs can all be made with this sort of intraoral scanner. Direct scanning for the prepared abutment or a scan body seated on the implant could be done by the dentist for crowns over implants [34].

Lava C.O.S. System

The LavaTM C.O.S. (Lava Chairside Oral Scanner; 3M ESPE, Seefeld, Germany) is an intraoral digital imprint device that was first launched in 2006. This system is mainly based on active wavefront sampling principle [35]. This principle as discussed before obtaining 3D data from a single-lens imaging system is referred to as. Twenty 3D datasets can be captured per second using three sensors by capturing at the same time clinical photos from various perspectives. Highly accurate image quality produced by Lava C. O. S. is a result of high data redundancy which is related to many overlapping pictures [36]. The Lava C. O. S. provided the smallest scanner tip only 13.2 mm wide [37]. Before scanning, a powder coating spray on the tooth surface is also required. same as CEREC AC Bluecam. The Lava C. O. S. exports data files in a formatted manner in most circumstances which necessitates its supporting CAD software and CAM device, but it is compatible with other software which makes it a semi-open system [38].

iTero System

iTero was launched to the market by Cadent Inc (Carstadt, NJ) in 2007. Based on the idea of parallel confocal imaging, the iTero system uses laser and optical scanning to capture images of intraoral surfaces and contours [39]. A total of 100,000 spots of laser light at 300 focal depths of the tooth structure can be collected during a single scan. These focal depth photos are split at a depth of about 50 metres. allowing for accurate storage of precise data for different tooth surfaces [40]. Parallel confocal scanning with the iTero system doesn't need coating for teeth surfaces with scanning powders. Moreover, this system includes a scanner, host computer, mouse, keyboard, and screen and employs a red laser as a light source [34,41].

Comparison Between Conventional and Digital Impression

The accuracy, patient acceptance, and operator preference of traditional and digital impressions are compared. The precision of impressions as well as the precision of the prosthesis can be used to assess the accuracy of digital and traditional impressions.

Accuracy

It can also be measured by assessing the die that was created from the impression. Factors influencing the marginal fit including: the size of the preparation area, and the placement of the finish line whether sub-gingival or supra-gingival, restorative material, impression material and technique and fabrication method [42]. A linear contact line or a gap-free transition between the restoration margin and the preparation margin is known as marginal fit. So, superior results have been shown when using digital impressions compared with the conventional impressions [43]. The ideal marginal fit for clinical success of complete crowns has long been thought to be 120 m or less. while the marginal discrepancy in CAD/CAM or copy-milling generated crowns is ranging between 60 μm and 300 μm. A niche for oral pathogens and saliva could result from wider marginal gaps resulting in periodontal inflammations, secondary caries, and cement disintegration, all of which shorten the restoration's longevity [44].

Twenty-five papers compared digital impressions to traditional impressions, with 16 claiming that digital impressions are superior to traditional impressions, even though clinically acceptable values for both are not optimal. Internal fit values for conventional impressions were slightly lower; this could be due to the workflow of this technique, which needs model construction, restoration, and then real processing [45]. In a digital impression, all these processes are removed. Because every step in the workflow causes an error, removing the master model and coping fabrication reduced the number of faults. Contraction and expansion of the imprint and model materials cause mistakes in traditional impressions. In comparison to internal fit mean values, marginal fit of digital impressions values is less precise [46].

By superimposition with the STL data set and scaned impression data, Lee SJ et al. examined the Precision of i-Tero; Cadent and iTero TM both exhibited acceptable results [47]. TRIOS accuracy was also investigated by Papaspyridakos P et al., who found that 3 shape via Superimposition using the STL data set and scaned impression data both showed acceptable results [48]. Berrendero S et al. used a Stereomicroscope with a built-in charge-couple device camera and Image analysis software to verify internal fit using Ultrafast Optical Sectioning technology at magnification factor [40], and the results showed that DI is better than CI [49]. Ender A et al., on the other hand, investigated the precision of CEREC Bluecam (CER; Sirona Dental Systems); CEREC Omnicam (OC; Sirona Dental Systems); Cadent iTero (ITE; Cadten Ltd); and Lava COS (LAV; Lava Dental Systems) [50].

Patient Acceptance

Is assessed by visual analog scales (VAS) and customized questionnaires. Patient comfort, gag response, queasiness, trouble breathing, pain, time perception, anxiety, taste irritation, and experience with the powdering method used for digital impressions are all criteria for evaluation. Digital impressions gained more acceptance by the patient as they are more concerned by the comfort and it is associated with reduced invasiveness, Segmental rescanning can also be used to correct missing or unsatisfactory portions. This cuts down on working time while also increasing patient satisfaction [46].

Benic GI et al. used visual analogue scales (VAS) to assess comfort using Lava (Lava COS; 3M ESPE), iTero (Align Technology Inc), and Cerec (CerecBluecam; Sirona Dental Systems GmbH) [51]. Patients' subjective convenience level, anxiety, unpleasant mouth taste, nauseous feeling, pain sensation during impression taking, patients' satisfaction with convenience, and speed were measured using Trios 3 IOS (3 Shape) by VAS and DI [52].

Operator Preference

Certain criteria, such as assessing working time, operator perception, and procedure difficulty, are also used to evaluate it. The digital impression technique's workflow takes less time. Even when a remake was required, the time spent rescanning the digital imprint was substantially shorter. The difficulties in scanning the interproximal contact areas and areas of reflection from the light source necessitated rescans. The level of difficulty in conducting the procedure was used to gauge operator perception, and the digital impression approach scored much lower. The intraoral scanner required less manipulation and had a shorter learning curve, and it appeared to be more user-friendly. Operators believed that digital impressions made it easier to fix missing or unsatisfactory areas, whereas the traditional process required more time [46].

Benic GI et al. assessed impression difficulty and time operator comfort while utilising Lava (Lava COS; 3M ESPE), iTero (Align Technology Inc), and Cerec (CerecBluecam; Sirona

Dental Systems GmbH by VAS-and found that CI prefers time. The traditional impression and the digital impression with iTero produced better results than the digital impression with Lava [53] in terms of clinician perception of difficulty. Employing VAS, Zitzmann NU et al. evaluated the level of difficulty, intraoral scanning efficacy, and time while using trios. DI has been discovered to be far superior [54]. Marti AM et al. investigated time utilizing LAVA COS through VAS and discovered that CI and DI produce similar results [55].

Conclusion

It was decided to adopt the intraoral digital imprint technique as a part of the CAD/CAM process. One of the main drawbacks of the digital impression techniques that need to be resolved is the deficits in repeatability, but the restorations fabricated using intraoral digital impressions have shown good accuracy compared to those fabricated with conventional impressions. Furthermore, intraoral digital impressions offer a significant advantage in terms of job productivity and material savings. The intraoral digital impression technology will become more widely used in dentistry as more advances are made.

References

1. Karlsson S (1993) The fit of Procera titanium crowns. An in vitro and clinical study. Acta Odontol Scand 51: 129-134.

2. Oden A, Andersson M, Krystek-Ondracek I, Magnusson D (1998) Five-year clinical evaluation of Procera AllCeram crowns. J Prosthet Dent 80: 450-456.

3. Besimo C, Jeger C, Guggenheim R (1997) Marginal adaptation of titanium frameworks produced by CAD/CAM techniques. Int J Prosthodont 10: 541-546.

4. May KB, Russell MM, Razzoog ME, Lang BR (1998)) Precision of fit: the Procera AllCeram crown. J Prosthet Dent 80: 394-404.

5. Martin N, Jedynakiewicz NM (2000) Interface dimensions of CEREC-2 MOD in- lays. Dent Mater 16: 68-74.

6. 0Sjogren G (1995) Marginal and internal fit of four different types of ceramic inlays after luting. An in vitro study. Acta Odontol Scand 53: 24-28.

7. White SN, Ingles S, Kipnis V (1994). Influence of marginal opening on microleakage of cemented artificial crowns. J Prosthet Dent 71: 257-64.

8. Christensen GJ. Marginal fit of gold inlay castings (1966) J Prosthet Dent 16: 297-305.

9. Eames WB, O'Neal SJ, Monteiro J, Miller C, Roan JD Jr, et al. (1978) Tech- niques to improve the seating of castings. J Am Dent Assoc 96:432-

10. Tuntiprawon M, Wilson PR (1995) The effect of cement thickness on the fracture strength of all-ceramic crowns. Aust Dent J 40: 17-21.

11. Christensen GJ (2008) Will digital impressions eliminate the current problems with conventional impressions? J Am Dent Assoc 139: 761-763.

12. Clancy JM, Scandrett FR, Ettinger RL (1983) Long-term dimensional stability of three current elastomers. J Oral Rehabil 10: 325-333.

13. Endo T, Finger WJ. Dimensional accuracy of a new polyether impression material (2006) Quintessence Int 37: 47-51.

14. Hondrum SO (2001) Changes in properties of non-aqueous elastomeric impression materials after storage of components. J Prosthet Dent 85: 73-81.

15. Thongthammachat S (2002) Moore BK, Barco MT 2nd, Hovijitra S, Brown DT, Andres CJ. Dimensional accuracy of dental casts: influence of tray material, impression material, and time. J Prosthodont 11: 98-108.

16. Rodriguez JM, Bartlett DW (2011). The dimensional stability of impression materials and its effect on in vitro tooth wear studies. Dent Mater 27: 253-258.

17. Campagni WV, Preston JD, Reisbick MH (1982) Measurement of paint-on die spacers used for casting relief. J Prosthet Dent 47: 606-611.

18. Gorman CM, McDevitt WE, Hill RG (2000) Comparison of two heat-pressed all-ceramic dental materials. Dent Mater 16: 389-395.

19. Mormann WH (2006) The evolution of the CEREC system. J Am Dent Assoc 137: 7S-13S.

20. Joda T, Bragger U (2015) Digital vs. conventional implant prosthetic workflows: a cost/time analysis. Clin Oral Implants Res 26: 1430-1435.

21. Lee SJ, Betensky RA, Gianneschi GE, Gallucci GO (2015) Accuracy of digital versus conventional implant impressions. Clin Oral Implants Res 26: 715-719.

22. Papaspyridakos P, Gallucci GO, Chen CJ, Hanssen S, Naert I et al. (2016) Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. Clin Oral Implants Res 27: 465-472.

23. Lin WS, Harris BT, Elathamna EN, Abdel-Azim T, Morton D (2015) 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 30: 102-129.

24. Ting-Shu S, Jian S (2015) Intraoral digital impression technique: a review. J Prosthodont; 24: 313-321.

25. Galhano GA, Pellizzer EP, Mazaro JV (2012) Optical impression systems for CAD-CAM restorations. J Craniofac Surg 23: e575-e579

26. Correia ARM, Sampaio Fernandes JCA, Cardoso JAP, et al. (2006) CAD-CAM: informatics applied to fixed prosthodontics. Rev Odontol UNESP 35: 183-189

27. Lee SJ, Kim SW, Lee JJ, Cheong CW (2020) Comparison of Intraoral and Extraoral Digital Scanners: Evaluation of Surface Topography and Precision. Dentistry journal 8: 52

28. Logozzo S, et al (2013) Recent advances in dental optics –Part I: 3D intraoral scanners for restorative dentistry. Opt Laser Eng.

29. Richert, Raphaël, et al. (2017) Intraoral Scanner Technologies: A Review to Make a Successful Impression. J Healthc Eng 2017: 8427595.

30. Tariq F (2016) Alghazzawi Advancements in CAD/CAM technology: Options for practical implementation journal of prosthodontic research 60: 72-84

31. Coronel CA, Valdiviezo ZOP, Naranjo OB (2019) Intraoral Scanning Devices Applied in Fixed Prosthodontics. Acta Scientific Dental Sciences 3.7: 44-51.

32. McLean JW, von Fraunhofer JA (1971) The estimation of cement film thickness by an in vivo technique. Br Dent J 131: 107-111.

33. Eames WB, O'Neal SJ, Monteiro J, Miller C, Roan JD Jr, et al. (1978) Tech- niques to improve the seating of castings. J Am Dent Assoc 96: 432-437.

34. Sjogren G (1995) Marginal and internal fit of four different types of ceramic inlays after luting. An in vitro study. Acta Odontol Scand 53: 24-28.

35. Clancy JM, Scandrett FR, Ettinger RL (1983) Long-term dimensional stability of three current elastomers. J Oral Rehabil 10: 325-333.

36. Endo T, Finger WJ (2006) Dimensional accuracy of a new polyether impression material. Quintessence Int 37: 47-51.

37. Sjogren G (1995) Marginal and internal fit of four different types of ceramic inlays after luting. An in vitro study. Acta Odontol Scand 53: 24-28

38. Eames WB, O'Neal SJ, Monteiro J, Miller C, Roan JD Jr, (1978) Tech- niques to improve the seating of castings. J Am Dent Assoc 96: 432-437.

39. Thongthammachat S, Moore BK, Barco MT, Hovijitra S, Brown DT, et al. (2002) Dimensional accuracy of dental casts: influence of tray material, impression material, and time. J Prosthodont 11: 98-108.

40. Rodriguez JM, Bartlett DW (2011) The dimensional stability of impression materials and its effect on in vitro tooth wear studies. Dent Mater 27: 253-258.

41. Hondrum SO (2001) Changes in properties of non-aqueous elastomeric impression materials after storage of components. J Prosthet Dent 85: 73-81.

42. Al-Odinee NM, Al-Hamzi M, Al-shami IZ, Madfa A, Abdulwahab I, et al. (2020) Evaluation of the quality of fixed prosthesis impressions in private laboratories in a sample from Yemen. BMC oral healthvol. 20: 304.

43. Abdel-Azim T, Rogers K, Elathamna E, Zandinejad A, Metz M, et al. (2015) Comparison of the marginal fit of lithium disilicate crowns fabricated with CAD/CAM technology by using conventional impressions and two intraoral digital scanners. J Prosthet Dent 114: 554-559.

44. Demir N, Ozturk AN, Malkoc MA (2014) Evaluation of the marginal fit of full ceramic crowns by the microcomputed tomography (micro-CT) technique. Eur J Dent 8: 437-444.

45. Chochlidakis KM, Papaspyridakos P, Geminiani A, Chen CJ, Feng IJ, et al. (2016) Digital versus conventional impressions for fixed prosthodontics: A systematic review and meta-analysis. J Prosthet Dent 116: 184-190.

46. Chandran SK, Babu AS, JL Jaini, Mathew A (2019) Digital Versus Conventional Impressions in Dentistry: A Systematic Review. J Clin Diag Res 13: ZE01-ZE06

47. Lee SJ, Betensky RA, Gianneschi GE, Gallucci GO (2015) Accuracy of digital vs. conventional implant impressions. Clin Oral Implants Res 26: 715-719.

48. Papaspyridakos P, Gallucci GO, Chen C-J, Hanssen S, Naert I, et al. (2016) Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. Clin Oral Implants Res. 27: 465-472.

49. Berrendero S, Salido MP, Valverde A, Ferreiroa A, Pradíes G (2016). Influence of conventional and digital intraoral impressions on the fit of CAD/CAM-fabricated all-ceramic crowns. Clin Oral Investig 20: 2403-2410.

50. Ender A, Attin T, Mehl A (2016) In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. J Prosthet Dent 115: 313-320.

51. Benic GI, Mühlemann S, Fehmer V, Hämmerle CHF, Sailer I (2016) 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. J Prosthet Dent 116: 777-782.

52. Joda T, Brägger U (2016) Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial. Clin Oral Implants Res 27: 85-89.

53. Benic GI, Mühlemann S, Fehmer V, Hämmerle CHF, Sailer I (2016) 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. J Prosthet Dent 116: 777-782.

54. Zitzmann NU, Kovaltschuk I, Lenherr P, Dedem P, Joda T (2017) Dental Students' Perceptions of Digital and Conventional Impression Techniques: A Randomized Controlled Trial. J Dent Educ 81: 1227-1232.

55. Marti AM, Harris BT, Metz MJ, Morton D, Scarfe WC, et al. (2017) Comparison of digital scanning and polyvinyl siloxane impression techniques by dental students: instructional efficiency and attitudes towards technology. Eur J Dent Educ 21: 200-205.