2018

Digital Versus Conventional Impressions in Fixed Prosthodontics: A Review

Ahlholm Pekka

Wiley-Blackwell

Tieteelliset aikakauslehtiartikkelit

http://dx.doi.org/10.1111/jopr.12527

Digital versus conventional impressions in fixed prosthodontics: A review

Pekka Ahlholm
Dental Student
Institute of Dentistry
University of Eastern Finland, Kuopio, Finland

Kirsi Sipilä
DDS, PhD, Professor
Institute of Dentistry, University of Eastern Finland, Kuopio, Finland
Oral and Maxillofacial Department, Kuopio University Hospital, Kuopio, Finland
Research Unit of Oral Health Sciences, Faculty of Medicine, University of Oulu, Oulu, Finland
Medical Research Centre, Oulu, Finland
Department of Oral and Maxillofacial Surgery, University Hospital, Oulu, Finland

Pekka Vallittu
DDS, PhD, CDT, Professor
Department of Biomaterials Science and Turku Clinical Biomaterials Centre – TCBC
Institute of Dentistry, University of Turku, Finland
Welfare Division, City of Turku, Finland

Minna Jakonen
DDS, PhD
Health Centre of Kuopio, Kuopio, Finland

Ulla Kotiranta
DDS, Clinical Teacher
Institute of Dentistry, University of Eastern Finland, Kuopio, Finland
Department of Oral and Maxillofacial Diseases, University Hospital, Kuopio, Finland

Corresponding author:
Pekka Ahlholm
Dental Student
Institute of Dentistry, University of Eastern Finland, Kuopio, Finland
BOX 1627
FI-70211 Kuopio, Finland
+358505769411

Abstract

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

Materials and Methods: Reports of digital impression techniques versus conventional impression techniques were systematically searched for 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 impression.

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 conventional impression technique is still recommended for full arch impressions.

KEYWORDS: CAD/CAM, digital impression, conventional impression, impression accuracy.

Introduction

The abbreviation “CAD/CAM” denotes computer-aided design and computer-aided manufacturing. Developed in the 1950s, CAD/CAM technology enables modelling, design and manufacture of objects for example in industrial processes. In dentistry CAD/CAM technology has been used since the 1980s to produce inlay and onlay fillings, crowns, laminates, FDPs and implants, and is increasingly used by dentists and technicians. The brand name “CEREC” was the first CAD/CAM system used in dentists' offices and came on the market in 1987 and was initially designed for the manufacture of aesthetic ceramic restorations. Over the years, the system has developed into the fourth version of the hardware, enabling the manufacture of inlay and onlay fillings, crowns, laminates, FDPs and even implants. In the CAD/CAM system, digital impressions are taken by intraoral scanner, which, like an ordinary camera, collects information about projecting light. Reproducible tissues are shown on the hardware display as natural looking. The main structures of the prosthetic design in terms of data are three-dimensional in the prepared teeth, the adjacent teeth and the occlusion with the opposing bite. The intraoral scanner measures the light reflection times of the subject surface. The description, based on data and calculation algorithms to copy the software, calculates and generates a computer screen image of the prepared area[1]. The dentist is responsible for monitoring a copy of graduation from a chair next to the reception screen and ensures that critical sites are correct. Intraoral cameras use video technique or still photo technique for scanning. Still images are based on triangulation or parallel confocal laser scanning. Systems take several still images from which three-dimensional image can be formed. These are basic principles and in addition to this each manufacturer uses their own techniques. Intraoral cameras may also use multiple techniques for data collection. LAVA C.O.S.© (3M ESPE, Lexington, USA) and Lava True Definition scanner© (3M ESPE, Lexington, USA) use active wave front sampling for data collection from which video image is formed. CEREC AC Bluecam© (Sirona Dental system GmBH, Bensheim, Germany) uses active triangulation and optical microscopy to produce still images. CEREC AC Omnicam© (Sirona Dental system GmBH, Bensheim, Germany) CAD/CAM system uses video for

data collection. iTero© (Invisalign, Cadent Inc, Or-Yehuda, Israel) and 3Shape Trios© (Copenhagen, Denmark) use parallel confocal method to produce digital data[1,2]. These two phases, digital impression and design software are called the CAD phases. In the CAM phase, prosthetic restoration is manufactured from solid block of selected material in the milling unit. Manufacturing technology used by the dentists' office is generally based on subtractive techniques. Additive systems and techniques are used by the technicians to produce more complex restorations[3].

Good marginal and internal fit along with high mechanical strength, good interfacial adhesion to veneering material and luting cement are the most important factors in improving the prognosis of prosthetic restoration of, for example, a crown. Each of the ceramic and impression manufacturing phases alters the dimensions and the fit of the final restoration. Additionally, the milling accuracy is also influenced by the material, including the filler size of a resin composite, for example. Minimal marginal gap prevents the plaque accumulation and the risk of formation of secondary caries. Most investigators use the criteria of marginal gap established by McLean and von Fraunhofer who concluded that maximum of 120 μm is allowed for marginal opening. Values between the range from 50 to 200 μm are reported with the absence of an objectively accepted threshold[4]. The accuracy of dental impressions is determined by the trueness and precision values, which together describe the accuracy of a specific impression method. The trueness is determined by the deviation of the tested impression method from the original geometry. Difference between trueness and precision is that precision indicates the deviations between the impressions within a test group. Linear distance measurements are the most commonly used method for accuracy of conventional intraoral impressions with gypsum casts, and they are restricted to a few measurement points[5]. The aim of this study was to conduct a systematic review to evaluate the evidence of possible benefits and accuracy of digital impression techniques versus conventional impression techniques in fabrication of FDPs.

Materials and methods

Search Strategy

An electronic search of publications from 1987 to 2015 was established from three electronic databases: PubMed, Cochrane Central Register of Controlled Trials, and Web of Science. The search strategy used a combination of controlled vocabulary and free-text words. The detailed search design and strategies, including key words, developed for each database are presented below.

Search in PubMed:

("computer-aided design"[MeSH Terms] OR ("computer-aided"[All Fields] AND "design"[All Fields]) OR "computer-aided design"[All Fields] OR ("cad"[All Fields] AND "cam"[All Fields]) OR "cad cam"[All Fields]) AND "digital impression"[All Fields] AND "conventional impression"[All Fields]

(MeSH, Medical Subject Heading)

Search in Web of Science:

("computer-aided design" OR ("computer-aided" AND "design") OR ("cad" AND "cam") OR "cad cam") AND "digital impression" AND "conventional impression"

Search in the Cochrane Central Register of Controlled trials:

("computer-aided design" OR ("computer-aided" AND "design") OR ("cad" AND "cam") OR "cad cam") AND "digital impression" AND "conventional impression"

Inclusion Criteria

The literature search included only English-language articles in the field of dentistry, published in peer-reviewed dental journals. To identify further studies, the reference lists of identified articles of digital impressions versus conventional impressions were screened. Unpublished reports or abstracts or case reports as well as reports that did not cover both conventional and digital impression techniques were not included. The selection of included titles was followed by an abstract search. After agreeing on abstract inclusion, a full text search followed. Final selection of articles was done based on full text reading. Search design was as followed: Electronic search: “digital impression versus conventional impression”->Review of abstracts- >Review of full texts->Individual selection of the final articles.

Results

Identified articles

The search yielded 17 references from the PubMed, 9 references from Web of Science and 1 reference from the Cochrane Central Register of Controlled Trials. Based on the assessment of the titles, abstracts and the whole text, 16 articles were selected from PubMed, 9 from Web of Science and 1 from the Cochrane Central Register of Controlled trials. The total number of articles was reduced to 19 because some studies were identified from two databases. One article was found in all three databases and 7 articles were found in both PubMed and Web of Science.

Digital impression versus conventional impression for fabrication of crowns and FDPs

The studies evaluating the impression accuracy for crowns and short fixed dental prostheses are presented in Table 1. Anadioti et al.[6] conducted an *in vitro* study to evaluate the 3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns. Crowns were made based on digital and conventional impressions using the following combinations: conventional impression/pressed crown, conventional impression/CAD/CAM crown, digital impression/press crown, and digital impression/CAD/CAM crown. Two points on the margin and at 0.75 mm above the margin were measured for the 2D measurements. 3D marginal fit measurements discovered the average marginal fit of selected area. Measurements revealed that the polyvinyl siloxane (PVS) impression/IPS e.max press group produced the most accurate marginal fit, whereas no significant differences in marginal fit were found between other groups. Seelbach et al.[7] conducted an *in vitro* experiment to evaluate the precision of crowns fabricated by using conventional and digital impressions, measuring the accessible marginal inaccuracy and the internal fit. They concluded that the accuracy of crowns fabricated by using digital impressions was at the same level as conventional impressions. Zarauz et al.[4] conducted an *in vivo* study to evaluate the marginal fit of crowns based on conventional silicone impressions and digital iTero© impressions. To evaluate the precision of crowns fabricated by using conventional and digital impression systems, 26 crowns were made on each technique and cemented on its corresponding clinical preparation. Means of the internal misfit and marginal misfit were measured using a stereomicroscopy of 2 mm thick slices in a bucco-lingual orientation. Results were more accurate for digital system. Based on this, computer aided impression system and CAD/CAM technology can improve the marginal adaptation of all ceramic single crowns. Further, Syrek et al.[8] and Ting-Shu and Jian[9] reported 49 μm for median marginal gap of crowns fabricated using Lava C.O.S.© CAD/CAM system, while the median marginal gap for conventional two-step impression group was poorer, 71 μm, although clinically acceptable. CAD/CAM crowns also had better interproximal contact points. In 2015 Abdel-Azim et al.[10] reported similar marginal accuracy for crown fabrication using Lava C.O.S.© and iTero© CAD/CAM systems and PVS impressions. In this

in vitro study all measured marginal gaps were clinically acceptable. Almeida e Silva et al.[11] conducted an *in vitro* study to evaluate the marginal and internal fit of four-unit fixed zirconia FDPs based on digital and conventional impression techniques. They found no statistical differences between Lava C.O.S.© digital impression group and conventional impression group, using Impregum© (3M ESPE, Seefeld, Germany), although impressions made by CAD/CAM system resulted in better marginal and internal fit at the premolar mesial and molar distal faces. In both groups the results were clinically acceptable. Vennerstrom et al.[12] reported similar marginal and internal fit values for crowns manufactured using digital impression and conventional impression technique, using CEREC© or iTero© or Lava C.O.S.© CAD/CAM systems.

Digital impression versus conventional impression for fabrication of implant-supported crowns and FDPs

An *in vitro* study by Abdel-Azim et al.[13] discovered the influence of computer aided impression options on the accuracy of dental implant–based single units and complete-arch frameworks. They reported that conventional impressions resulted in a smaller marginal discrepancy for single-implant framework as compared to digital methods. For single implants a mean marginal gap was 24.1 μm for conventional impressions compared to 61.4 μm for digital impressions. In full-arch impressions a mean marginal gap of 135.1μm was measured for conventional impressions compared to 63.1 μm for the digital impressions. Additionally, Lee et al.[14] conducted an *in vitro* study to compare the accuracy of implant impressions made with digital manufactured models versus gupsym models versus CAD/CAM system models. The digital impressions were made with iTero© system and the conventional close-tray impressions with a vinyl polysiloxane material. Gypsym models represented more details in grooves and fossae compared to CAD/CAM models. According this study milled models based on digital impression were comparable to gypsum models based on conventional impression.

Digital impression versus conventional impression for full-arch FDPs

Studies concerning the impression accuracy for fabrication of full-arch FPDs are presented in Table 2. Ender and Mehl[5] published an *in vitro* study on the accuracy of conventional and digital impression methods used in full-arch dental impressions. Four different digital impression systems including CEREC Bluecam©, CEREC AC Omnicam©, iTero©, and Lava C.O.S.© and four conventional impression materials were used. A highly accurate reference scanner was used to evaluate the accuracy for both full-arch conventional and digital impressions of the same dental morphology. The results showed that the highest trueness and precision was measured for CEREC Bluecam©, vinylsiloxanether and direct scannable vinylsiloxanether. In general, local deviations of the full arch-impressions were higher for digital impression systems as compared to conventional impression methods. Flügge and coworkers[15] conducted an *in vivo* study to evaluate the practical application and precision of digital scanning. Ten full-arch intraoral scans with the iTero© CAD/CAM system and 10 conventional Impregum© impressions were taken of one patient. Plaster casts based on conventional impressions were then scanned again with iTero© and a model scanner. The results showed that the lowest precision was measured for iTero© scans from patient. Extraoral model scanning with iTero© showed a higher precision than patient's iTero© scans. The highest precision was measured for stone model scanning. Another study by Güth et al.[16] also evaluated the accuracy of full-arch impressions based on digital and conventional impression techniques. Their *in vitro* study used a straight bar between mandible quadrants. This approach showed to be a reliable method to analyse deviations in full-arch scans. Data of test groups were analysed using inspection software to determine the aberration of the bar length, the linear shift and the angle deviation caused by the digitalization method. Lava True Definition scanner© showed same or higher accuracy compared to conventional Impregum© impressions. For the linear shift in Y- and Z-axis and for the overall angle and the angle in coronal direction the digital scanner showed significant lower values as compared to conventional methods. Ender and Mehl[17] investigated if the new reference scanner is capable of

measuring accuracy of conventional and digital full-arch impressions. In this *in vitro* study trueness and precision was evaluated from five conventional impressions with a vinyl siloxanether impression material and from five digital impressions of the reference model made with the CEREC AC Omnicam©. The results showed that the trueness and the precision of the digital complete-arch impression were less accurate than the conventional impressions. The deviation patterns of conventional and digital impressions were also different. In their earlier *in vitro* study Ender and Mehl[18] evaluated the precision of conventional and digital impressions on full-arch scanning, showing that the accuracy of digital impressions was similar to that of conventional impressions. Later, Ender et al.[19] studied impression accuracy of quadrant impressions and found out that digital quadrant impressions were comparable to conventional methods based on a level of precision. However, the precision differed significantly between the digital impression systems including Lava True Definition Scanner©, Lava Chairside Oral Scanner©, Cadent iTero©, 3Shape Trios©, 3Shape Trios Color©, CEREC Bluecam Software 4.0©, CEREC Bluecam Software 4.2 ©, and CEREC AC Omnicam©.

Time efficiency and operator's perception

Several studies have compared the conventional and digital impressions from both the patient's and the dentist´s point of view. In 2014 Yuzbasioglu et al.[20] showed that the overall treatment time and impression time were lower with digital impression technique as compared to conventional methods. The digital impression took time approximately 248.48 ± 23.48 s and conventional impression 605.38 ± 23.66 s. The patients felt the uptake of digital impressions with CEREC AC Omnicam© more pleasant and kept it as a primary option. Further, Lee et al.[21] evaluated the difficulty level and the operator's perception of digital and conventional implant impressions. In this *in vitro* study 30 experienced professionals and 30 dental students made impression of a single implant model. The student group scored a mean difficulty level of 43.1 for the conventional impression technique and 30.6 for the digital impression technique on a 0–100 a visual analogue scale, VAS. Sixty percent of the students preferred the digital impression and seven percent the conventional impression as their first choice. The clinician group scored a mean difficulty level of 30.9 for conventional impressions and 36.5 for digital impressions on a 0–100 VAS scale. In the clinician group, 33 % preferred the digital impression and 37 % the conventional impression. Forty percent of the clinicians chose the digital impression as the most effective technique, and 53 % of them preferred using the conventional impression. The conventional impression was more difficult to be performed by the student group than the clinician group. The difficulty level of the digital impression was the same in both groups. It was also found that the student group preferred the digital impression as the most efficient impression technique, and the clinician group had an even distribution in the choice of preferred and efficient impression techniques. An *in vivo* study reported that digital impression technique was more efficient and convenient method than conventional impression method. The use of digital technique also resulted in better occlusal contacts as compared to the conventional impression techniques. The mean total procedure times for digital and conventional impression technique were 14:33 ± 5:27 minutes and 20:42 ± 5:42 minutes and the mean impression times were 7:33 ± 3.37 minutes and 11:33 ± 1.56 minutes, respectively. The mean scores for the dentist's assessment on difficulty on VAS-scale 0–100

were 24.00 ± 18.02 and 48.02 ± 21.21 for digital and conventional impression technique, respectively. The mean VAS scores for the patients' assessment of discomfort were 6.50 ± 5.87 and 44.86 ± 27.13 for digital and conventional impression technique, respectively (the value 100 meaning the most discomfort)[22].

Discussion

In this study all reported marginal gaps of crowns fabricated by using digital impressions resulted in clinically acceptable marginal gaps. All marginal gaps were less than 120 μm, which is the clinical acceptable limit. Only Zarauz et al.[4] reported crowns' mean internal misfit and mean marginal misfit of 173.0 μm and 133.5 μm for a conventional one-step silicone impressions compared to 111.4 μm and 80.2 μm for digital impression group. However, there were variations on the results comparing the marginal fit between conventional and digital impressions. Anadioti et al.[6] reported that IPS e.max crowns fabricated with conventional PVS impressions produced the most accurate marginal fit compared to conventional impression and CAD/CAM crown, digital impression and press crown and digital impression and CAD/CAM crown. This study concluded that indirect digitalization results are clinically acceptable when concerning crowns. For fabrication of implant-supported crowns and FDPs digital impression accuracy is clinically acceptable. Trueness and precision differs significantly between the digital impression systems and impression methods. Local deviations over 100 μm can lead to inaccurate fitting, thus causing problems in large prosthetic restorations[5,19]. Impression accuracy and the fit of the final prosthesis depend on every phase of the process. In conventional techniques every step, including impression, stone casts, wax patterns, investment and casting, must be carried out precisely to achieve the best fit. Instead, dental CAD/CAM systems usually needs lower number of steps to go through, i.e. digital impression, design and milling, where the number of source of errors is less than in the conventional method, and also the milling method is standardized[13]. In fabrication of full-arch FDPs digital impressions showed higher amount of local deviations compared to conventional impressions. As clinical implications of this study, it can be concluded that the accuracy of CAD/CAM systems and digital impressions is compatible for conventional impressions. The time efficiency of digital impression systems is better than one of the conventional technique[20]. On the operator's perception, the digital impressions are easier to take for inexperienced clinicians[21]. On the other hand, distal targets are challenging to impress with intraoral cameras. The size of digital intraoral cameras is still bigger compared to traditional impression trays. Some digital

systems, for example CEREC Bluecam©, also require use of titanium oxide to improve the contrast. In dental digital impression systems number of error resources are smaller compared to traditional impression methods. Digital impression is monitored on the hardware display screen, thus enabling poorly scanned objects to be reproduced smoothly without losing the whole impression data. The intraoral camera is often more comfortable and less invasive option for patients with sensitive gag reflex or profuse salivation, and the data transmission is cheap and fast. Digital impression data is also easier to store[1]. Digitalization has already become commonplace in dentistry in other specialized areas such as radiology. On the other hand, high investment costs are a barrier to uptake of technologies.

Reports of digital impression techniques versus conventional impression techniques were systematically searched from 1987-2015. This review was done systematically from Cochrane Central Register of Controlled Trials, PubMed and Web of Science databases. The search strategy used a combination of controlled vocabulary and free-text words. The detailed search design and strategies developed for each database were presented clearly based on the distinct selection criteria. Based on search results 19 articles were selected. The number of studies was relatively low, which is why any strong conclusions cannot be drawn. Further, the number of the studies varied with regard the examined structure, as for example there were only two studies on implant impressions. Many of these studies measured the accuracy of the final restoration, and consequently the results may be influenced by each of the ceramic manufacturing phase, not only impression. The fit of the final restoration is measured from from gap between the restoration and the clinical preparation. In these studies, there was variation on how the fit of the final restoration was evaluated. Although all studies measured the accuracy of the restoration, this should be noted when results are compared together. We condensed these results into two columns: marginal gap and internal fit in table 1. Marginal gap describes the restoration fit in the margin and internal fit describes the fit in inner areas of the restoration. It should also be noted that CAD/CAM systems include several variations, of which

CEREC© is used in the office only, whereas iTero© system's milling unit is used in laboratory. Digital impression techniques also vary as regards the video or still photo technique. These facts influence the fit of final restoration and impression accuracy.

Conclusions

Based on this literature review, it seems that the accuracy of digital impression is at the same levels as conventional impression methods in fabrication of crowns and short FPDs, and thus both of these technique can be used. For fabrication of implant-supported crowns and FDPs the digital impression systems result also in clinically acceptable fit. However, for large, full- arch FPDs, the conventional impression technique results in better accuracy as compared to digital method, which is why the conventional methods may be preferred. When used for the right indication, digital impression-making seems to be the preferred method over conventional impressions, with regard to time efficiency and patient preference. Dental students have also shown preference for this technique, which means its use will likely continue to grow. Due to the relatively low number of studies, however, additional investigations are needed to confirm these findings.

References

1. Dahl BE, Ronøld HJ. Digital impressions. Finnish dent J. 2014;4:32–8.

2. Bolding S. Advanced digital implant dentistry. 2012. http://tinyurl.com/c7yb-nop

3. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. Br Dent J 2008; 505–11.

4. Zarauz C, Valverde A, Martinez-Rus F, et al. Clinical evaluation comparing the fit of all- ceramic crowns obtained from silicone and digital intraoral impressions. Clin Oral Investig 2015;Epub.

5. Ender A, Mehl A. In-vitro evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence Int 2015;46:9–17.

6. Anadioti E, Aquilino SA, Gratton DG, et al. 3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impressions. J Prosthodont 2014;23:610–7.

7. Seelbach P, Brueckel C, Wostmann B. Accuracy of digital and conventional impression techniques and workflow. Clin Oral Investig 2013;17:1759–64.

8. Syrek A, Reich G, Ranftl D, et al. Clinical evaluation of all-ceramic crowns fabricated from intraoral digital impressions based on the principle of active wavefront sampling. J Dent 2010;38:553–9.

9.Ting-Shu S, Jian S. Intraoral Digital Impression Technique: A Review. J Prosthodont 2015;24:313–21.

10. Abdel-Azim T, Rogers K, Elathamna E, et al. 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 2015;114:554–9.

11. Almeida e Silva JS, Erdelt K, Edelhoff D, et al. Marginal and internal fit of four-unit zirconia fixed dental prostheses based on digital and conventional impression techniques. Clin Oral Investig 2014;18:515–23.

12. Vennerstrom M, Fakhary M, Von Steyern PV. The fit of crowns produced using digital impression systems. Swed Dent J 2014;38:101-10.

13. Abdel-Azim T, Zandinejad A, Elathamna E, et al. The influence of digital fabrication options on the accuracy of dental implant-based single units and complete-arch frameworks. Int J Oral Maxillofac Implants 2014;29:1281–8.

14. Lee SJ, Betensky RA, Gianneschi GE, et al. Accuracy of digital versus conventional implant impressions. Clin Oral Implants Res 2015;26:715–9.

15. Flügge TV, Schlager S, Nelson K, et al. Precision of intraoral digital dental impressions with iTero and extraoral digitization with the iTero and a model scanner. Am J Orthod Dentofacial Orthop 2013;144(3):471-8.

16. Güth JF, Edelhoff D, Schweiger J, et al. A new method for the evaluation of the accuracy of full-arch digital impressions in vitro. Clin Oral Investig 2015;Epub.

17. Ender A, Mehl A. Accuracy of complete-arch dental impressions: a new method of measuring trueness and precision. J Prosthet Dent 2013;109:121–8.

18. Ender A, Mehl A. Full arch scans: conventional versus digital impressions--an in-vitro study. Int J Comput Dent 2011;14:11-2.

19. Ender A, Zimmermann M, Attin T, et al. In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. Clin Oral Investig 2015;Epub.

20. Yuzbasioglu E, Kurt H, Turunc R, et al. Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health 2014;14:10.

21. Lee SJ, Macarthur RX,4th, Gallucci GO. An evaluation of student and clinician perception of digital and conventional implant impressions. J Prosthet Dent 2013;110:420–3.

22. Gjelvold B, Chrcanovic BR, Korduner EK, et al. Intraoral Digital Impression Technique Compared to Conventional Impression Technique. A Randomized Clinical Trial. J Prosthodont 2015;Epub.

Table 1. Precision of crowns fabricated by using digital and conventional impression techniques (results are in µm)

Author	Study type	Experimental group	N	Marginal gap (mean/median)	Internal fit
Anadioti et al. 2015	*In vitro*	PVS impression/IPS e.max Press crowns	15	40	
		PVS impression/E.max CAD crowns		76	
		Lava C.O.S/IPS E.max Press crowns		75	
		Lava C.O.S/IPS E.max CAD crowns		74	
Seelbach et al. 2013	*In vitro*	CEREC /Empress CAD	10		88
		Lava C.O.S./ Lava zirconia			29
		iTero/Copran Zr-i			50
		Single-step putty-wash impression/Lava zirconia			36
		Single-step putty-wash impression/Cera E alloy			44
		Two-step putty-wash impression/Lava zirconia			35
		Two-step putty-wash impression/Cera E alloy			56
Zarauz et al. 2015	*In vitro*	iTero/zirconia	26	80.2	111.4
		One-step silicone impression/zirconia		133.5	173.0
Syrek et al. 2010	*In vivo*	Lava C.O.S./Lava zirconia	18	49	
		Two-step silicone/Lava zirconia		71	
Abdel-Azim et al. 2015	*In vitro*	Lava C.O.S./E.max	10	89.8	
		iTero/E.max		89.6	
		Two-step PVS impression/E.max	9	112.3	
Almeida e Silva et al. 2014	*In vitro*	Lava C.O.S./zirconia	12	63.9	58.4
		Conventional impression/zirconia		65.3	65.9

Table 2. Precision of full-arch dental bridges fabricated by using digital and conventional impression techniques (results are in µm)

Author	Study type	Experimental group	N	Trueness	Precision
Ender and Mehl 2015	*In vitro*	Polyether	5	60.2	66.7
		Vinyl siloxanether		13.0	12.3
		Direct scannable vinylsiloxanether		11.5	14.6
		Irreversible hydrocolloid		37.7	59.6
		CEREC Bluecam		29.4	19.5
		CEREC Omnicam		37.3	35.5
		iTero		32.4	36.4
		Lava C.O.S.		44.9	63.0
Flugge et al. 2013	*In vivo*	Intraoral scanning with iTero	10		50
		Extraoral model scanning with iTero			25
		Extraoral model scanning with D250			10
Ender and Mehl 2013	*In vitro*	Reference scanner	5	5.3	1.6
		Conventinal impression		20.4	12.5
		CEREC Bluecam		58.6	32.4
Ender and Mehl 2011	*In vitro*	Conventional Impregum impression	5	55	61.3
		CEREC Bluecam		49	30.9
		Lava C.O.S.		40.3	60.1
Ender et al. 2015	*In vivo*	Converntional impression/metal full-arch tray	15		18.8
		Conventional impression/T-tray			58.5
		Lava True Definition Scanner			21.8
		Lava Chairside Oral Scanner			47.7
		iTero			49.0
		3Shape Trios			25.7
		3Shape Trios Color			26.1
		CEREC Bluecam 4.0			34.2
		CEREC Bluecam 4.2			43.3
		CEREC Omnicam			37.4