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Review

Use of digital impression systems with intraoral scanners for fabricating restorations and fixed dental prostheses

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Abstract: Accurate impressions are essential in fabricating dental restorations and fixed dental prostheses. During the last decade, digital impression systems have improved substantially. This review discusses the accuracy of digital impression systems for fabrication of dental restorations and fixed dental prostheses. A literature search in PubMed was performed for the period from July 2010 through June 2017. The search keywords were Cerec, digital impression, direct digitalization, indirect digitalization, and intraoral scanner. Only relevant studies are summarized and discussed in this review. In general, the latest systems have considerably reduced the time required for impression making, and the accuracy and marginal fit of digital impression systems have recently improved. Restorations and fixed dental prostheses fabricated with currently available digital impression systems and intraoral scanners exhibit clinically acceptable ranges of marginal gap in both direct and indirect procedures.

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Introduction

Dental computer-aided design/computer-aided manufacturing (CAD/CAM) technology was introduced to prosthodontics in the 1970s. Digital impression systems can utilize intraoral scanners (direct digitalization) or extraoral scanners (indirect digitalization). Indirect digital impression for dental CAD/CAM systems was introduced to dental laboratory work in the 1980s because, at that time, direct digital impressions of abutments required considerable chair time and had limited accuracy. In indirect digitalization, casts are scanned with extraoral scanners. The scanning data are stored digitally and thus can be easily transmitted over the internet if there is any change in the scanning data. Hence, CAD/CAM systems are now clinically practical (1,2).

In direct digitalization, an intraoral scanner acquires data on the dental arches before the use of CAD/CAM technologies. Current digital impression techniques that use intraoral scanners can accurately scan abutments and satisfy the requirements of dental restorations with the use of a computer display, i.e., without fabrication of dental casts. This system has important advantages in reducing impression time, patient burden, and vomiting reflex.

This review discusses recent research on digital

Table 1 Intraoral scanners available in Japan

Intraoral scanner	Manufacturer	Trader	Powder	System
3M True Definition Scanner	3M, St. Paul, MN, USA	3M Japan Ltd.	+	Open
TRIOS	3Shape Trios A/s, Copenhagen, Denmark 3Shape Poland Sp. z o.o., Szczecin, Poland Asahi roentgen Ind. Co., Ltd., Kyoto, Japan	MIC Medical Corp.	−	Open
TRIOS 3	3Shape Trios A/s, Copenhagen, Denmark 3Shape Poland Sp. z o.o., Szczecin, Poland Asahi roentgen Ind. Co., Ltd., Kyoto, Japan	MIC Medical Corp.	−	Open
CEREC AC	Sirona Dental Systems GmbH, Bensheim, Germany	Dentsply Sirona K.K.	+	Closed
CEREC AC Omnicam	Sirona Dental Systems GmbH, Bensheim, Germany	Dentsply Sirona K.K.	−	Closed
Trophy 3DI SYSTEM	Rayco Medical Products Co., Ltd., Shanghai, P.R.China	Trophy Radiologie Japan Inc.	−	Open
Trophy 3DI Pro	Rayco Medical Products Co., Ltd., Shanghai, P.R.China	Trophy Radiologie Japan Inc.	−	Open
Planmeca PlanScan	D4D Technologies, Llc, Richardson, TX, USA	GC Corp.	−	Open

Findings as of August 2017

impressions with intraoral scanners for dental restorations and fixed dental prostheses. The included studies evaluated impression accuracy, marginal fit, impression time, dentist and patient assessments of impressions, and clinical outcomes of CAD/CAM-fabricated dental restorations and fixed dental prostheses fabricated after direct and indirect digitalization.

The principles of digital impression systems

Digital impression data transfer systems are classified as open and closed. Open systems handle three-dimensional data for the abutment in stereolithography (STL) format, the format most commonly used in dental CAD/CAM systems. The manufacturer can then easily access the STL data. In closed systems, impression data are used for fabricating restorations and prostheses, in accordance with the limitations of the system. At present, eight intraoral scanner models are used in Japan (Table 1).

Accuracy of digital impressions and conventional techniques

Ender et al. (3-5) evaluated the accuracy of full-arch digital impression techniques and conventional impression techniques. The accuracy of digital impression techniques was lower than that of silicone impression techniques but better than the accuracy of polyether and irreversible hydrocolloid impression techniques. However, another study of intraoral scanners (6) found that digital impression techniques were better than silicon impression techniques in the quadrant range. In other words, accuracy differed in relation to the manufacturer of the intraoral scanner.

In vitro marginal gaps after intraoral and extraoral scanning

The scanning of stone casts from conventional impressions is the standard for dental restorations and fabrication of fixed dental prostheses with indirect digital impression systems. As is the case for other techniques, scanning of a conventional impression and creation of polyurethane casts by fabricating from intraoral scanners milling systems based on the virtual casts are applied.

Studies have compared the marginal gaps of dental restorations and fixed dental prostheses fabricated after intraoral and extraoral scans *in vitro* (Table 2). Seelbach et al. and Pedroche et al. (7,8) reported good marginal fit in dental restorations produced with the CEREC Bluecam, Lava Chairside Oral Scanner, iTero, and 3Shape TRIOS intraoral scanners. An et al. (9) reported that marginal fit for the iTero was low or similar to that obtained by using polyurethane casts fabricated with a milling system based on virtual casts. Pedroche et al. (8) reported that the marginal fit obtained from intraoral scans was better than that obtained from extraoral scans of polyvinyl siloxane impressions. Ng et al. (10) reported that marginal fit was better than that of a restoration fabricated from lithium-disilicate glass-ceramic ingots by anatomic contour waxing (without cutback) for the lost-wax and/or pressed method by the technician.

Previous studies (11-13) reported that, for fixed dental prostheses, marginal fit with direct digital impressions obtained by using intraoral scanners was equal to or better than that obtained with indirect digital systems. In contrast, Shembesh et al. (14) reported that, as compared with extraoral scanning of stone casts with polyvinyl siloxane impression, marginal fit for intraoral scans was worse for the iTero system and better for the 3M True Definition Scanner. Thus, the results depend on the intraoral scanner used. Keul et al. (11) compared the marginal fit of frameworks fabricated with milling technique after direct digitalization. Marginal fit was better for a Co-Cr framework than for zirconia.

Table 2 Comparison of marginal gaps for intraoral and extraoral scanners *in vitro*

Intraoral scanner	Fabrication	Scanning method		Marginal gap (μm)		Material	Powder	Reference
		Intraoral scanner	Extraoral scanner	Intraoral scanner	Extraoral scanner			
CEREC Bluecam	Restoration	Stainless steel model	Stone cast (polyvinyl siloxane impression, single-step and two-step)	30	Single-step: Zirconia 33, Alloy 38 Two-step: Zirconia 60, Alloy 68	Zirconia Ag-Pd alloy	+	7
Lava Chairside Oral Scanner				48			−	
iTero				41			−	
iTero		Typodont model	Metallic cast (Ni-Cr alloy)	104	93	Zirconia	−	9
			Polyurethane casts made with the iTero digital scanner data		103			
3Shape TRIOS		Typodont model	Stone cast (polyvinyl siloxane impression)	59	87	Zirconia	−	8
			Polyvinyl siloxane impression		71			
Lava Chairside Oral Scanner	Fixed dental prostheses	Typodont model	Stone cast (polyether impression)	64	65	Zirconia	+	12
Lava Chairside Oral Scanner		Titanium model	Stone cast (polyether impression)	Zirconia: 63 Alloy: 32	Zirconia: 87 Alloy: 81	Zirconia Co-Cr alloy	+	13
iTero		Titanium model	Stone cast (polyether impression)	Zirconia: 127 Alloy: 57	Zirconia: 141 Alloy: 91	Zirconia Co-Cr alloy	−	11
iTero		Typodont model	Polyvinyl siloxane impression	62	81	Zirconia	−	14
			Stone cast (polyvinyl siloxane impression)		50			
3M True Definition Scanner			Polyvinyl siloxane impression	27	81		+	
			Stone cast (polyvinyl siloxane impression)		50			

Table 3 Comparison of marginal gaps for intraoral and extraoral scanners *in vivo*

Intraoral scanner	Fabrication	Impression material	Marginal gap (μm)		Material	Powder	Reference
			Intraoral scanner	Extraoral scanner			
Lava Chairside Oral Scanner	Restoration	Vinyl polysiloxane	49*	71*	Zirconia	+	15
Lava Chairside Oral Scanner			76	91	Zirconia	+	16
iTero			80	134	Zirconia	−	18
3Shape TRIOS			107	120	Zirconia	−	19
cara TRIOS			87	82	Zirconia	−	20
Lava Chairside Oral Scanner	Restoration and fixed dental prostheses	Polyether	61	70	Zirconia	+	17

*Median

In vivo marginal gaps after intraoral and extraoral scanning

Numerous studies investigated digital impression and conventional impression techniques *in vivo* (Table 3). Considerable evidence (15-20) indicates that marginal gaps obtained with intraoral scanners are equal to or better than those obtained with extraoral scanners. Ahrberg et al. (17) reported that the marginal fit of fixed dental prostheses was more accurate after direct digitalization than after indirect digitalization.

Digital impression time

The time required for impression was compared between direct digitalization and conventional impression in four

Table 4 Time required for direct digitalization and conventional impression

Intraoral scanner	Impression range	Material of conventional impressions	Preparation		Impression		Total		Reference
		Impression	Digital	Conventional	Digital	Conventional	Digital	Conventional	
CEREC Omnicam	Full arch (maxillary)	Polyether	33 s	47 s	1 m 42 s	4 m	4 m 8 s	10 m 5 s	21
	Full arch (mandibular)				1 m 38 s	3 m 46 s			
CEREC Bluecam	Single abutment	Polyether /Vinyl polysiloxane /Vinylsiloxanether	1 m 46 s	30 s / 1 m / 5 m	23 s	4 m / 3 m / 3 m 30 s	2 m 54 s	8 m 45 s / 8 m 15 s / 12 m 45 s	22
	Quadrant		1 m 57 s		23 s		3 m 8 s		
iTero	Single abutment		1 m 42 s		1 m 18 s		3 m 58 s		
	Quadrant		1 m 45 s		1 m 24 s		4 m 9 s		
	Full arch		2 m 54 s		4 m 44 s		10 m 49 s	11 m 45 s / 11 m 15 s / 15 m 45 s	
Lava Chairside Oral Scanner	Single abutment		2 m 16 s		1 m 42 s		4 m 53 s	8 m 45 s / 8 m 15 s / 12 m 45 s	
	Quadrant		1 m 58 s		2 m 12 s		5 m 18 s		
	Full arch		2 m 21 s		6 m 45 s		12 m 30 s	11 m 45 s / 11 m 15 s / 15 m 45 s	
Lava Chairside Oral Scanner	Quadrant	Polyether	1 m 26 s	4 m 25 s	5 m 25 s	7 m 1 s	10 m 21 s	15 m 33 s	17
	Full arch		2 m 09 s	4 m 38 s	7 m 45 s	8 m 9 s	15 m 27 s	17 m 07 s	
3Shape TRIOS	Quadrant	Polyether	7 m	7 m 48 s	7 m 33 s	11 m 33 s*	14 m 33 s	20 m 42 s	23

Ref. 21 and 22 data are revised from an original data.
*: Impression of antagonist (Irreversible hydrocolloid) and maxillomandibular registration (Wax) are included in impression time.

Table 5 Time required for maxillomandibular registration and antagonist for direct digitalization and conventional impression

Intraoral scanner	Impression range	Material of conventional impressions		Maxillomandibular registration		Antagonist		Reference
		Maxillomandibular registration	Antagonist	Digital	Conventional	Digital	Conventional	
CEREC Omnicam	Full arch	Polysiloxane	—	14 s	1 m 31 s	–		21
CEREC Bluecam	Single abutment	Polydimethylsiloxane	Alginate	16 s	1 m 30 s	29 s	2 m 45 s	22
	Quadrant			17 s		31 s		
iTero	Single abutment			15 s		43 s		
	Quadrant			15 s		45 s		
	Full arch			29 s	4 m 30 s	2 m 42 s		
Lava Chairside Oral Scanner	Single abutment			9 s	1 m 30 s	46 s		
	Quadrant			12 s		56 s		
	Full arch			33 s	4 m 30 s	2 m 51 s		
Lava Chairside Oral Scanner	Quadrant	Bis-acrylic	Alginate	42 s	1 m 33 s	2 m 52 s	2 m 48 s	17
	Full arch			1 m 18 s	1 m 20 s	4 m 20 s	3 m 29 s	

Ref. 21 and 22 data are revised from the original data.

studies (Tables 4, 5). A number of studies reported that the total time needed for digital impressions was shorter than that needed for conventional impressions (17,21-23); however, Patzelt et al. (22) reported that the interval required for scanning of the full arch was longer for the Lava Chairside Oral Scanner than for other intraoral scanners. In particular, digital maxillomandibular registration scan times were shorter than those for conventional techniques.

Assessment of digital impressions

A clinical study of patients answering a 9-item comparative questionnaire (21) found that digital impression techniques yielded better results than did conventional impression techniques. The questionnaire assessed overall impression discomfort, overall impression time, smell/voice, taste/heat, queasiness, discomfort during mouth opening, temporomandibular joint discomfort, breathing difficulty, and tooth and periodontal sensitivity. Gjelvold et al. (23) reported that visual analog scale assessments of dentists and patients showed greater comfort and less difficulty with a digital impression technique than with conventional impression techniques.

Clinical performance

Gherlone et al. and Selz et al. examined the clinical performance of zirconia-based restorations and fixed dental prostheses fabricated with digital impression CAD/CAM systems equipped with intraoral scanners (24,25). Gherlone et al. (24) reported that the chipping rate for the veneering material was 30.2% during a 3-year follow-up period. The chipping rate for all-ceramic restorations increased exponentially from 24 to 36 months, and the success rates were 86.0% after 24 months and 69.8% after 36 months. Selz et al. (25) found that fixed dental prostheses luted with self-curing luting agent did not result in secondary caries, change in anatomic form, endodontic complications, or loss of retention after 18 months of follow-up, but the rate of unacceptable marginal adaptations (visible evidence of crevices and/or catch of a dental explorer; no explorer penetration) were 4.0% after 6 months and 8.0% after 18 months. In addition, marginal discoloration (superficial discoloration at the margin between the restoration and the tooth structure; no penetration in pulpal direction) was 8.0% after 18 months, and color mismatch of the adjacent tooth (mismatch between the restoration and tooth structure within the normal ranges for color, shade, and/or translucency) was 4.0% after 18 months. An increase in surface roughness was observed in 21.0% of patients after 6 months and in 58.0% of patients after 18 months. The rate of chipping fracture was 8.0% after 18 months. On subjective assessments, dentists and patients were highly satisfied with the overall aesthetic and functional outcomes of all-ceramic fixed dental prostheses resulting from a digital workflow.

Discussion

Conventional fabrication of dental restorations and fixed dental prostheses utilizes lost-wax technique. During the previous decade, CAD/CAM systems were introduced as an alternative technique. Such systems mainly use extraoral scanners for indirect digitalization of stone casts. In Japan, composite resin-based CAD/CAM restorations have been covered by health insurance since 2014.

Digital impression systems using intraoral scanners have improved. However, studies (26-28) reported that information obtained by intraoral scanning was less accurate than that obtained by extraoral digitalization of stone casts and that the former is affected by intraoral conditions such as saliva, blood, limited spacing, preparation shape, and scanning position. Therefore, the impression technique should be selected in accordance with clinical conditions.

Digital impression systems have two classes. Some digital impression systems require coating powder before impression. Clinically, marginal gaps are affected by powder when intraoral scanners are used. However, all marginal gaps for dental restorations and fixed dental prostheses fabricated with intraoral scanners were less than 120 μm, within the range of *in vivo* reports (15-20,29). These results were regarded to be as clinically acceptable as those obtained by indirect digitalization.

The most distinctive feature of digital impression techniques is total impression time, which tends to be shorter than for conventional techniques. In addition, maxillomandibular registration times are noticeably shorter. Furthermore, two studies (15,30) found that ceramic restorations fabricated from intraoral scans had equal or better interproximal contact point quality and occlusal point quality as compared with ceramic restorations from conventional impressions. Thus, occlusal and interproximal contact adjustment were effective. In addition, total chair time is likely to be shorter. These characteristics will increase the uptake of intraoral scanners in dentistry.

Use of digital impression systems will gradually increase in dental practice. However, the present findings indicate that use of digital impression systems with intraoral scanners for fabrication of dental restorations and fixed dental prostheses requires that the operator understand the characteristics and adaptations required when using intraoral scanners, as these systems can reduce patient discomfort during impression-making.

A number of Japanese studies investigated digital impression systems with intraoral scanners in the second half of 2017. A study of the 3Shape TRIOS noted that an intraoral scanner did not significantly differ from extraoral scanners with regard to trueness of marginal value (31). Studies in all areas of prosthodontics are examining digital impression with intraoral scanners (32). Further discussions are expected to culminate in health insurance reimbursement for use of digital impression systems with intraoral scanners in Japan.

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Conflict of interest

The authors have no conflict of interest to declare.

References

1. Beuer F, Schweiger J, Edelhoff D (2008) Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. Br Dent J 204, 505-511.
2. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y (2009) A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dent Mater J 28, 44-56.
3. Ender A, Mehl A (2011) Full arch scans: conventional versus digital impressions--an in-vitro study. Int J Comput Dent 14, 11-21.
4. Ender A, Mehl A (2015) In-vitro evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence Int 46, 9-17.
5. 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.
6. Ender A, Zimmermann M, Attin T, Mehl A (2016) In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. Clin Oral Investig 20, 1495-1504.
7. Seelbach P, Brueckel C, Wöstmann B (2013) Accuracy of digital and conventional impression techniques and workflow. Clin Oral Investig 17, 1759-1764.
8. Pedroche LO, Bernardes SR, Leão MP, Kintopp CC, Correr GM, Ornaghi BP et al. (2016) Marginal and internal fit of zirconia copings obtained using different digital scanning methods. Braz Oral Res 30, e113.
9. An S, Kim S, Choi H, Lee JH, Moon HS (2014) Evaluating the marginal fit of zirconia copings with digital impressions with an intraoral digital scanner. J Prosthet Dent 112, 1171-1175.
10. Ng J, Ruse D, Wyatt C (2014) A comparison of the marginal fit of crowns fabricated with digital and conventional methods. J Prosthet Dent 112, 555-560.
11. Keul C, Stawarczyk B, Erdelt KJ, Beuer F, Edelhoff D, Güth JF (2014) Fit of 4-unit FDPs made of zirconia and CoCr-alloy after chairside and labside digitalization--a laboratory study. Dent Mater 30, 400-407.
12. Almeida e Silva JS, Erdelt K, Edelhoff D, Araújo É, Stimmelmayr M, Vieira LC et al. (2014) Marginal and internal fit of four-unit zirconia fixed dental prostheses based on digital and conventional impression techniques. Clin Oral Investig 18, 515-523.
13. Ueda K, Beuer F, Stimmelmayr M, Erdelt K, Keul C, Güth JF (2016) Fit of 4-unit FDPs from CoCr and zirconia after conventional and digital impressions. Clin Oral Investig 20, 283-289.
14. Shembesh M, Ali A, Finkelman M, Weber HP, Zandparsa R (2017) An in vitro comparison of the marginal adaptation accuracy of CAD/CAM restorations using different impression systems. J Prosthodont 26, 581-586.
15. Syrek A, Reich G, Ranftl D, Klein C, Cerny B, Brodesser J (2010) Clinical evaluation of all-ceramic crowns fabricated from intraoral digital impressions based on the principle of active wavefront sampling. J Dent 38, 553-559.
16. Pradíes G, Zarauz C, Valverde A, Ferreiroa A, Martínez-Rus F (2015) Clinical evaluation comparing the fit of all-ceramic crowns obtained from silicone and digital intraoral impressions based on wavefront sampling technology. J Dent 43, 201-208.
17. Ahrberg D, Lauer HC, Ahrberg M, Weigl P (2016) Evaluation of fit and efficiency of CAD/CAM fabricated all-ceramic restorations based on direct and indirect digitalization: a double-blinded, randomized clinical trial. Clin Oral Investig 20, 291-300.
18. Zarauz C, Valverde A, Martinez-Rus F, Hassan B, Pradies G (2016) Clinical evaluation comparing the fit of all-ceramic crowns obtained from silicone and digital intraoral impressions. Clin Oral Investig 20, 799-806.
19. 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.
20. Rödiger M, Heinitz A, Bürgers R, Rinke S (2017) Fitting accuracy of zirconia single crowns produced via digital and conventional impressions--a clinical comparative study. Clin Oral Investig 21, 579-587.
21. Yuzbasioglu E, Kurt H, Turunc R, Bilir H (2014) Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health, Jan 30, doi/ 10.1186/1472-6831-14-10.
22. Patzelt SB, Lamprinos C, Stampf S, Att W (2014) The time efficiency of intraoral scanners: an in vitro comparative study. J Am Dent Assoc 145, 542-551.
23. Gjelvold B, Chrcanovic BR, Korduner EK, Collin-Bagewitz I, Kisch J (2016) Intraoral digital impression technique compared to conventional impression technique. A randomized clinical trial. J Prosthodont 25, 282-287.
24. Gherlone E, Mandelli F, Capparè P, Pantaleo G, Traini T, Ferrini F (2014) A 3 years retrospective study of survival for zirconia-based single crowns fabricated from intraoral digital impressions. J Dent 42, 1151-1155.
25. Selz CF, Bogler J, Vach K, Strub JR, Guess PC (2015) Veneered anatomically designed zirconia FDPs resulting from digital intraoral scans: preliminary results of a prospective clinical study. J Dent 43, 1428-1435.
26. Flügge TV, Schlager S, Nelson K, Nahles S, Metzger MC (2013) Precision of intraoral digital dental impressions with iTero and extraoral digitization with the iTero and a model scanner. Am J Orthod Dentofacial Orthop 144, 471-478.
27. Rudolph H, Salmen H, Moldan M, Kuhn K, Sichwardt V, Wöstmann B et al. (2016) Accuracy of intraoral and extraoral digital data acquisition for dental restorations. J Appl Oral Sci 24, 85-94.
28. Güth JF, Runkel C, Beuer F, Stimmelmayr M, Edelhoff D,

Keul C (2017) Accuracy of five intraoral scanners compared to indirect digitalization. Clin Oral Investig 21, 1445-1455.
29. Brawek PK, Wolfart S, Endres L, Kirsten A, Reich S (2013) The clinical accuracy of single crowns exclusively fabricated by digital workflow--the comparison of two systems. Clin Oral Investig 17, 2119-2125.
30. Tamim H, Skjerven H, Ekfeldt A, Rønold HJ (2014) Clinical evaluation of CAD/CAM metal-ceramic posterior crowns fabricated from intraoral digital impressions. Int J Prosthodont 27, 331-337.
31. Shimizu S, Shinya A, Kuroda S, Gomi H (2017) The accuracy of the CAD system using intraoral and extraoral scanners for designing of fixed dental prostheses. Dent Mater J 36, 402-407.
32. Monaco C, Ragazzini N, Scheda L, Evangelisti E (2017) A fully digital approach to replicate functional and aesthetic parameters in implant-supported full-arch rehabilitation. J Prosthodont Res, Nov 27, doi: 10.1016/j.jpor.2017.10.005.