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Comparison of Dimensional Accuracy of Crowns and Bridges Fabricated Using Digital versus Conventional Impression Technique - A Systematic Review

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ABSTRACT

Purpose: The purpose of this systematic review is to compare the dimensional accuracy of fixed dental prostheses fabricated by the digital impressions to that of the conventional impressions

Materials and method: Internet sources such as Pubmed, Cochrane, Google scholar were electronically searched using the keywords 'dimensional accuracy', 'Fixed prosthodontics', 'digital impression', 'conventional impression' sort by 10 years and other journals were hand searched. The studies evaluating the dimensional accuracy in terms of marginal fit, internal fit , trueness and precision of single, short span , cross arch and complete arch fixed dental restorations fabricated by the digital and conventional impressions were selected.

Result: Most of the studies resulted that the dimensional accuracy of the prosthesis fabricated by digital impressions were better than that of conventional impressions. The marginal and internal discrepancies were higher in conventional groups. The studies involving cross arch and complete arch impressions showed better dimensional accuracy with the conventional groups than the digital groups. But, both the groups resulted within acceptable range of discrepancies and are not statistically significant.

Conclusion: The conclusion is based mainly on in vitro studies. Digital impressions are better in fabrication of single and short span restorations. In case of cross arch and complete arch restorations, the conventional impressions showed better accuracy than the digital impressions.

Keywords: Conventional impression, Digital impression, Dimensional accuracy, Fixed prosthodontics, Impression

INTRODUCTION

Fixed partial dentures have been a successful mode of restoring the missing tooth for years. The emergence of materials like zirconia, Polyether Ether Ketone (PEEK) has aided in the fabrication of prostheses not only fulfilling the functions but also the aesthetic need of the patient. With concern to the fixed partial dentures such as single crowns, multiunit bridges, etc the major factor that determines the quality and success of the prosthesis is the dimensional accuracy. Poor marginal fit may lead to overhang, plaque accumulation followed by periodontitis, root caries leading to the overall failure of the prosthesis, but the poor marginal fit is not the only cause attributed to marginal leakage. Previous studies have concluded that the accepted crown margin –finish line discrepancy is 34-119µm[(1)]. FPDs fabricated with marginal discrepancy of less than 120µm were successful[(2)]. Internal fit is an important

dimensional parameter that aids in proper seating of the prosthesis over the tooth surface thereby contributing to the proper marginal fit. In a study, it was concluded that a die spacer of 25µm provided proper seating and retention of the crown[3]

On other hand, accuracy consists of precision and trueness[4]**(ISO 5725-1).** Precision describes how closely the repeated measurements are to each other. The higher the precision, the more predictable is the measurement. Trueness describes how far the measurement deviates from the actual dimension of the measured object. Higher the trueness, closer or equal is the results to the actual dimension of the measured object. In a perfectly fit casting, the casting margin and the Cavo surface angle of the tooth would coincide.

To fabricate a fixed dental prosthesis, an accurate cast is required. The impression material and method have a major role in the fabrication of a successful prosthesis. Various impression materials are available for making definitive impressions to fabricate a fixed partial denture, among which polyvinyl siloxane followed by polyether were considered to reproduce the dental and oral structure with more accuracy [21][23] and have been used in fixed dental prosthodontics for many years. With concern to the methods, the 2 step putty/ light-body addition silicone is the most dimensionally accurate impression method [22][23] and either custom or stock tray can be used to make an accurate impression[21]. Even though the silicone impression materials have excellent dimensional stability and reproducibility, there are certain factors such as temperature, wettability by gypsum products, the time period between impression making and cast pouring may affect the accuracy of the impression. Best surface details were obtained using addition silicone only under dry conditions[24]. Besides, laboratory procedures such as die making, wax pattern fabrication, dewaxing, casting, etc may also lead to procedural errors in making a precise prosthesis.

The emergence of the CAD/CAM system in the early 1980s has enabled the dentists and dental technicians to fabricate aesthetic and durable prostheses by harnessing the power of computer and computer-aided designing. There are various CAD/CAM systems available in the dental market. Dr. Duret was the first in the field of dental CAD/CAM development, from 1971 he began to fabricate crowns with an optical impression. This is followed by the design and milling of an optimal crown using a numerically controlled milling machine. Later he developed the Sopha® System, which had an impact on the later development of dental CAD/CAM systems. He produced the first dental CAD/CAM restoration in 1983 and demonstrated his system at the French Dental Association's international congress in November 1985 by creating a posterior crown restoration for his wife in less than an hour. Dr. Moermann, the developer of the CEREC® system. He attempted to use new technology in a dental office clinically at the chairside. The emergence of this system was innovative because it allowed same-day ceramic restorations. When this system was announced, it rapidly spread the term CAD/CAM to the dental profession. Dr. Anderson in 1994 developed the Procera system which later in 1998 developed as a processing centre networked with satellite digitalizer around the world. The development of alumina and zirconia ceramic materials which possess excellent physical properties and machinability became another vital factor for CAD/CAM in dentistry. Dr. Rekow worked on a dental CAD/CAM system in the mid-1980s to acquire data using photographs and a high-resolution scanner, and to mill restorations using a 5-axis machine

The intra and extraoral scanners have become a favourable mode of impression making which overcame certain factors in conventional techniques such as accurate reproduction of the tissues, time consumption, eliminating lab procedures, and patient comfort. CEREC, LAVA, TRIOS (3 shape), iTero, etc are some scanners available in dentistry that are being upgraded continuously by the manufacturer. The digital impressions are advantageous over conventional impressions in various aspects like patient comfort, simplified procedure, reduced consumption of materials, time efficiency, etc. Even though digital scanners have been used in recent days, the conventional method of impression making is being extensively used among dentists on a routine basis. Various studies measure the dimensional accuracy of the restoration fabricated by digital and conventional techniques. The purpose of this systematic review is to compare the dimensional accuracy of the crowns and bridges fabricated by

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digital to those restorations fabricated by conventional techniques.

MATERIALS AND METHODS:

This review was conducted in accordance with PRISMA. The PICO frame was formulated to answer a primary question

The primary question was framed as,

Which of the impression technique, conventional or digital, aids in fabricating dimensionally accurate crowns and bridges?

Three internet sources were used for searching the eligible articles based on the inclusion and exclusion criteria which are as follows (Table 1). The internet sources include Pubmed advanced search, Cochrane central register for controlled trials, and Google scholar. In addition, other journals such as *International journal of prosthodontics (IJPD), Journal of prosthetic dentistry (JPD), American college of Prosthodontics, International journal of esthetic and restorative dentistry* were hand searched for supporting eligible articles from the time period of 2008 to 2019 as per guidelines. The search strategy included the combination of random keywords such as 'Dimensional accuracy', 'fixed partial dentures', 'fixed prosthodontics', digital impression', 'conventional impression'

((Dimensional accuracy) AND Fixed Partial Denture)

(Digital impression) AND conventional impression sort by last 10 years (Figure 1)

RESULT:

All the data are collected by strategic searching which is screened based on the inclusion and exclusion criteria and those related to the PICO frame (Table 2). On complete reading of the articles, 13 articles resulted that the dimensional accuracy of the crowns and bridges fabricated from the digital impression is better than that of the conventional impression. 3 articles resulted that the conventional impression is better than digital impressions. Even though there was a statistically significant difference between the digital and conventional groups most of the studies concluded that there was less clinical significance among the two groups. A study concluded that the digital impression made using an intraoral scanner can accurately reproduce the tooth structure irrespective of the geometry[8]. 1 article resulted that the Digital models made of direct digitalization are more accurate than those made by indirect digitalization within limitations.

DISCUSSION:

This systematic review tried to compare the dimensional accuracy of FPD fabricated by digital and conventional impression. Conventional impressions using elastomeric impression materials such as polyether, polyvinyl siloxane, etc have been successfully used for decades in fabricating fixed dental prostheses. Certain factors such as temperature, working time, patient comfort, tearing of impression while retrieving, cast pouring, dimensional stability, etc have been disadvantages of the conventional method. Digital impressions have become a new entity of interest in compensating all those disadvantages associated with conventional techniques. A Digital impression can be acquired either by directly scanning the oral structures (direct method) or by scanning the replica obtained from a conventional elastomeric impression (indirect). There are various intraoral scanner systems available in the dental market such as Lava COS, iTero, CEREC, E4D TRIOS, etc. Among the different systems, each intraoral scanner has been upgraded by the manufacturers. CEREC system was the first intraoral scanner introduced in dentistry which has been upgraded with various generations like CEREC AC Omnicam, CEREC AC Bluecam, CEREC MC, CEREC In-lab. Each intraoral scanner has its peculiar principle of scanning.CEREC Bluecam captures a single image data collection while the CEREC Omnicam captures continuous images and gives a 3D image on data collection and was the first among the CEREC system that does not require powder application[5]**.** Lava COS works on the principle of active wave front sampling. This system needs the powdering of the tooth surface. iTero works on the principle of parallel confocal imaging which digitally captures 100,00 points of laser light providing remarkable tooth images of more than 300 mm focal length and does not require scanning powder[6]. TRIOS works under the principle of ultrafast optical sectioning and confocal microscopy. Indirect digitalization uses Lava scan ST. Besides, a study has reported the use of a High-frequency Ultrasound scanner for scanning the prepared tooth[19]. A new reference scanner working based on focus variation technique combined with a high precision objective

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lens movement over a large measurement field (infinite focus, Alicona Imaging with IM software 3.5.0.1) has been used as a digital scanning medium in a study[4].

Various studies have been conducted to compare the dimensional accuracy of the Fixed dental prostheses fabricated by conventional and digital impression techniques. A study conducted on a single zirconia crown concluded that the accuracy of the restorations obtained by the digital and conventional methods are comparable to each other and digital impressions can be successfully used as an alternative for conventional impressions with consecutive digital workflow while the finish line is clearly visible and dry. It also discussed that conventional impressions show high accuracy than digital impressions in the case of the in-vivo study where factors such as saliva, need to retract cheek tongue, blood, etc may foster inaccuracies of digital impression[5]. Another study conducted on single crowns concluded the digital impressions can be used as an alternative for fabricating fixed dental prostheses with similar accuracy as conventional impressions[7]. Preparation geometry may influence the accuracy of the impressions. A study concluded that the conventional impression alone or those further digitalized indirectly cannot reproduce abutment tooth preparation when the total occlusal convergence is close to 0 degrees. It also stated that the digital impression can accurately reproduce abutment tooth preparation irrespective of the geometry[8]. Digital data can be acquired by the direct or indirect method. A study concluded that the direct digitalized restoration is more accurate in comparison with those made by indirect digitalization of the conventional impression. It also supports the fact that superior digitalization can result in superiorly accurate restoration[9]. Another study supports this fact by concluding that the trueness and precision of direct digitalization are more than the virtual counterpart of the conventional impression[10].The accuracy of restoration can vary among different digital systems. A study conducted among different digital scanners on comparing the accuracy of direct digital scanning to indirect scanning of the conventional impression concluded that CS 3500 and Tdef showed the best performance. It also included that direct digitalization was not superior to indirect digitalization[11]. Accurate models aids in the fabrication of accurate restorations. A study concluded that conventional impression are more accurate than those models obtained by digital impression but both the groups shows clinical acceptance for placement[6]. Another study concluded that the gypsum models made from conventional impressions showed higher accuracy than the stereolithography additive cast(SLA)[12]. In concern with quadrant impression, an in vivo study concluded that digital impression achieves more precision than conventional impression but there was a significant difference in precision between different digital systems. It also added that the conventional impression Triple tray (T tray) showed displacement with height local deviation at occlusal contacts of the upper and lower jaw[13].In the case of complete arch impressions, a study concluded that the conventional impression shows high accuracy on full arch impression than the digital impression, yet digital impression showed excellent result with proper strategic scanning method[14][28]. This study also reported that the video-based system like OC, LAVA are proved to compress the dental arch in full arch impression and single image stitching showed more local deviation at the distal end of the arch[14]. Following this study, the author conducted another study using a new reference scanner which also concluded that the conventional impression produces high accuracy in terms of trueness and precision while digital was less accurate[4]. Another study concluded that the intraoral scanner showed equal or high accuracy than that of a conventional impression. It also included that the clinical relevance of single or small span restorations has proven excellence. For long-span restorations, an additional scanning strategy is required [15]. A recent in vivo study[16] conducted on complete arch impression in cadaver maxilla using conventional and seven different scanning system concluded that there is no significant difference in the accuracy of the models fabricated using digital to that conventional method with a cross arch deviation ranging from 18 to 34µm for each method. It also added that the Planmeca Plans can system has the least accuracy in cross arch impression and digital impressions are found to be as accurate as polyvinyl siloxane impression. The success of an implant prosthesis depends on suitable surgical technique and a passive fit of the prosthesis. An accurate and passive fitting prosthesis can be attained by proper impression technique and working

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model. A study on optical impression on angulated implants in comparison with models made by a conventional impression concluded that the optical impression showed greater distance error than that of conventional models. Yet, the trueness and precision could be improved by using a long healing abutment. A study conducted with divergent implant concluded that the amount of divergence had no effect on the accuracy of the stone cast made conventionally but it affected the cast which is digitally milled. Besides, at 0º and 15º of divergence, the digital method resulted in significantly less accuracy and at 35º and 45º, the digital cast showed no or marginal difference when compared with the conventional cast. It also added that verification devices and cast may be used to ensure a passive fit of the prosthesis when produced digitally[18]. A recent study conducted on the accuracy of single zirconia crowns with and without gingival porcelain coverage using a High-frequency ultrasound scanner with other intraoral scanner concluded that ultrasound scanner produces less accuracy when compared to intraoral scanners with gingival coverage, but in the case of non-gingival coverage, it produced similar fit when compared with at least one scanner[19]. A conducted on comparing the dimensional accuracy of intracoronal restorations fabricated by conventional and digital impressions concluded that the intracoronal restorations fabricated conventionally yielded more accuracy than 3D printed restorations[25]. A clinical study conducted on assessing the accuracy, scan time, and patient acceptance of chairside oral scanner for full arch scan stated that despite the high accuracy of chairside scanners, conventional impressions are preferred more concerning chair time and patient acceptance[26]. A study comparing the marginal adaptation of zirconium dioxide coping concluded that the LAVA chairside scanner displayed smaller marginal gaps than the LAVA All-ceramic system within the range of clinical acceptability for both groups[27]. A study on the accuracy of full-arch impressions using different strategies stated that the scanning strategy beginning from occlusal to palatal and returning to the buccal surface is recommended as it provides the highest trueness and precision[29]. An in vivo study conducted on inter-operator reproducibility of digital and conventional impressions concluded that the inter-operator reproducibility with digital impression technique may be better than that of conventional impressions and is independent of the clinical experience of the operator[30].

CONCLUSION:

This review concludes that digital impressions produce accurate restorations when compared with conventional impressions but there is no clinically significant difference among the two entities.

1. Digital impressions are proven to show excellence in fabricating single and short span restorations.
2. With concern to the available data regarding complete arch impressions,conventional impressions shows more accuracy when compared to digital impression and both showed a less significant cross arch deviation.

Digital impression can be corrected by overlapping several images but the conventional impressions cannot be corrected. This clears the fact of having large standard deviation among the conventional methods. In addition, even though there are lots of in-vitro studies concluded that digital method is more accurate,certain clinical factors such as saliva,blood,need for retraction of tongue and cheek in mandibular arch can foster inaccuracies in digital impressions. This emphasise the fact that the in vivo studies assessing the dimensional accuracy of restorations fabricated by digital and conventional impression are not adequate and necessitates the need for more data regarding the clinical comparison of accuracy and other dimensional parameters between the two criteria. Digital impressions can produce accurate and passive restorations with proper scanning strategies along with verification parameters. Development of information technology could improve the accuracy of optical impressions in near future.

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Table 1: Inclusion and exclusion criteria

INCLUSION CRITERIA	EXCLUSION CRITERIA
• In vitro and in vivo studies • Experimental and control group • Articles related to the research question • Study conducted on dimensional accuracy of FPD	• Articles other than English language • No experimental and control group • Articles based on charts and questionnaires • Animal study

Table 2:

Table 2: comparison of dimensional accuracy between digital and conventional impressions

sample size				impression techniques		prosthesis given		dimensional accuracy	
Reference	**study design**	**Conventional**	**digital**	**conventional**	**digital**		**conventional**		**digital**
Mennito et al[16]	comparative study	25 eaqch	25 each	PVS	TRIOS 3		37µm		32µm
					CEREC omnicam				32µm
					carestream 3600				46µm
					Itero element II				25µm
					itero element				29µm
					planmeca emerald				50µm
					planmeca planscan				
Ajioka et al[17]	comparative study	10	10	PVS	LAVA COS(optical)			65.94	58.46
Boeddinghaus et al[5]	comparative study	24	24	PVS	Ocam,Tdef,CTRIOS	single crown		113	Tdef-88
									CTRIOS-112

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									Ocam-149
Ender et al[4]	comparison study	8	8	POE,VSE,VSES,	CER,ITE,OC,iTero,LAVA	full arch scan			
				ALG,polyether			POE-60.2		CER-29.4
							VSE-13.0		OC-37.3
							VSES-11.5		ITE-32.4
							ALG-37.7		LAVA-44.9
									VSES dig-35.1
Kim et al[6]	comparative study	15	15	Exafine putty	iTero			17.6	23.9
Lin et al[18]	comparative study	10	10	PVS	cadent iTero			0.084	0.304
Seelbech et al[7]	RCT	10	10	PVS(2 & 1 step)	Lava COS,iTero,CEREC	single crown	1 step		Lava -48
							(lava zirconia)-33		iTero-41
							1 step		CEREC-30
							(cera E alloy)-38		
							2 step		
							(lava zirconia)-60		
							2 step		
							(cera E alloy)-68		
Guth et al(2013)[9]	comparative study	12	24	polyether	Lava COS-direct,				Lava COS-17µm
					Lava Scan ST- indirect				conv-digital-23µm
									Lava ST-36µm
Guth et	compara	12	12	polyethe	Tdef				conv digi-

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al (2015)[15]	tive study			r					0.077
									Tdef-.089
Guth et al[11]	compara tive study	12	12 each	polyethe r	CS 3500,ZFX,C EREC BLU				Tdef-0.11
					CEREC AC,Tdef				CS 3500-0.14
									conv-digital-0.19
									CEREC BLU-0.29
									CEREC AC-0.31
									ZFX-0.33
Meija et al[8]	compara tive study	45	45	PVS	Kavo arcticascan	single crown		26.2	TRIOS-19.1
					TRIOS				Kvo-23.5

Al-Imam et al[12]	comparative study	9	9	PVS	TRIOS	Dreve model	21.5µm	Scanbiz-23.2µm
						Scanbiz model		Dreve-29.1µm
Ender et al(2013)[14]	comaprative study	5	5	vinyl siloxanet her	reference scanner			conv-digital-12.5,20.4µm
					(infocus standard,			digitalmodel - 32.4,58.6µm
					Alicona imaging			
Ender et al(2015)[28]	comparative study	15	15 each	vinylsilox anether	Tdef,Lava COS,iTero,		full arch tray-18.8	Tdef-21.8
				(full arch tray,T tray)	TRIO,TRIO S C,CEREC 4.0,		T tray-58.5	COS-47.7
					CEREC 4.2,CEREC			ITE-49.0

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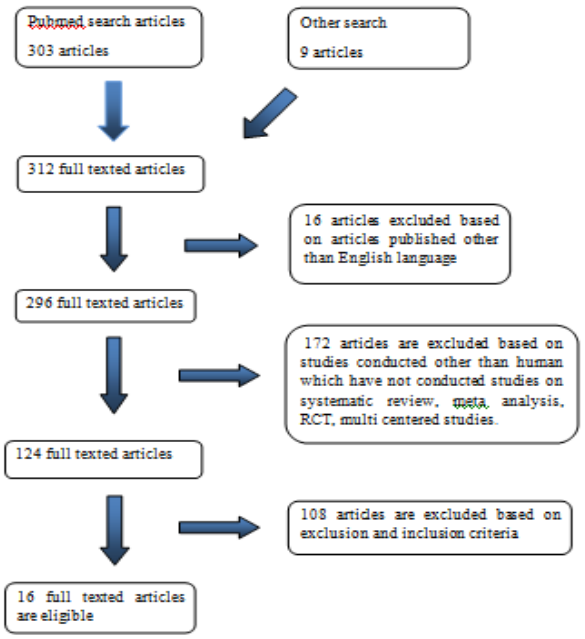
					OC)			
								TRI-25.7
								TRIC-26.1
								BC 4.0-34.2
								BC 4.2-43.3
								OC-37.4
Vecsi et al[10]	comaprative study	10	10 each	PVS	ItERO,cerec, trios			direct - -40.3
								indirect-22.3
Praca et al[19]	comparative		40 each		ultrasound scanner,CS2			ultrasound-113.8µm
					intraoral - TRIOS,LAVA COS			CS2-31.74µm
								LAVA COS-41.98µm
								TRIOS-42.70µm

Figure 1: Search strategy



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REFERENCE:

1. Christensen GJ. Marginal fit of gold inlay castings. Journal of Prosthetic Dentistry. 1966 Mar 1;16(2):297-305.
2. Fransson B, Øilo G, Gjeitanger R. The fit of metal-ceramic crowns, a clinical study. Dental Materials. 1985 Oct 1;1(5):197-9.
3. Eames WB, O'Neal SJ, Monteiro J, Miller C, Roan JD, Cohen KS. Techniques to improve the seating of castings. The Journal of the American Dental Association. 1978 Mar 1;96(3):432-7.
4. Ender A, Mehl A. Accuracy of complete-arch dental impressions: a new method of measuring trueness and precision. The Journal of prosthetic dentistry. 2013 Feb 1;109(2):121-8.
5. Boeddinghaus M, Breloer ES, Rehmann P, Wöstmann B. Accuracy of single-tooth restorations based on intraoral digital and conventional impressions in patients. Clinical oral investigations. 2015 Nov 1;19(8):2027-34.
6. Kim SY, Kim MJ, Han JS, Yeo IS, Lim YJ, Kwon HB. Accuracy of dies captured by an intraoral digital impression system using parallel confocal imaging. International Journal of Prosthodontics. 2013 Mar 1;26(2)..
7. Seelbach P, Brueckel C, Wöstmann B. Accuracy of digital and conventional impression techniques and workflow. Clinical oral investigations. 2013 Sep 1;17(7):1759-64.
8. Mejía JB, Wakabayashi K, Nakamura T, Yatani H. Influence of abutment tooth geometry on the accuracy of conventional and digital methods of obtaining dental impressions. The Journal of prosthetic dentistry. 2017 Sep 1;118(3):392-9.
9. Güth JF, Keul C, Stimmelmayr M, Beuer F, Edelhoff D. Accuracy of digital models obtained by direct and indirect data capturing. Clinical oral investigations. 2013 May 1;17(4):1201-8.
10. Vecsei B, Joós-Kovács G, Borbély J, Hermann P. Comparison of the accuracy of direct and indirect three-dimensional digitizing processes for CAD/CAM systems–an in vitro study. Journal of prosthodontic research. 2017;61(2):177-84.
11. Güth JF, Runkel C, Beuer F, Stimmelmayr M, Edelhoff D, Keul C. Accuracy of five intraoral scanners compared to indirect digitalization. Clinical oral investigations. 2017 Jun 1;21(5):1445-55.
12. Al-Imam H, Gram M, Benetti AR, Gotfredsen K. Accuracy of stereolithography additive casts used in a digital workflow. The Journal of prosthetic dentistry. 2018 Apr 1;119(4):580-5.
13. Ender A, Zimmermann M, Attin T, Mehl A. In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. Clinical oral investigations. 2016 Sep 1;20(7):1495-504.
14. Ender A, Mehl A. Full arch scans: conventional versus digital impressions--an in-vitro study. International journal of computerized dentistry. 2011;14(1):11-21.
15. Güth JF, Edelhoff D, Schweiger J, Keul C. A new method for the evaluation of the accuracy of full-arch digital impressions in vitro. Clinical oral investigations. 2016 Sep 1;20(7):1487-94.
16. Mennito AS, Evans ZP, Nash J, Bocklet C, Lauer A, Bacro T, Cayouette M, Ludlow M, Renne WG. Evaluation of the trueness and precision of complete arch digital impressions on a human maxilla using seven different intraoral digital impression systems and a laboratory scanner. Journal of Esthetic and Restorative Dentistry. 2019 May 6.
17. Ajioka H, Kihara H, Odaira C, Kobayashi T, Kondo H. Examination of the position accuracy of implant abutments reproduced by intra-oral optical impression. PloS one. 2016 Oct 5;11(10):e0164048.
18. Lin WS, Harris BT, Elathamna EN, Abdel-Azim T, Morton D. Effect of implant divergence on the accuracy of definitive casts

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created from traditional and digital implant-level impressions: an in vitro comparative study. International Journal of Oral & Maxillofacial Implants. 2015 Jan 1;30(1).

19. Praça L, Pekam FC, Rego RO, Radermacher K, Wolfart S, Marotti J. Accuracy of single crowns fabricated from ultrasound digital impressions. Dental Materials. 2018 Nov 1;34(11):e280-8.
20. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. The Journal of prosthetic dentistry. 1989 Oct 1;62(4):405-8.
21. Thongthammachat S, Moore BK, Barco MT, Hovijitra S, Brown DT, Andres CJ. Dimensional accuracy of dental casts: influence of tray material, impression material, and time. Journal of Prosthodontics. 2002 Jun;11(2):98-108.
22. Caputi S, Varvara G. Dimensional accuracy of resultant casts made by a monophase, one-step and two-step, and a novel two-step putty/light-body impression technique: an in vitro study. The Journal of prosthetic dentistry. 2008 Apr 1;99(4):274-81.
23. Kumari N, Nandeeshwar DB. The dimensional accuracy of polyvinyl siloxane impression materials using two different impression techniques: An in vitro study. The Journal of the Indian Prosthodontic Society. 2015 Jul;15(3):211.
24. Petrie CS, Walker MP, O'Mahony AM, Spencer P. Dimensional accuracy and surface detail reproduction of two hydrophilic vinyl polysiloxane impression materials tested under dry, moist, and wet conditions. The Journal of prosthetic dentistry. 2003 Oct 1;90(4):365-72.
25. Ashtiani RE, Khanlar LN, Mahshid M, Moshaverinia A. Comparison of dimensional accuracy of conventionally and digitally manufactured intracoronal restorations. The Journal of prosthetic dentistry. 2018 Feb 1;119(2):233-8.
26. Grünheid T, McCarthy SD, Larson BE. Clinical use of a direct chairside oral scanner: an assessment of accuracy, time, and patient acceptance. American Journal of Orthodontics and Dentofacial Orthopedics. 2014 Nov 1;146(5):673-82.
27. Euán R, Figueras-Álvarez O, Cabratosa-Termes J, Oliver-Parra R. Marginal adaptation of zirconium dioxide copings: influence of the CAD/CAM system and the finish line design. The Journal of prosthetic dentistry. 2014 Aug 1;112(2):155-62.
28. Ender A, Mehl A. In-vitro evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence International. 2015 Jan 1;46(1).
29. Müller P, Ender A, Joda T, Katsoulis J. Impact of digital intraoral scan strategies on the impression accuracy using the TRIOS Pod scanner. Quintessence international. 2016 Apr 1;47(4).
30. Kamimura E, Tanaka S, Takaba M, Tachi K, Baba K. In vivo evaluation of inter-operator reproducibility of digital dental and conventional impression techniques. PloS one. 2017 Jun 21;12(6):e0179188.

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