Review

Accuracy of an intraoral digital impression: A review

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Abstract Intraoral scanners (IOSs) are used for capturing the direct optical impressions in dentistry. The development of three-dimensional technology and the trend of increasing the use of IOSs in dental office routine lead to the need to assess the accuracy of intraoral digital impressions. The aim of this review was to assess the accuracy of the different IOS and the effect of different variables on the accuracy outcome. An electronic search using PubMed with specific keywords to obtain potential references for review. A search of MEDLINE (PubMed) identified 507 articles. After title and abstract screening, 412 articles were excluded for not meeting the inclusion criteria and discarding duplicate references. Ninety-five articles were followed for full screening; only 24 articles were included in the final analysis. The studies indicated a variable outcome of the different IOS systems. While the accuracy of IOS systems appears to be promising and comparable to conventional methods, they are still vulnerable to inaccuracies.

Keywords: Accuracy, digital impression, intraoral scanner, optical impression

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INTRODUCTION

Progress in digital dentistry has not only popularized the concepts of computer-aided design (CAD) and computer-aided manufacturing (CAM) but also created the provision for more efficacious and predictable therapeutic outcomes.

Obtaining three-dimensional images have accentuated the accuracy of the conventional prosthetic options and also provides for the virtual definition of various treatment strategies and to digitally design and fabricate varied types of restorations. Based on the type of tissue scanned, various principles and technologies have been developed and are being applied. The predicaments associated with conventional impression procedures have further highlighted the applications of intraoral scanners (IOSs). The intraoral digital scanning has been perceived as a more rapid and convenient technique from the perspective of both the dentists and the patients.[1]

Digital intraoral scanning has provided numerous benefits such as real-time visualization, easy repeatability, selective capture of the relevant areas, no need to disinfect and clean dental impressions and impression trays, cast pouring, no wear of the model, rapid communication and availability.[2-8]

Many CAD-CAM systems are available in the market for chairside digital impression and prosthesis fabrication.[9-12] Different IOSs by the numbers of company are increasing

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that offer user-friendly, perceived as pleasant for the patient[13,14] and time efficient[15,16]

Dental impressions, either conventional or digital, are primarily aimed at obtaining an imprint of one or more prepared teeth, the adjacent and antagonist as well, in conjunction with the inter-occlusal record relationship.[17] Thus, the reproducibility of the impression is a core criterion that reflects the definitive outcome of the planned restoration. Apart from the operational and clinical differences (speed of use, need of powder, and size of the tips) and cost (purchase and management) of various scanners, the essential aspect to be considered must be the quality of the data derived from scanning, which is defined as "accuracy."[18] Accuracy is the consolidation of two elements, both essential and complementary; "trueness" and "precision."[18] The term "trueness" refers to the ability of a measurement to match the actual value of the quantity being measured.[18] Precision is defined as the ability of a measurement to be consistently repeated, or simply put, the ability of the scanner to derive repeatable outcomes when applied in varied measurements of the same object.[18]

Different scanning techniques are been implemented in different IOSs that may yield different scanning accuracies.[9] Therefore, the purpose of this review was to compare the accuracy of different IOSs and the effect of different variables on the accuracy outcome.

I STUDY DESIGN AND METHODS

An electronic search of literature was performed using a PubMed database of Medline. Applying the PICO format of population = tooth/teeth/arch; intervention = IOS technique(s); comparison = alternative impression technique(s); and outcome = accuracy, was done to define the search question. The search was aimed to collect the articles that investigated the accuracy of IOS for teeth/arch published until 2018.

Different combination of the following terms was applied using Boolean operator of PubMed database:

Teeth/arch, digital impression, optical impression, IOS, and accuracy, to obtain potential references for review. Articles were considered for inclusion criteria if it was published in English language, laboratory or clinical study, evaluating a current IOS system, evaluating scanning accuracy, quantitative results provided, excluding the article other than in English, literature review, article that evaluate the marginal adaptation and fit evaluation of the fabricated restoration, scanning done for digital implant impression or implant-supported prosthesis and duplicates were discarded [Table 1].

Table 1: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Study evaluating IOS accuracy, without computer-aided manufacturing	Study evaluating the marginal adaptation and fit evaluation of the fabricated restoration
Study done for tooth/arch scanning	Scanning done for digital implant impression or implant supported prosthesis
Laboratory or clinical study	Article not in English language
Article published in English language	Article published in nonindex journals

IOS: Intraoral scanner

RESULTS

A search of MEDLINE (PubMed) identified 507 articles. After title and abstract screening, 412 articles were excluded for not meeting the inclusion criteria and discarding duplicate references. Ninety-five articles were followed for full screening; only 24 were included in the final analysis.

DISCUSSION

The purpose of the present review was to determine the accuracy of the different IOSs. The studies included in the review have been mentioned in Table 2. Different IOSs evaluated in studies with their respective advantages and disadvantages have been summarized in Tables 3 and 4. A multitude of factors influences the reproducibility of an IOS, including the scanning technology, data processing algorithm, the choice to use powder, and image acquisition method. Active triangulation, a traditional scanning technology that is frequently utilized, offers the highest trueness.[31] Comparatively, the parallel confocal technology need not require a certain distance for focusing, thus ensuring accurate images irrespective of whether the scanner tip is in contact with the teeth when the oral cavity is scanned.[31] Concurrently, the optical coherence tomography provides for high resolution to procure an image of the micromorphology of the abutment by consolidating the optical interference phenomenon and the confocal microscopy technology.[31] Park[31] reported that restoration type, the preparation outline form, the scanning technology and the application of power affect the accuracy of the IOS.

Hack and Patzelt[26] reported that TRIOS to be the most accurate (trueness ± 0.9 μm and precision 4.5 ± 0.9 μm) when scanned for single tooth compared to the other scanner (True definition, ITero, CS3500, Omnicam, and Planscan) and Omnicam and Planscan to be least accurate.

Table 2: Studies including the accuracy of different intraoral scanner

Study	Study design	Model	IOS used	Accuracy
Ender and Mehl[19]	*In vitro*	Complete arch model with 3 prepared teeth	Cerec AC Bluecam Lava COS	Cerec AC Bluecam Trueness: 49.0 µm Precision: 30.9 µm Lava COS Trueness: 40.3 µm Precision: 60.1 µm
Patzelt *et al*.[20]	*In vitro*	Model with 14 prepared abutments	iTero, CEREC AC Bluecam, Lava COS, and Zfx IntraScan	Cerec bluecam Trueness: 332.9 µm Precision: 99.1 µm iTero Trueness: 49.6 µm Precision: 40.5 µm Lava COS Trueness: 38.0 µm Precision: 37.9 µm Zfx Intrascan: Trueness: 73.7 µm Precision: 90.2 µm
Patzelt *et al*.[21]	*In vitro*	Edentulous jaw models	CEREC AC Bluecam, Lava Chairside Oral Scanner COS, iTero, Zfx IntraScan	CEREC AC Bluecam Trueness Maxilla: 591.8 µm Mandible: 558.4 µm Precision Maxilla: 332.4 µm Mandible: 698.0 µm ITero Trueness Maxilla: 144.2 µm Mandible: 191.5 µm Precision Maxilla: 178.5 µm Mandible: 197.9 µm Lava Chairside Oral Scanner COS Trueness Maxilla: 52.9 µm Mandible: 44.1 µm Precision Maxilla: 30.8 µm Mandible: 21.6 µm Zfx IntraScan Trueness Maxilla: 283.8 µm Mandible: 283.8 µm Precision Maxilla: 425.3 µm Mandible: 319.4 µm
Patzelt *et al*.[22]	*In vitro*	Full-arch polyurethane cast (14 prepared abutments)	iTero, Lava Chairside Oral Scanner, CEREC AC Bluecam	Lava Chairside Oral Scanner Trueness: 67.50 µm Precision: 13.77 µm iTero Trueness: 98.23 µm Precision: 48.83 µm CEREC AC Bluecam Trueness: 75.80 µm Precision: 21.62 µm
Ender and Mehl[23]	*In vitro*	Steel reference model fabricated from maxillary impression with two full crown and one inlay preparation	CEREC Bluecam, CEREC Omnicam, Cadent iTero, Lava COS	CEREC Bluecam Trueness: 29.4 µm Precision: 19.5 µm CEREC Omnicam Trueness: 37.3 µm Precision: 35.5 µm Cadent iTero Trueness: 32.4 µm Precision: 36.4 µm

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Table 2: Contd...

Study	Study design	Model	IOS used	Accuracy
				Lava COS Trueness: 44.9 µm Precision: 63.0 µm
Ender *et al*.[24]	*In vivo*	Five participants with a complete dentition	CEREC Bluecam, CEREC Omnicam, Cadent iTero, Lava COS, True Definition Scanner, 3Shape TRIOS, 3Shape TRIOS Color	CEREC Bluecam Precision: 56.4 µm CEREC Omnicam Precision: 48.6 µm Cadent iTero Precision: 68.1 µm Lava COS Precision: 82.8 µm True Definition Scanner Precision: 59.7 µm 3Shape TRIOS Precision: 47.5 µm 3Shape TRIOS Color Precision: 42.9 µm
Su and Sun[25]	*In vitro*	Nissin Dental Study Model (upper jaw) with prepared abutments designed to form 5 set of arrangements Arrangement 1: Single prepared maxillary central incisor Arrangement 2: Single prepared maxillary first molar Arrangement 3: Prepared central incisor and canine with the lateral incisor absent Arrangement 4: Half of the upper arch with 7 prepared teeth Arrangement 5: Entire upper arch with 14 prepared teeth	TRIOS intraoral digital scanner	TRIOS Precision for arrangement 1: 13.33 µm Precision for arrangement 2: 7.0 µm Precision for arrangement 3: 16.33 µm Precision for arrangement 4: 41.56 µm Precision for arrangement 5: 88.44 µm
Hack and Patzelt[26]	*In vitro*	Typodont teeth - first right maxillary molar Prepared for an all-ceramic embedded in acrylic	iTero, True Definition, PlanScan, CS 3500, TRIOS, CEREC AC OmniCam	iTero Trueness: 9.8 µm Precision: 7.0 µm True Definition Trueness: 10.3 µm Precision: 6.1 µm PlanScan Trueness: 30.9 µm Precision: 26.4 µm CS 3500 Trueness: 9.8 µm Precision: 7.2 µm TRIOS Trueness: 6.9 µm Precision: 4.5 µm CEREC AC OmniCam Trueness: 45.2 µm Precision: 16.2 µm
Jeong *et al.*[27]	*In vitro*	Maxillary complete-arch of unprepared teeth	CEREC Omnicam, CEREC Bluecam	CEREC Omnicam Trueness: 197.0 µm Precision: 58.0 µm CEREC Bluecam Trueness: 378.0 µm Precision: 116.0 µm

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Table 2: Contd...

Study	Study design	Model	IOS used	Accuracy
Renne *et al*.[28]	*In vitro*	Custom maxillary complete-arch model scanned for posterior sextant and complete arch	CEREC omnicam, CEREC Bluecam, Planmeca Planscan, Cadent iTero, Carestream 3500, 3Shape TRIOS 3	CEREC Omnicam Trueness: 101.5 µm Precision: 133.4 µm CEREC Bluecam Trueness: 140.5 µm Precision: 194.2 µm Planmeca Planscan Trueness: 96.2 µm Precision: 124.6 µm Cadent iTero Trueness: 56.2 µm Precision: 89.4 µm Carestream 3500 Trueness: 76.0 µm Precision: 113.8 µm 3Shape TRIOS 3 Trueness: 69.4 µm Precision: 105.6 µm
Lee *et al*.[29]	*In vitro*	Single prepared molar tooth for crown (PMMA)	CEREC Omnicam, Cerec Bluecam	Cerec Bluecam Trueness: 17.5 µm Precision: 12.7 µm CEREC Omnicam Trueness: 13.8 µm Precision: 12.5 µm
Kim *et al*.[30]	*In vitro*	Mandibular quadrant model (resin) with 4 prepared teeth, and 2 arrangements With edentulous area With alumina landmark on the middle of the edentulous area	CS3500, Cerec Omnicam, TRIOS	CS3500 Trueness with no marker: 38.8 µm Trueness with marker: 26.7 µm Precision with no marker: 43.6 µm Precision with marker: 12.4 µm Cerec Omnicam Trueness with marker: 31.8 µm Precision with marker: 10.5 µm TS TRIOS Trueness with no marker: 36.1 µm Trueness with marker: 30.6 µm Precision with no marker: 13.0 µm Precision with marker: 9.2 µm
Park[31]	*In vitro*	Maxillary arch model containing five prepared teeth	E4D dentist, Fastscan, iTero, TRIOS, Zfx Intrascan	E4D Trueness: 114.2 µm Precision: 97.6 µm Fastscan Trueness: 45.2 µm Precision: 26.0 µm iTero Trueness: 52.1 µm Precision: 25.8 µm TRIOS Trueness: 49.7 µm Precision: 13.0 µm Zfx Intrascan Trueness: 89.4 µm Precision: 132.3 µm
Kuhr *et al*.[32]	In vivo	Complete lower arch natural dentition with 4 metal spheres, Measuring the linear distance between the center of the spheres that correspond to a) Intercanine distance b) Intermolar distance c) Diagonal distances d) Segment distances	CEREC Omnicam, True Definition, TRIOS	The control group (polyether impression) showed the lowest deviation for all the distances followed by True Definition, TRIOS and Cerec Omnicam greatest deviation was observed for inter molar distance

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Table 2: Contd...

Study	Study design	Model	IOS used	Accuracy
Anh *et al*.[33]	*In vitro*	Maxillary arch of unprepared teeth with different degree of crowding Arch 1: Ideal arch Arch 2: Mild crowding Arch 3: Moderate crowding Arch 4: Severe crowding	iTero, TRIOS	iTero Arch 1: 28.2 μm Arch 2: 29.6 μm Arch 3: 28.4 μm Arch 4: 33.2 μm TRIOS Arch 1: 23.8 μm Arch 2: 21.9 μm Arch 3: 21.0 μm Arch 4: 22.0 μm
Güth *et al*.[34]	*In vitro*	A titanium model with a premolar and molar with a chamfer preparation representing the base for a four-unit FPD	CS 3500, Zfx Intrascan, CEREC AC Bluecam, CEREC AC Omnicam, True Definition	CS 3500 Trueness: 14.0 μm Zfx Intrascan Trueness: 33.0 μm CEREC AC Bluecam Trueness: 29.0 μm CEREC AC Omnicam Trueness: 31.0 μm True Definition Trueness: 11.0 μm
Nedelcu *et al*.[35]	*In vitro*	Dental model with a crown preparation including supra and subgingival finish line	3M True Definition, Care-stream CS3500 CS3600, Dental wings IOS, Omnicam, Planscan, and TRIOS	Accuracy in term of resolution of triangles TRIOS: 23.5000 IMPR: 18.000 Dental wings: 14.500 Omnicam: 12.000 CS3500: 11.000 3M: 9000 CS3600: 8.500 Planscan: 7.500
Treesh *et al*.[36]	*In vitro*	Maxillary complete-arch reference cast	CEREC Bluecam, CEREC Omnicam, 3Shape TRIOS Carestream CS 3500	CEREC Bluecam Trueness: 37.4 μm Precision: 27.6 μm CEREC Omnicam Trueness: 48.8 μm Precision: 40.2 μm 3Shape TRIOS Trueness: 45.8 μm Precision: 40.4 μm Carestream CS 3500 Trueness: 84.6 μm Precision: 90.4 μm
Kim *et al*.[1]	*In vitro*	Bimaxillary complete-arch model with various cavity preparations (epoxy resin)	CEREC Omnicam, CS 3500, E4D Dentist, iTero, PlanScan, TRIOS, True Definition, Zfx IntraScan, FastScan	Trueness according to capture principle Confocal microscopy: 49.35 μm Triangulation: 73.50 μm Swept source optical coherence tomography: 137.0 μm Wavefront sampling: 43.50 μm Trueness according to data capturing mode Individual images: 70.55 μm Video sequence: 56.45 μm Trueness according to Powder coating Yes (need for coating): 46.70 μm No (no nned for coating): 79.05 μm
Lee[37]	In vivo	32 participates were scan for maxillary as well as mandibular arch	TRIOS and iTero	Average deviations between the two intraoral scans were 0.057 mm in the maxilla and 0.069 mm in the mandible
Malik *et al*.[38]	*In vitro*	Model of a maxillary arch form	TRIOS, 3Shape, CEREC Omnicam, Sirona	TRIOS, 3Shape Trueness: 87.1 μm Precision:49.9 μm CEREC Omnicam, Sirona Trueness: 80.3 μm Precision: 36.5 μm

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Table 2: Contd...

Study	Study design	Model	IOS used	Accuracy
Rehmann *et al*.[39]	*In vitro*	Laser-sintered cobalt-chromium master model of maxillary arch with 3 prepared teeth	CEREC Bluecam (decalibrated), CEREC Bluecam (calibrated), Lave Chairside Oral Scanner (decalibrated), Lave Chairside Oral Scanner (calibrated), iTero scanner (control scanner)	CEREC Bluecam (decalibrated) Trueness: 108.4 μm CEREC Bluecam (calibrated) Trueness: 16.5 μm Lave Chairside Oral Scanner (decalibrated) Trueness: 80.9 μm Lave Chairside Oral Scanner (calibrated) Trueness: 34.9 μm iTero scanner (control scanner) Trueness: 24.4 μm
Müller *et al*.[40]	*In vitro*	cobalt-chromium alloy master maxillary model with 3 prepared teeth Three different scanning strategies were used a) Buccal-occlusal surface of the whole arch followed by occlusal-palatal surface b) Occlusal-palatal surface of the whole arch followed by buccal-occlusal surface c) Alternating between the buccal, occlusal and palatal surface of each tooth and moving along the arch)	TRIOS	Buccal-occlusal then occlusal-palatal scanning strategy Trueness: 17.9 μm Precision: 35.0 μm Occlusal-palatal then buccal-occlusal scanning strategy Trueness: 17.5 μm Precision: 7.9 μm Alternation between buccal, occlusal, and palatal surface scanning strategy Trueness: 26.8 μm Precision: 8.5 μm
Ali[41]	*In vitro*	Model 3 unit fixed partial denture abutments (epoxy resin)	CadentiTero, Lava COS, CEREC Bluecam, E4D Dentist	CadentiTero Trueness: 23.0 μm Lava COS Trueness: 36.0 μm CEREC Bluecam Trueness: 68.0 μm E4D Dentist Trueness: 84.0 μm

IOS: Intraoral scanner, FDP: Fixed partial denture

Even Güth *et al*.[34] results showed that Cerec Bluecam and Omnicam were least accurate in term of trueness compare to other scanners (CS 3500, Zfx Intrascan CEREC AC Bluecam, CEREC AC Omnicam, True Definition) with the True Definition and CS 3500 to be most accurate when used to scan a titanium model for four unitsfixed prosthesis (FPD).

The most critical component in prosthodontics for fixed prosthesis is the finish line accuracy when IOSs are used. Nedelcu *et al*.[35] studied the finish line distinctness and finish line accuracy in 7 IOSs (3M, CS3500 and CS3600, DWIO, Omnicam, Planscan and TRIOS). TRIOS displayed the highest level of finish line distinctness and together with CS3600, the highest finish line accuracy, DWIO and PLAN, on the other hand, displayed a generally low level of finish line distinctness and finish line accuracy.[35] The author, thus, reached on a consensus that there are sizeable variations between IOSs with both higher and lower finish line distinctness and finish line accuracy. High finish line distinctness had more correlation to high localized finish line resolution, and nonuniform tessellation than to high overall resolution, color output from some scanners may better delineate the finish line due to the contrast provided; but relies on the underlying technology.[35]

In vitro scanning done for a complete arch by Kim *et al*.[1] using 9 IOS found that median average trueness values were better for TRIOS as compared to the E4D and Zfx IntraScan scanners, which were found to be least accurate for full arch scan. The authors also observed that Fast Scan and True Definition IOSs, which require a powder coating before scanning, exhibited significantly better trueness than IOSs that did not require powdering.[1]

Another *in vitro* study on scanning complete arch model by Ender and Mehl[19] compared the accuracy of digital scanning (Lava COS and CEREC Bluecam) to conventional impressions (Impregum) reported similar trueness between the digital and conventional impressions, whereas the CEREC Bluecam showed significantly higher precision than the conventional and Lava COS. However, Patzelt *et al*.,[20] in their evaluation of 4 IOSs (CEREC Bluecam, iTero, Lava

Table 3: Details of intraoral scanner systems included in studies

Scanners	Manufacturing company	Scanning principle	Scanning surface treatment with powder application
Cerec Bluecam	Sirona, Bensheim, Germany	Image acquisition after visible blue light emission Working principle - triangulation of light	Yes
Cerec Omnicam	Sirona, Bensheim, Germany	Continuous imaging, data acquisition generate 3D model Working principle - triangulation of light	-
Cadent iTero	Cadent Inc., Carstadt, New Jersey, United State	Image after laser emission (light source- red laser) Working principle-confocal microscopy principles	-
Lava COS	3M ESPE, Seefeld, Germany	Scanning method - 3D in-motion technology Working principle-active wavefront sampling	Yes
Lava True Definition	3M ESPE, Seefeld, Germany	3D in-motion video imaging technology	Yes
TRIOS	3Shape, Copenhagen, Denmark	Ultrafast imaging Working principle-confocal Microscopy principles	-
TRIOS Color	3Shape, Copenhagen, Denmark	Ultrafast imaging Working principle-confocal Microscopy principles Natural colored imaging	-
E4D	D4D Technologies, LLC, Richardson, Texas, United State	High speed image acquisition after red light emission Working principle-Optical coherent tomography and confocal microscopy	-
Planscan	Planmeca, Richardson, Texas, United State	Highspeed image acquisition after blue laser emission Working principle-confocal microscopy principles	-
Carestream 3500	Carestream Dental, Atlanta, Georgia, United State	Single image acquisition with the aid of light guidance Working principle- optical triangulation	-
Carestream 3600	Carestream Dental, Atlanta, Georgia, United State	Active speed 3D video	-
Zfx intrascan	Zfx GmbH, Dachau, Germany	Working principle-confocal microscopy principles	-

3D: Three-dimensional

Table 4: Advantage and disadvantage of scanners

Scanner	Advantage	Disadvantage
CEREC AC-Bluecam	Distortion-free image Automatic shake detection system Image stabilization systems Have in office milling unit	Needs coatings
iTero	No need to apply any coatings to the teeth Generates a colored 3D-virtual model Can have output files in STL format	Larger scanner head No in office milling units
E4D	In office milling units	Must be held at a specific distance from the target Occasionally needs coatings
Lava COS	Capturing 3D data in a video sequence Improper scanning shows hole in image, re-scanning can be done and software patches the hole	Needs coatings No in office milling units
TRIOS	Variation of the focal plane without moving the scanner	No in office milling units

3D: Three-dimensional, STL: Standard Tessellation or Stereolithographic File

COS, and Zfx Intra Scan), demonstrated that the CEREC Bluecam was the least accurate (trueness 332.9 ± 64.8 μm; precision 99.1 ± 37.4 μm) and highest accuracy was observed with the Lava COS (trueness 38.0 ± 14.3 μm; precision 37.9 ± 19.1 μm). Similar finding was observed by the same author in 2014 while determining the accuracy of CAD/CAM-generated dental casts based on IOS data.[22] Rehmann *et al*. found recently calibrated Cerec Bluecam had the highest trueness, followed by iTero and Lava COS.[39]

A study by Jeong *et al*.[27] for the complete arch model, digital impressions obtained by the Omnicam intraoral video scanner were more accurate than those obtained by the Bluecam intraoral still image scanner. In a comparison of the accuracy of Bluecam and Omnicam for single tooth scanning, Lee *et al*.[29] reported similar precision for the two scanners.

Ender and Mehl[23] analyzed the accuracy of four different IOSs and four different impression materials. The results revealed that CEREC Bluecam was the most accurate (trueness 29.4 ± 8.2 μm and precision 19.5 ± 3.9 μm) followed by iTero (trueness 32.4 ± 7.1 μm and precision 36.4 ± 21.6 μm), then Omnicam (trueness 37.3 ± 14.3 μm and precision 35.5 ± 11.4 μm), followed by Lava COS (trueness 44.9 ± 22.4 μm and precision 63.0 ± 21.6 μm). The authors concluded that digital systems with single image stitching (iTero and CEREC Bluecam) showed local deviations at the terminal end of the arch, whereas the video-based systems (CEREC Omnicam and Lava COS) showed compression of the dental arch[23] and also stated that deviations of 100 μm and above across the full arch may lead to inaccurate fitting of the maxilla and mandible, which can be problematic in the case of large rehabilitations.[23] Even other studies had stated that digital impression show distortion of distal aspect when scan for complete arch[24,36,42]

Treesh *et al*.[36] in his study of complete arch accuracy with four different IOS (CEREC Bluecam, CEREC Omnicam, TRIOS Color, and Carestream CS 3500) found that TRIOS was most accurate among the scanner and CS3500 was the least whereas Renne *et al*.[28] had found that CS3500 performs better than the CEREC Bluecam, CEREC Omnicam for full-arch scan, but when the same scanner was used to scan the sextants, CS3500 was less accurate than the two. Authors gave the conclusion that scanners differ regarding the speed, trueness, and precision of sextant scans, with the Planscan and the CEREC Omnicam providing the best combination of speed, trueness, and precision and 3Shape TRIOS for the complete arch scan.[28]

Ali[41] founded differences in trueness between the different scanners (Cerec Bluecam, iTero, Lava COS, and E4D). Most accurate systems were iTero and Lava COS, and the least accuracy was reported for E4D followed by Cerec Bluecam.

Lee[37] found no statistical significance between the TRIOS and iTero scanners. Even Anh *et al*.[33] results showed the same when comparing the precision of the TRIOS and iTero. However, the scanning strategies have been shown to affect the accuracy.[33,40,43]

In 2018, Malik *et al*.[38] observed that conventional full-arch polyvinyl siloxane impressions exhibited higher accuracy compared to two direct optical scanners (TRIOS, 3Shape, and CEREC Omnicam, Sirona). Similar results were found when different scanner used to scan complete arch against the conventional impression in an *in vivo* studies as well as *in vitro* studies.[23,24,32,42] Hence, optical scanners seem to perform better in an *in vitro* environment, and their accuracy seems to be reduced *in vivo* as patient-specific factors, such as anatomic restrictions, movement, saliva, and soft tissue, contribute toward the accuracy of scan.[24,44]

Software version used for scanning can have a significant impact on the accuracy of an IOS.[45] Nedelcu and Persson[46] observed that even the type of material being scanned has a significant impact on the accuracy of the scanner. Greater deviations can be observed in the area of change of curvature,[47] so it is better that grooves, sharp preparation edges, boxes should be avoided. Rounded internal line angles are easier to replicate by the CAM process on the fitting surface of prostheses.[10]

Su and Sun[25] reported decline in the precision of intraoral digital impression with the increase in the area of scanned arch. Precision was clinically acceptable when scanning scope was less than half arch, that means the larger and more complicated the scan area, the lower the accuracy[25,48] Therefore, it is difficult to compare individual studies directly to arrive at a general conclusion regarding the accuracy of IOS. Studies done for the digitization of edentulous arch with the IOS found out to be feasible in *in vitro,* but research is to be needed to recommend the use of the scanners for the digitization of edentulous jaws *in vivo*.[21,30]

For longer span prosthesis, not only recording the tooth surface accurately but also registration of the occlusal relationship is needed, which is difficult to record by IOS after preparation of several teeth. Indeed, studies[3,4,6,7,49-51] have demonstrated that fabrication of single unit and short span prostheses (3 or 4 unit prostheses) using an IOS exhibit similar accuracy to prostheses fabricated by conventional techniques.

Digital dentistry is ushering in its popularity due to continued showcase of its potentials; however, much research is imperative to evaluate and compare the clinical accuracy of digital impression techniques for the complete arch. An amalgamation of the digital and conventional approach may provide the added benefits in clinical practice, in specific relation to the treatment strategies planned for each case.

CONCLUSION

Digital intraoral impression systems continue to undergo rapid development. Due to the heterogeneity of the data, it was difficult to compare individual studies directly to arrive at a general conclusion regarding the accuracy of IOSs, as different parameters (clinical or laboratory study, scanning for complete arch, partial edentulous arch or single tooth, and accuracy measured in term of resolution) are used to evaluate the accuracy of scanners. The accuracy of IOS is affected by several factors including the scanner technology, use of powder material being scanned, software for scanning, scanning strategy. Intraoral scanning systems, in comparison to conventional impressions, can be reliably used for diagnostic purposes and short-span scanning. However, for whole arch scanning, the IOS is susceptible of more deviation. The studies indicated a variable outcome of the different IOS systems. While the accuracy of IOS systems appears to be promising and comparable to conventional methods, they are still vulnerable to inaccuracies.

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Conflicts of interest

There are no conflicts of interest.

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