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Accuracy of digital implant impressions with intraoral scanners. A systematic review

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Aim: The use of intraoral scanners (IOS) for making digital implant impressions is increasing. However, there is a lack of evidence on the accuracy of IOS compared with conventional techniques. Therefore, the aim of this systematic review was to collect evidence on the accuracy of digital implant impression techniques, as well as to identify the main factors influencing the accuracy outcomes.
Materials and methods: Two reviewers searched electronic databases in November, 2016. Controlled vocabulary, free-text terms, and defined inclusion and exclusion criteria were used. Publications in English language evaluating the accuracy outcomes of digital implant impressions were identified. Pooled data were analysed qualitatively and pertinent data extracted.
Results: In total, 16 studies fulfilled the inclusion criteria: one *in vivo* and 15 *in vitro* studies. The clinical study concluded that angular and distance errors were too large to be acceptable clinically. Less accurate findings were reported by several *in vitro* studies as well. However, all *in vitro* studies investigating the accuracy of newer generation IOS indicated equal or even better results compared with the conventional techniques. Data related to the influence of distance and angulation between implants, depth of placement, type of scanner, scanning strategy, characteristics of scanbody and reference scanner, operator experience, etc were analysed and summarised. Linear deviations (means) of IOS used in *in vitro* studies ranged from 6 to 337 µm. Recent studies indicated small angle deviations (0.07–0.3°) with digital impressions. Some studies reported that digital implant impression accuracy was influenced by implant angulation, distance between the implants, implant placement depth and operator experience.
Conclusions: According to the results of this systematic review and based on mainly *in vitro* studies, digital implant impressions offer a valid alternative to conventional impressions for single- and multi-unit implant-supported restorations. Further *in vivo* studies are needed to substantiate the use of currently available IOS, identify factors potentially affecting accuracy and define clinical indications for specific type of IOS. Data on Data on accuracy OF digital records, as well as accuracy of printed or milled models for implant-supported restorations, are of high relevance and are still lacking.

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■ Introduction

Oral implants have improved the care of partially and completely edentulous patients for several decades. Although implant-supported dental prostheses have proved to be a reliable long-term solution[1,2], many biological and technical challenges still remain[3,4]. Digital technologies have revolutionised clinical prosthodontics, extending diagnostic, treatment and follow-up possibilities[5,6]. They have improved

conventional prosthetic approaches and enabled completely new treatment workflows, as well as introducing the concept of the "virtual patient"[7].

Accuracy is a key aspect in function and aesthetics of indirect restorations. The fit of implant-supported dental restorations has been discussed extensively in the literature[8]. In contrast to natural teeth, osseointegrated implants are not able to compensate for small inaccuracies of the prostheses, as they are virtually immobile[9]. Their sensory discrimination is more limited than for teeth[10]. The demand for accurately fitting implant-supported prostheses is further increased with the use of screw-retained restorations or when stiff and prone to cracking materials (e.g. materials (e.g. ceramics) are used to splint multiple implants with fixed partial dentures (FPD). Due to a build-up of errors in each clinical and laboratory step, a certain degree of inaccuracy is unavoidable. Many techniques have been proposed to evaluate the passive fit of restorations, however, none of them can be relied on solely[8]. Consequently, various methods to improve the fit of the multiple implant-supported restorations has been suggested[11,12,13]. Non-passively fitting restorations could potentially be related to mechanical complications: loss of retention, screw loosening, fracture of framework or veneering material[14,15]. However, consensus on the clinically acceptable level of misfit has not yet been reached. Several authors have proposed different recommendations for clinically acceptable misfit ranging from 10 µm to 150 µm[16]. It has even been suggested that for maintaining osseointegration of endosseous implants, passivity of fit of multi-unit restorations seems not to be as critical as previously thought[17]. Since the definition of the passive fit is still hypothetical and the level of clinically acceptable misfit has not been determined, clinicians should always strive to achieve the most accurate fit possible for implant-supported FPDs.

While modern CAM technologies technologies are capable of achieving a precise fit exceeding that of casting techniques, they still rely on the accuracy of impressions, definitive models and bite registrations[18]. Many previous studies reported on the accuracy of different conventional implant impression (CII) techniques, addressing the influence of number of implants, angulation, implant placement depth, type of implant-abutment connection, direct or indirect technique, and splinting of impression copings[19,20]. As a result, several systematic reviews have addressed the accuracy of conventional implant impression techniques[21-26]. Recently published studies preferred direct to indirect impressions and splinted over non-splinted techniques, especially with increased number of implants[21,27,28]. Implant angulation of 20 to 25 degrees negatively affected the multiple implant impression accuracy[24]. Results reported for internal connection implants were less consistent, in contrast to reports on external connection implants[29]. Even with procedural diligence, conventional impression techniques involve process-related risks, uncontrolled variables, expensive laboratory and chairside time, material expense, and patient discomfort[30].

Digital impressions were proposed as viable alternative to make impressions for tooth- and implant-supported restorations. The number of digital intraoral scanners (IOS) on the market is increasing, and new improved hardware and software versions are released continuously. IOS can capture the images as digital photographs or video. They eliminate tray selection, dispensing, setting and volumetric changes of impression materials, disinfection and transporting to dental laboratory, gypsum pouring and cast preparation for articulation[28].

As defined by ISO-5725-1:1994, accuracy of IOS consists of trueness and precision. Trueness describes the deviation of scans from the true dimensions of the object, while precision describes how much separate scans of the same object differ from each other.

IOS usage for teeth-supported restorations has more documentation than use with implant-supported prostheses. According to a recent systematic review, tooth-supported single-unit crowns fabricated using the digital impression technique presented statistically similar marginal discrepancies compared with those obtained with the conventional impression technique[31]. However, there is less evidence available on the accuracy of digital impressions for implant-supported restorations, especially FPDs[24]. In fact, a systematic review, addressing the accuracy of different implant impression techniques concluded that insufficient data exists on digital impression techniques and that the further studies are needed[28]. Recently, a number of articles addressing the accuracy of digital implant impressions (DII) have been published.

Table 1 Search strategy for MEDLINE/PubMed.

Search terms	Number of records returned
MeSH terms:	
"Dental Impression Technique"[Mesh]) AND "Dental Implants"[Mesh]	657
"Dental Impression Technique"[Mesh]) AND "Dimensional Measurement Accuracy"[Mesh]	59
"Dental Implants"[Mesh]) AND "Printing, Three-Dimensional"[Mesh]	23
"Dental Implant-Abutment Design"[Mesh]) AND "Dental Impression Technique"[Mesh]	136
"Dental Impression Materials"[Mesh] AND "Dental Implants"[Mesh]	398
Free-text:	
Implant AND intraoral scanner	37
Implant position AND digital	163
Implant AND impression	1007
Implant impression AND accuracy	233
Implant impression AND optical	44
Implant impression AND digital	104

Therefore, the aim of this review was to collect available evidence and evaluate accuracy outcomes of DII techniques. Additionally, different variables influencing accuracy of DII were identified when possible.

Materials and methods

This systematic review was conducted following PRISMA (Preferred Reporting for Systematic Reviews and Meta-Analyses) guidelines.

Focused question

What are the accuracy outcomes of digital implant impression techniques?

Inclusion and exclusion criteria

PICOS (patient, intervention, comparison, outcomes, study design) criteria were used for inclusion and exclusion of studies:

- Patients: partially or completely edentulous dental arch or replica with implants.
- Intervention: taking single-unit or multi-unit conventional and digital, or only digital implant impressions with commercially available IOS, using scanbodies.
- Comparison: accuracy of DII (or model produced from DII) compared to the reference model (or the model produced from CII).
- Outcomes: quantitative measurement of accuracy (linear, angular).
- Study design: *in vivo* and *in vitro* experimental studies.

Studies with clearly explained impression accuracy assessment methodology were included in the systematic review. Case reports, expert opinions, technical or clinical reports, incomplete publications, and review articles were excluded. However, potentially relevant information from these publications was also considered, though these publications were not included into the systematic review. Studies comparing outcomes of restorations fabricated from digital and conventional impressions were not included, as the restoration the fabrication process alone can considerably influence accuracy.

Search strategy and data collection

An electronic search was performed using selected databases: MEDLINE/PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, AMED (Ovid). Only English language publications were Included. Published and early-view online articles were identified. The latest search was conducted on November 10, 2016. A detailed search strategy was prepared including free-text and MeSH (Medical Subject Headings) terms for each database search. Search strategy for MEDLINE/PubMed is presented in Table 1. Additionally, a hand search was performed reviewing references of potentially

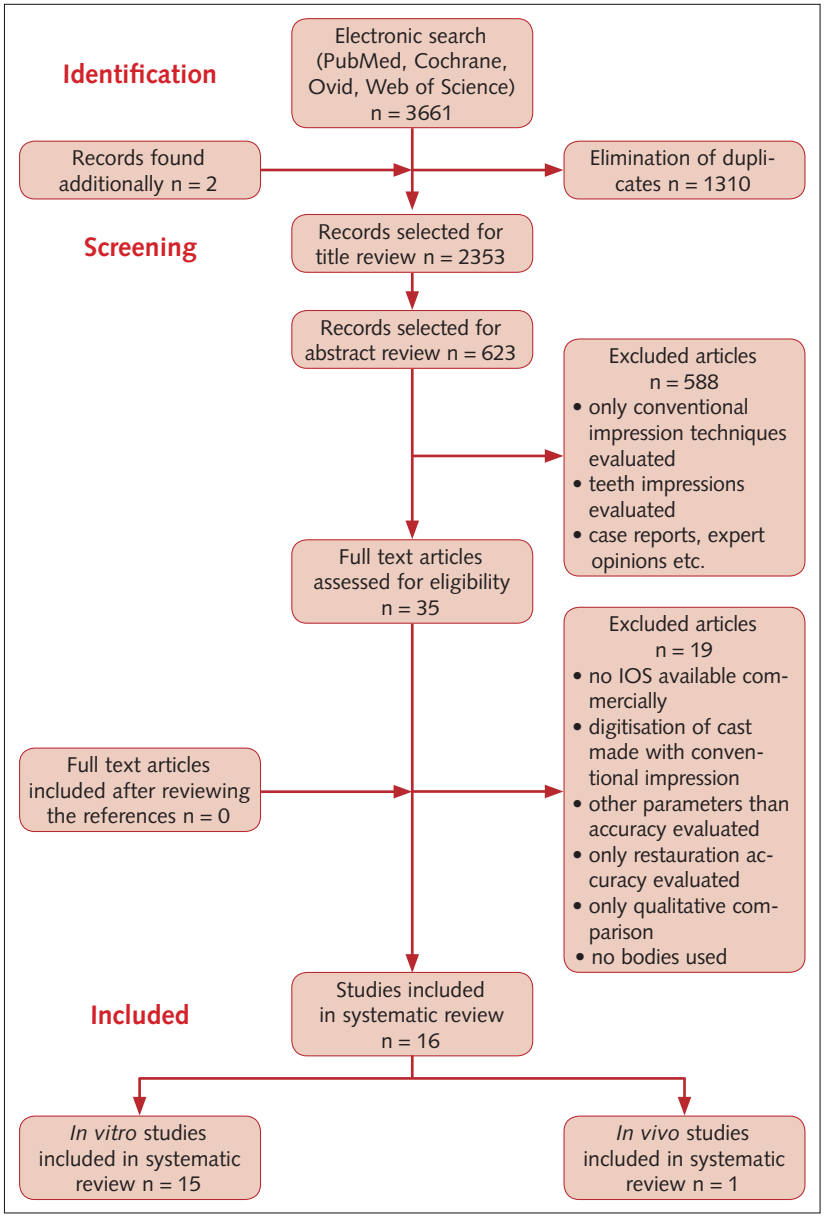

Fig 1 Study selection process.

pertinent papers, review papers as well as content of the following journals: Journal of Dental Research, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, European Journal of Oral Implantology, Implant Dentistry, International Journal of Oral and Maxillofacial Surgery, Journal of Cranio-Maxillo-Facial Surgery, Journal of Oral Implantology, Journal of Dentistry, Clinical Oral Investigations, and Journal of Oral Rehabilitation.

Identified publications were imported into the reference manager program (Zotero, Fairfax, VA, USA) and duplicates were removed electronically. Titles of the publications were screened by two calibrated reviewers (VR and AG). Abstracts of remaining publications were then screened. In cases when information provided in the abstract was insufficient, full-text articles were reviewed. Selected records were obtained for the full-text review. Based on inclusion and exclusion criteria, publications were selected for the systematic review. References of these publications were additionally searched for the other relevant publications. Following data, when possible, was extracted using the electronic spreadsheet: anatomic location, implant type, distance and angulation between implants, depth of placement, impression level, implant-abutment connection type, type of the scanner (powder/no powder), scanning strategy, characteristics of scanbody and reference scanner, operator experience, accuracy measurement methodology. Disagreements regarding record screening, title, abstract or full-text review, and data extraction were solved by discussion, leading to the consensus between all authors. In order to reduce the risk of bias, PRISMA guidelines were followed.

RESULTS

Included studies

The initial search resulted in 3661 records. After removing duplicates and adding records identified through other sources (one of them a PhD thesis published online), 2353 records were selected for title review. The subsequent selection at the title level yielded 623 titles. Screening of the abstracts revealed 35 publications. Of the 35 articles selected for the full-text review, 16 publications were finally included (Fig 1). Articles that were not included in this systematic review and the reasons for exclusion are shown in Table 2.

Characteristics of the included studies

Of the 16 included studies, one study was an *in vivo* study and 15 others were *in vitro* studies.

The majority of studies evaluated the accuracy of iTero IOS (n = 8), then True Definition (n = 5), Trios (n = 3), Lava COS (n = 3), Trios Color (n = 2), Cerec Bluecam (n = 2), ZFX Intrascan (n = 2), Cerec Omnicam (n = 1), 3D Progress (n = 1), CS3500

Table 2 Excluded studies and reasons for exclusion.

Studies	Reason for exclusion
Ortorp et al[62] 2005; Bergin et al[63] 2013	No commercially available scanner. Limited clinical applications.
Eliasson et al[64] 2012; Howell et al65 2013	Conventional impressions from digitally coded healing abutments taken. No digital impression technique with intraoral scanner was used.
Lee et al[66] 2013; Lee et al[67] 2013; Wismeijer et al[68] 2014; Calesini et al[69] 2014; Joda et al[53] 2015; Schepke et al[70] 2015; Joda et al[52] 2015; Joda et al[71] 2016	Accuracy of digital implant impression techniques was not evaluated.
Aktas et al[72] 2014; Abdel-Azim et al[73] 2014; Karl et al[74] 2012	Accuracy of different impression techniques was not evaluated. Fit of the prosthesis produced from conventional and digital impressions was evaluated *in vitro*.
Gherlone et al[75] 2015; Lee et al[76] 2015; Gherlone et al[77] 2016	Clinical study. No evaluation of digital implant impression accuracy.
Ajioka et al[38] 2016	No scanbodies used for the experiment.

(n = 1) and Planmeca Planscan (n = 1). Eight studies indicated the version of the IOS software[32–37,39,40], while the other eight studies did not[41–48]. Eight of the included studies evaluated accuracy of DII in the maxilla[33–35,42–45,40] and the other eight related to the mandible[32,36,37,41,46–48,39]. Six studies investigated situations with partially edentulous arch (from 1 to 3 implant-supported single- and multi-unit restorations)[41,44–46,37,40], and 10 looked at completely edentulous situations with two to six implants[32–36,42,43,47,48,40]. Data obtained from DII was compared with data from the reference model in 12 studies[33–35,41–44,48,40,36,47,39], with data from conventional models in four studies[36,47,39,32]. The majority of studies evaluated trueness of DII as a measure of accuracy. Precision was evaluated by five studies[41,44,45,48,40]. Three studies compared the accuracy of milled models fabricated from DII with reference or conventional models[44–46]. Distance (3D or in specific plane) and angle deviations were estimated in the included studies. Detailed characteristics and main findings of the included studies are listed in Tables 3 and 4.

Table 3 Characteristics and main findings of included *in vivo* study.

Article	No. of implants, positions	No. of patients, restorations	Implant angulation, average distance	Implant characteristics	Impression level	Scanned object, strategy	Type of intraoral scanner	Reference	Accuracy evaluation	Conclusion
Andriessen et al[32] 2014	2, regio #33 and #43	25, 25	No data	Standard SLA-active RN (Straumann, Basel, Switzerland), 4.1/12 mm; Internal connection	Implant level	RN Scanbody (Straumann); Hand-tightened; 5 scans (occlusal, 45 degrees buccal, 45 degrees lingual, mesioproximal, and distoproximal)	iTero (Cadent Inc); Software version 3.5.0; No powder	Master model, scanned with Lava Scan STscanner (3M ESPE, Seefeld, Germany)	Linear and angular. Measurement of the mid-centre line of the 2 scan abutments, showed a distance mean error of 226.0 mm compared with the reference scan. Distance error was smaller than 100 µm in 5 of the 21 scans. The mean absolute angulation error was 2.582 degrees. An angulation error <0.4 degrees was recorded in 3 of the 21 scans.	Digital impression accuracy is not adequate

Table 4 Characteristics and main findings of included *in vitro* studies.

Article	No. of implants. positions	Angulation	Placement depth (mm)	Implant manufacturer. connection	CII technique	DII technique: IOS; use of powder; scanning strategy	Number of impressions	Scanbody. torque value Ncm
Single-unit digital implant impressions								
Lee et al[45] 2015	1. #25	No data	No data	Bone Level. Regular Crossfit. (Straumann); Internal connection	CT. IL	iTero (Align Technology. Israel). no data on version; NP; No data on strategy	30	Scanbody (Straumann); No data on torque value
Koch et al[44] 2016	1. #25	No data	No data	Bone Level. Regular Crossfit (Straumann); Internal connection	Not used	iTero (Align Technology). no data on version; NP; No data on strategy	30	Scanbody (Straumann); No data on torque value
Multi-unit digital implant impressions								
Lin et al[46] 2015	2. #35 and #37. distance of 10 mm	0° divergency	1 mm coronal	RN. Standard Plus (Straumann); Internal connection	OT. NSp. IL	iTero (Align Technology). no data on version; NP; No data on strategy	40	Two-piece scanbody (Straumann); 15 Ncm
		15° divergency						
		30° divergency						
		45° divergency						
Papaspyridakos et al[47] 2015	5. interforaminal region	The medial 3implants - parallel; distal left - 10°. distal right - 15°.	No data	Bone Level Regular Crossfit (Straumann); Internal connection	OT 1)IL. Sp 2) IL. NSp 3) AL. Sp 4) AL. NSp	Trios (3Shape). No data on version; NP; No data on strategy	10	Scanbody (Straumann). No data on torque value
Vandeweghe et al[48] 2016	6. #36. #34. #32. #42. #44. #46	Parallel	No data	IBT. Southern Implants (Irene. South Africa); External connection	Not used	Lava COS (3M ESPE). no data on version; P; No data on strategy	10	PEEK. (Proscan Zonhoven Belgium); 10 Ncm preload
						3M True Definition (3M ESPE). no data on version; P; No data on strategy		
						Cerec Omincam (Sirona). no data on version; NP; No data on strategy		
						Trios (3Shape). no data on version; NP; No data on strategy		

VPS – polyvinylsiloxane; PE – polyether; CII – conventional implant impression; DII – digital implant impression; IOS – intraoral scanner; CMM – coordinate measuring machine; CT – closed tray; OT – open tray; IL – implant level; AL – abutment level; Sp – splinted; NSp – non-splinted; S – significant; NS – non-significant; BL – bone level; TL - tissue level; Absd - absolute angular distortion; P – powdered; NP – non-powdered.

<table>
<tr><th>Reference scanner</th><th>Accuracy evaluation. results</th><th>Conclusions</th></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Lava Scan ST (3M ESPE)</td><td>Comparison (linear): models produced from DII (milled model) and CII (gypsum model). compared to reference model
Horizontal CII 34 ± 9 mm. DII 11 ± 13 mm (NS)
Vertical CII -88 ± 44 mm. DII 93 ± 61 mm (S)</td><td>Vertical position of the implant in milled models was more coronal than in the plaster model. Cause of vertical position errors is commented to be processing errors of the analogue placement.</td></tr>
<tr><td>Lava Scan ST (3M ESPE)</td><td>Comparison: mean volumetric deviations at 5 selected points between DII model (digitized milled model) at implant surface and reference model
DII vs reference model -6 ± 40μm
DII vs milled model from DII 19 ± 162μm
DII model (milled) vs reference model 14 ± 170μm</td><td>Cumulative errors were found in the line of workflow. Software. scanner. and milling error (standard deviations. respectively: ±1. ±21. and ±98 μm) were shown to propagate throughout the digital workflow to the milled model (100 μm).</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Cagenix scanner (Cagenix Inc)</td><td>Differences between models produced from DII (digitised milled models) and CII (digitised impression models) (comparison of CII/DII models with reference model is not included in the table)
<table>
<tr><th>Linear differences</th><th>Angular differences</th></tr>
<tr><td>221 ± 35μm (S)</td><td>0.986 ± 0.218° (S)</td></tr>
<tr><td>260 ± 35 μm (S)</td><td>1.551 ± 0.218° (S)</td></tr>
<tr><td>159 ± 36 μm (S)</td><td>0.004 ± 0.218° (NS)</td></tr>
<tr><td>75 ± 36 μm (NS)</td><td>0.438 ± 0.218° (NS)</td></tr>
</table></td><td>Models made from CII were more accurate than made from DII. Divergence between the two implants significantly affected the accuracy. In 0° and 15° groups. the digital pathway resulted in less accurate models compared with the conventionally created ones. DII produced more accurate definitive models when the two implants diverged more.</td></tr>
<tr><td>IScan D103i (Imetric)</td><td>Comparison of 3D deviations (μm) of scanbodies on models produced from DII (digital model) and CII (digitised stone model) as compared to reference model (Interquartile range is shown in parenthesis).
<table>
<tr><th>Implant number</th><th>IL - Sp</th><th>IL - NSp</th><th>DII</th><th>AL - Sp</th><th>AL - NSp</th></tr>
<tr><td>1</td><td>5.79 (5.69–5.94)</td><td>21.89 (21.84–21.98)</td><td>23.39 (23.27–23.47)</td><td>33.10 (32.93–33.24)</td><td>14.59 (14.52–14.76)</td></tr>
<tr><td>3</td><td>9.16 (8.99–9.28)</td><td>13.00 (12.84–13.21)</td><td>15.27 (15.18–15.53)</td><td>14.31 (13.98–14.49)</td><td>1.27 (1.19–1.37)</td></tr>
<tr><td>4</td><td>4.70 (4.54–4.81)</td><td>13.39 (12.97–13.46)</td><td>7.60 (7.54–7.67)</td><td>12.04 (11.86–12.13)</td><td>6.91 (6.69–6.96)</td></tr>
<tr><td>5</td><td>12.52 (12.44–12.67)</td><td>131.75 (131.6–132.1)</td><td>29.02 (28.78–29.15)</td><td>8.86 (8.81–9.01)</td><td>9.63 (9.37–9.78)</td></tr>
</table></td><td>The accuracy of DII was not different than the implant-level. splinted CII and more accurate than the implant-level. non-splinted impressions.
The accuracy of implant impressions was not affected by the implant angulation up to 15°</td></tr>
<tr><td>104i scanner (Imetric)</td><td>Comparison: 3D deviations comparing DII (digital model) and reference model
<table>
<tr><th>Trueness</th><th>Precision</th></tr>
<tr><td>112 ± 25 μm</td><td>66 ± 25 μm</td></tr>
<tr><td>35 ± 12 μm</td><td>30 ± 11 μm</td></tr>
<tr><td>61 ± 23 μm</td><td>59 ± 24 μm</td></tr>
<tr><td>28 ± 7 μm</td><td>33 ± 12 μm</td></tr>
<tr><td colspan="2">Non-significant difference between 3M True Definition and Trios for trueness and precision.</td></tr>
</table></td><td>Significant differences in accuracy between the different scanners were found. Lava COS scanner did not achieve the necessary level of accuracy to be used for large-span implant-supported reconstructions. Other scanners demonstrated an acceptable level of trueness and precision for this indication.</td></tr>
</table>

Article	No. of implants. positions	Angulation	Placement depth (mm)	Implant manufacturer. connection	CII technique	DII technique: IOS; use of powder; scanning strategy	Number of impressions	Scanbody. torque value Ncm
Flügge et al[41] 2016	Model 1: 2. #36. #35 Model 2: 5. #36. #35. #33 and #45. #47	Non parallel	No data	Bone Level and Tissue Level (Straumann); Internal connection	Not used	iTero (Align Technology). no data on version; NP; No data on strategy Trios (3Shape). no data on version. NP; No data on strategy True Definition (3M ESPE). no data on version;P; No data on strategy	10	Bone Level and Tissue Level scanbody (Straumann) No data on torque value
Gimenez et al[43] 2016	6. #17. #15. #12. #22. #25. #27	#17. #12. #22. #27 - 0° #15 - 30° distally. #25 - 30° mesially	#17. #27. #15. #25- 0 mm #12 - 4 mm #22 - 2 mm	Certain 4. 1/11 mm. (Biomet 3i. Palm Beach Gardens. FL. USA); Internal connection	Not used	True Definition (3M ESPE); no data on version; P	4 operators. 5 DII each	PEEK (Createch Medical S.L.); No data on torque value
Gimenez et al[42] 2015	6. #17. #15. #12. #22. #25. #27	#17. #12. #22. #27 - 0° #15 - 30° distally. #25 - 30° mesially	#17. #27. #15. #25- 0 mm #12 - 4 mm #22 - 2 mm	Certain 4. 1/11 mm. (Biomet 3i); Internal connection	Not used	Lava COS (3M ESPE); Version 0.3.0.2; P	4 operators. 5 DII each	PEEK (Createch Medical S.L.); No data on torque value
Gimenez et al[35] 2015	6. #17. #15. #12. #22. #25. #27	#17. #12. #22. #27 - 0° #15 - 30° distally. #25 - 30° mesially	#17. #27. #15. #25- 0 mm #12 - 4 mm #22 - 2 mm	Certain 4. 1/11 mm. (Biomet 3i); Internal connection	Not used	3D Progress (MHT); no data on version; NP ZFX Intrascan (ZFX); no data on version; NP	4 operators. 5 DII each	PEEK (Createch Medical S.L.); No data on torque value
Gimenez et alAM[34] 2015	6. #17. #15. #12. #22. #25. #27	#17. #12. #22. #27 - 0° #15 - 30° distally. #25 - 30° mesially	#17. #27. #15. #25- 0 mm #12 - 4 mm #22 - 2 mm	Certain 4. 1/11 mm (Biomet 3i); Internal connection	Not used	CEREC AC Bluecam (Sirona); Version 4.0; P	4 operators. 5 DII each	PEEK (Createch Medical S.L.); No data on torque value

VPS – polyvinylsiloxane; PE – polyether; CII – conventional implant impression; DII – digital implant impression; IOS – intraoral scanner; CMM – coordinate measuring machine; CT – closed tray; OT – open tray; IL – implant level; AL – abutment level; Sp – splinted; NSp – non-splinted; S – significant; NS – non-significant; BL – bone level; TL - tissue level; Absd - absolute angular distortion; P – powdered; NP – non-powdered.

Reference scanner	Accuracy evaluation. results					Conclusions
D250 (3Shape)	Measurement location	Comparison: DII (digital model) distances and angles between two neighboring scanbodies (only statistically significant (p<0.05) data)				A smaller variation of the distance measurements was observed for the intraoral scanners True Definition and Trios. and a higher variation was seen for the iTero. Scanning precision worsened with increasing distance and angulation between scanbodies. Differences of mean distances between scanbodies comparing to dental lab scanning system (D250. 3Shape) were less than 40 µm.
		Mean distance (mm) and standard deviation (µm)		**Mean angle and standard deviation**		
		iTero	**True Definition**	**iTero**	**True Definition**	
	#35 - #36	6.669 (28)	6.647 (4)	8.06° (0.18)	8.20° (0.04)	
	#35 - #36 (model 2)			8.19° (0.24)	8.12° (0.10)	
	#35 - #45	40.608 (28)	40.566 (44)	17.47° (0.21)	17.33° (0.09)	
	#36 - #47	50.479 (64)	50.405 (60)	23.09° (0.20)	23.28° (0.15)	
CMM Crista Apex (Mitutoyo)	Comparison: DII (digital model) vs reference model					Accuracy is clinically acceptable. Scanbody visibility. observer experience. and scanning area affect accuracy.
		Distance		**Angulation**		
	First quadrant	7.6 ± 17.6 µm (S)		0.21 ± 0.17° (S)		
	Second quadrant	-10.3 ± 39.2 µm (S)		0.28 ± 0.16° (S)		
CMM Crista Apex (Mitutoyo)	Comparison: DII (digital model) vs reference model					Experienced operators delivered more accurate DII. Angulated implants and the deeply placed implants did not decrease the accuracy in digital impressions.
	Group			Mean (SD)		
	Experienced			-30.8 ± 25.9 µm		
	Inexperienced			13.3 ± 51.2 µm		
	Angulated			-20.2 ± 21.9 µm		
	Parallel			-37.9 ± 26.2 µm		
	Deep implant			-34.3 ± 18.7 µm		
	Gingival margin level			-28.5 ± 29.8 µm		
CMM Crista Apex (Mitutoyo)	Comparison: DII (digital model) vs reference model					The 3D progress IOS performed significantly better in the first quadrant. ZFX Intrascan in the second quadrant. Tested scanners not suitable for multi-implant impressions.
	Group	ZFX Intrascan		3D Progress		
	Experienced	-179 ± 601 µm		249 ± 702 µm		
	Inexperienced	-101 ± 705 µm		224 ± 930 µm		
	Angulated	-125 ± 596 µm		257 ± 776 µm		
	Parallel	-150 ± 693 µm		224 ± 854 µm		
	Deep implant (2 mm)	-150 ± 397 µm		87 ± 403 µm		
	Gingival margin level	-133 ± 782 µm		337 ± 997 µm		
CMM Crista Apex (Mitutoyo)	Comparison: DII (digital model) vs reference model					Tested scanner is clinically acceptable. The experience of the operator affected the accuracy. Angulation and location of the camera affect scanner results. The error increased from the first to the last implant scanned.
	Group			Mean (SD)		
	Experienced			-85.4 ± 98.9 µm		
	Inexperienced			-47.3 ± 75.7 µm		
	Angulated			-72.7 ± 81.7 µm		
	Parallel			-84.3 ± 99.9 µm		
	0 mm implant depth			-89.47 ± 105.59 µm		
	2 mm implant depth			-22.46 ± 30.92 µm		
	4 mm implant depth			-107.25 ± 68.65 µm		
	First quadrant			-17 ± 26.3 µm		
	Second quadrant			-116 ± 103 µm		

Article	No. of implants. positions	Angulation	Placement depth (mm)	Implant manufacturer. connection	CII technique	DII technique: IOS; use of powder; scanning strategy	Number of impressions	Scanbody. torque value Ncm
Gimenez et alAM[33] 2014	6. #17. #15. #12. #22. #25. #27	#17. #12. #22. #27 - 0° #15 - 30° distally. #25 - 30° mesially	#17. #27. #15. #25- 0 mm #12 - 4 mm #22 - 2 mm	Certain 4. 1/11 mm (Biomet 3i); Internal connection	Not used	iTero (Align Technology); Version 4.5.0.1.5.1; NP	4 operators. 5 DII each	PEEK (Createch Medical S.L.); No data on torque value
van der Meer et al[37] 2012	3. #36. #41. #46	-	Gingival level	No information	Not used	CEREC Bluecam. (Sirona); Version 3.85 P iTero. (Align Technology); Version 3.5.0 NP Lava COS (3M ESPE); Version 2.1 P	n = 10	PEEK (Createch Medical S.L.); No data on torque value
Mangano et al[40] 2016	Model 1: 3. #21. #24. #26; Model 2: 6. #16. #14. #11. #21. #24. #26	No data	No data	BTK implants (Dueville. Vicenza. Italy)	Not used	Trios Color (3Shape); Version 2014 – 1. 1.3.3.1. NP CS 3500 (CarestreamHealth. Rochester. NY. US); Version 2016-4. 2.1.4.10. NP ZFX Intrascan (MHT); Version 0.9 RC33 2.8. NP Planmeca PlanScan (E4D Technologies. LLC. Richardson. TX. USA); Version 5 – 2015. NP	n = 5	PEEK; No data on torque value
Chew et al[39] 2016	2. #44. #45	Parallel	No data	Tissue and Bone Level Standard Plus (Straumann)	OT	Trios Color (3Shape); Version 3.1.4 NP iTero (Align Technology); Version HD 2.9; NP True Definition (3M ESPE); no data on version. P	n = 5	Core Scanbody 2077 RC and 2088 WN (Core 3D centres); Handtightened

Reference scanner	Accuracy evaluation. results						Conclusions
CMM Crista Apex (Mitutoyo)	Comparison: DII (digital model) vs reference model						Angulated implants did not decrease digital impression accuracy. Impressions of implants placed at a depth of 0 mm?? were less accurate then deeper placed ones.
	Implant depth		Mean error and standard deviation				
	0 mm		-23.1 ± 149.485 µm				
	2 mm		-16.2 ± 34.569 µm				
	4 mm		-27.9 ± 61.643 µm				
	First quadrant		-28 ± 153 µm				
	Second quadrant		-15 ± 30 µm				
Contact scannerLeitz (PMM 12106)	Comparison: DII (digital model) vs reference model						The Lava COS resulted in the smallest mean distance errors in full arch impressions. Lava COS had smallest angulation errors between cylinder 1–2 and the largest errors between cylinder 1–3. Although the absolute difference with the best mean value (iTero) was very small.
	Absolute errors in distance between cylinders						
	CEREC Bluecam		**iTero**		**Lava COS**		
	1-2	1-3	1-2	1-3	1-2	1-3	
	79.6 ± 77.1 µm	81.6 ± 52.5 µm	70.5 ± 56.3 µm	61.1 ± 53.9 µm	14.6 ± 12.7 µm	23.5 ± 14.2 µm	
	Absolute errors in angle between cylinders						
	CEREC		**iTero**		**Lava COS**		
	1-2	1-3	1-2	1-3	1-2	1-3	
	0.6303 ± 0.5499°	0.4378 ± 0.3211°	0.3451 ± 0.3382°	0.4192 ± 0.1667°	0.2049 ± 0.0440°	0.4722 ± 0.1436°	
IScan D104I (Imetric3D GmbH)	Comparison: DII (digital model) vs reference model						No significant differences were found between partial and total edentulous models. CS 3500 intraoral scanner had the best result in terms of trueness and precision.
	Scanner	**Model 1**	**Model 2**	**Significance**			
	Mean trueness						
	Trios Color	72.2 ± 19.5 µm	71.6 ± 26.7 µm	NS			
	CS 3500	47.8 ± 7.3 µm	63.2 ± 7.5 µm	S			
	ZFX Intrascan	117.0 ± 28.6 µm	103.0 ± 26.9 µm	S			
	Planscan	233.4 ± 62.6 µm	253.4 ± 13.6 µm	S			
	Mean precision						
	Trios Color	51.0 ± 18.5 µm	67.0 ± 32.2 µm	S			
	CS 3500	40.8 ± 6.4 µm	55.2 ± 10.4 µm	S			
	ZFX Intrascan	126.2 ± 21.2 µm	112.4 ± 22.6 µm	S			
	Planscan	219.8 ± 59.1 µm	204.2 ± 22.7 µm	S			
CMM (Model Global Silver Edition. Brown and Sharpe)	Comparison: DII (digital model) vs reference model						Between BL and TL groups BLCNV had the lowest global linear distortion. which was statistically significant. All TL groups were not significantly different. There were no significant differences in absolute angular distortions among all test groups.
	Test group		**Global linear distortion**		**Absolute angular distortion**		
					AbsdΘ	**AbsdΘ**	
	BLCII		35 ± 6 µm		0.058 ± 0.031°	0.09 ± 0.082°	
	BLTrios Color		64 ± 10 µm		0.105 ± 0.058°	0.206 ± 0.044°	
	BLiTero		62 ± 18 µm		0.191 ± 0.124°	0.154 ± 0.113°	
	BLTrue Definition		63 ± 17 µm		0.315 ± 0.138°	0.226 ± 0.143°	
	TLCII		49 ± 10 µm		0.186 ± 0.161°	0.196 ± 0.147°	
	TLTrios Color		58 ± 11 µm		0.089 ± 0.039°	0.066 ± 0.033°	
	TLiTero		66 ± 34 µm		0.203 ± 0.094°	0.160 ± 0.121°	
	TLTrue Definition		64 ± 16 µm		0.206 ± 0.115°	0.195 ± 0.140°	

Article	No. of implants. positions	Angulation	Placement depth (mm)	Implant manufacturer. connection	CII technique	DII technique: IOS; use of powder; scanning strategy	Number of impressions	Scanbody. torque value Ncm
Gintaute AM[36] 2015	4. #34. #32. #42. #44	Parallel	No data	Osseotite 2 Certain Implants (Biomet 3i); Internal connection	OT. Sp. IL	True Definition Scanner (3M ESPE); Version 4.0.3.1. P		PEEK (Createch Medical S.L.); No data on torque value
		2 anterior - parallel. 2 posterior - 40-45°						

VPS – polyvinylsiloxane; PE – polyether; CII – conventional implant impression; DII – digital implant impression; IOS – intraoral scanner; CMM – coordinate measuring machine; CT – closed tray; OT – open tray; IL – implant level; AL – abutment level; Sp – splinted; NSp – non-splinted; S – significant; NS – non-significant; BL – bone level; TL - tissue level; Absd - absolute angular distortion; P – powdered; NP – non-powdered.

The *In vivo* study evaluated accuracy of multi-unit DII (two implant-supported bar in the edentulous mandible) in 25 patients. The scanning procedure was done with iTero IOS, after detaching the bars, using a defined scanning strategy. Definitive casts, which had been used for the fabrication of bars, served as reference casts. Authors presumed that the maximum acceptable horizontal misfit and angulation errors, considering two implant-supported restoration, should not exceed 100 µm and 0.4° respectively[32].

Of 15 included *in vitro* studies, two evaluated accuracy of single-unit and 13 evaluated the multi-unit DII. As for multi-unit DII, three studies used models with two implants[46,49,39], two had three implants[50,40], one was with 4 implants[36], two were with five implants[47,49], and seven used models with six implants[33–35,42,43,48,40]. Five of the studies evaluating the accuracy of full-arch DII from six implants, used the identical model[33–35,42,43]. Five studies evaluated the influence of operator experience and implant placement depth[33–35,42,43], nine evaluated implant angulation[33–36,41–43,46,47], eleven the distance between the implants[33–37,41–43,39–40], and one looked at the influence of scanning protocol[42].

Main findings

The majority of included studies indicated the importance of error accumulation process throughout the digital workflow. Lack of reference points, scanbody design, scanned surface characteristics, sensor size, scanning strategy, software and some other factors were considered to affect accuracy. The factors potentially influencing the DII accuracy are summarised in Figure 2.

A workflow to produce indirect restoration in the laboratory starts from the time of impression. Therefore, accuracy of the impression is one of the most important aspects. If inaccuracies build up this could lead to misfits and strains in the final restoration. As the threshold for a clinically acceptable misfit is not defined clearly, it is difficult to judge the accuracy of DII, reported in the included studies, as clinically acceptable or not. In the literature, misfit of the implant-supported restoration of 100 µm or less is often considered as clinically acceptable[51]. However, level of the acceptable misfit could relate to the extent of the implant-supported restoration[14]. Different IOS utilising various data acquisition principles were investigated in the included studies. A summary of separate accuracy measurements collected from included studies is presented in Figures 3 and 4.

In vivo study

According to the results of only one *in vivo* study included, due to a poor reference points caused by the mucosa of edentulous sites with little variation

Reference scanner	Accuracy evaluation. results			Conclusions
CMM Crista Apex (Mitutoyo)	Comparison: DII (digital model) and CII (digitised VPS and PE models) vs reference model			Digital and conventional impression-making approaches (with polyether and VPS materials) are applicable for straight and tilted dental implants.
		Distance deviation	**Angulation deviation**	
	Model 1			
	DII	9.46 ± 16.04 µm (NS)	0.17 ± 0.14° (S DII vs PE); S DII vs VPS)	
	VPS	12.74 ± 12.5 µm (NS)	0.07 ± 0.1°	
	PE	12.22 ± 16.93 µm (NS)	0.08 ± 0.07°	
	Model 2			
	DII	35.78 ± 24.22 µm (S DII vs VPS)	0.22 ± 0.19°. (NS DII vs VPS)	
	VPS	4.87 ± 21.34 µm	0.04 ± 0.04°. (S)	
	PE	19.78 ± 21 µm	0.16 ± 0.1 6° (S)	

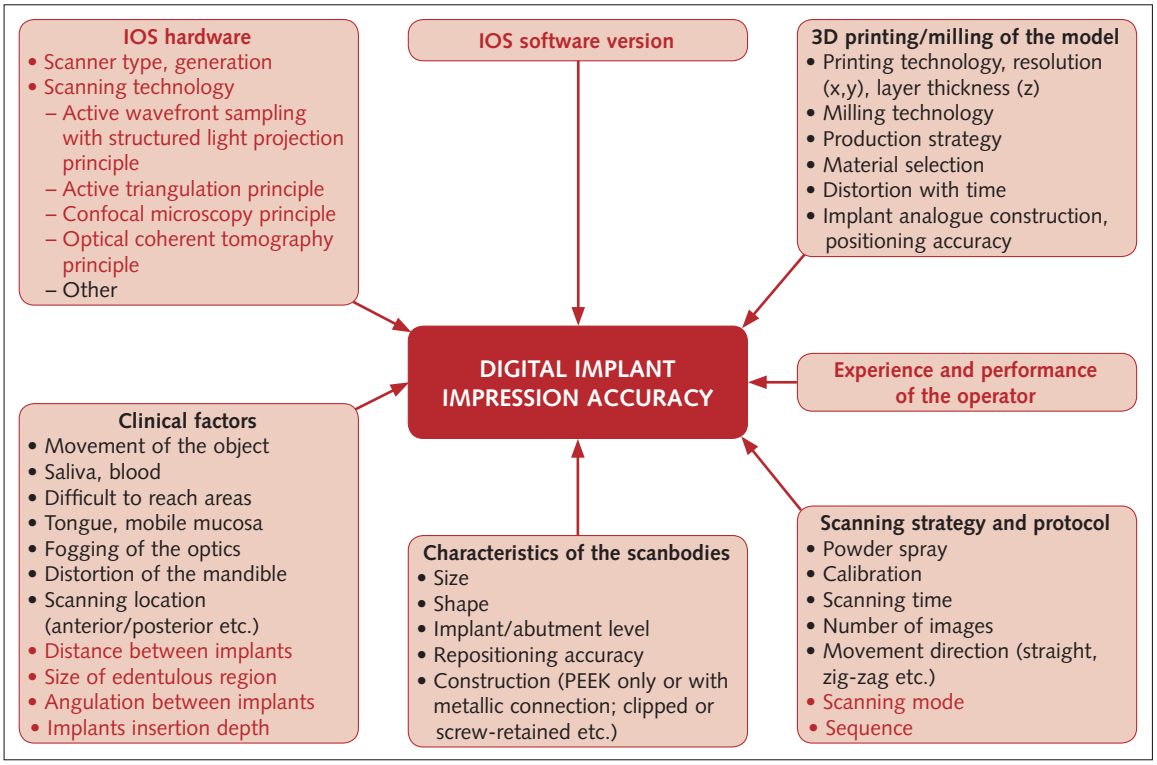

Fig 2 Main factors potentially affecting accuracy of digital implant impressions (DII). Items presented in red were investigated in the included studies.

in texture and height, digital impressions of four patients were impossible to perform[32]. Only in five cases were no optical irregularities of the IOS scans noticed. It was concluded that mean angular and distance errors were too large to be clinically acceptable.

In vitro studies

Two studies comparing models made from DII and CII for single-unit implant crowns reported different results. One study indicated significant change in the vertical position (93 µm) of the implant analogue in milled models[45], while in another the mean error was comparatively small, but with a larger

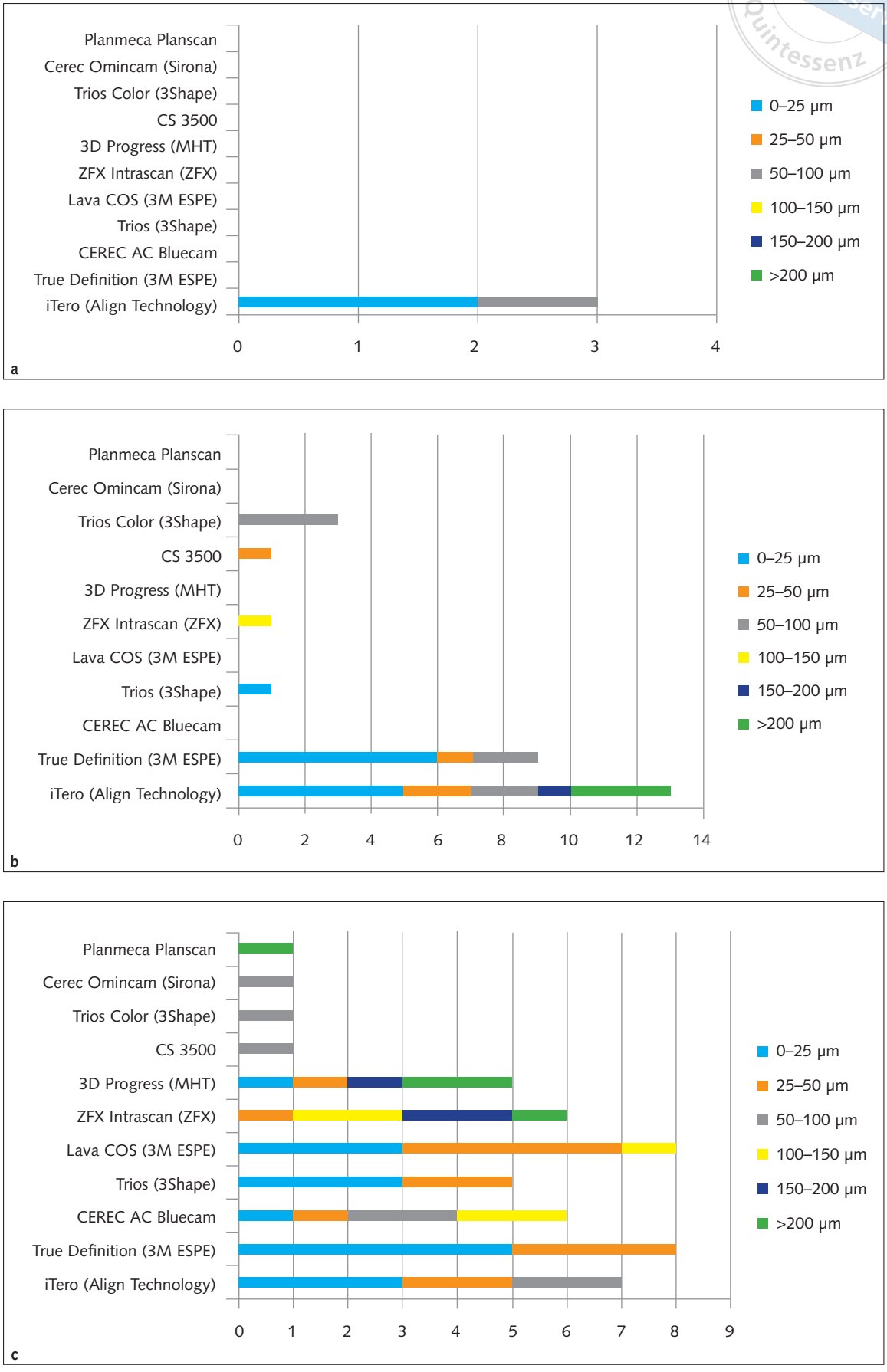

Fig 3 Digital implant impressions for: a) single-unit cases, b) FPD cases, c) fixed full-arch cases. Number of results reporting different linear absolute mean error intervals with certain IOS.

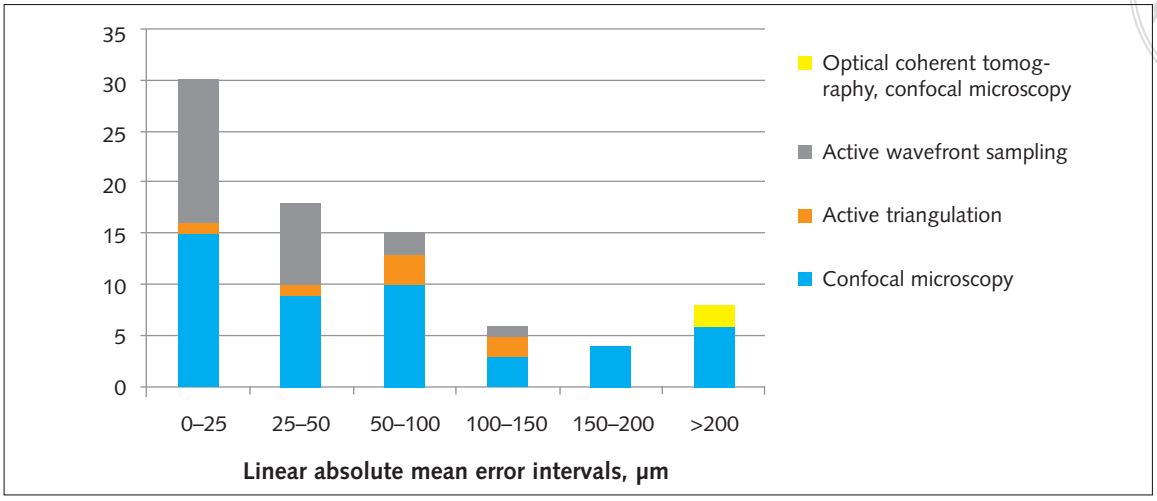

Fig 4 Number of results reporting linear absolute mean error intervals with different scanning technologies.

standard deviation: 14 ± 170 µm[45]. These results could not be considered as clinically acceptable, however reported deviations are the net result of inaccuracies introduced during digital impression taking, milling of the model, and positioning of the implant analogue. One of these studies also compared deviations between DII and the reference model (isolated assessment of only DII accuracy), and the difference was considerably smaller – -6 ± 40 µm[46]. Analysis of the accumulated errors in the digital workflow showed that the largest source of inaccuracy was the milling process (contributed SD is ± 98 µm) followed by the DII (contributed SD is ± 21 µm)[44]. Therefore, other factors besides DII could be responsible for less consistent results reported in these studies.

Thirteen studies investigated the accuracy of DII for multi-unit implant-supported restorations. Mean errors of several IOS used in five of these studies was higher than 100 µm[34,35,46,40,48].

The results diverged with older generation IOS used in the included studies (Lava COS, iTero, Cerec Bluecam, 3D Progress, ZfX Intrascan), as there were studies reporting deviations above[34,35,46,48] and below[33,37,42] 100 µm.

Different results could be explained by methodological differences as well. One of the studies reporting adequate results used less clinically relevant full-arch models, with between distantly oriented scanbodies, dentate segments, avoiding simulation of edentulous areas[37]. Remaining teeth in between the implants could help as reference areas, facilitating stitching of the images and, possibly, improving the accuracy. In contrast, a study utilising the single-implant model reported higher mean errors with iTero IOS for single-unit implant situation, as measurements were done on the model milled from polyurethane material based on DII data. Thus, error accumulation during fabrication of the model was inevitable[46].

All studies analysing IOS of the newer generation (Trios, Color, True Definition, Cerec Omnicam, CS3500) reported deviations of less than100 µm[36,43,47,48,40]. Interesting to note, was that all of these studies employed full-arch models with four to six implants. However, the accuracy of Planscan IOS was significantly less – 253,4 ± 13,6 µm for the full-arch situation[40].

One study investigated only precision of DII with three different IOS[41]. It was concluded that the precision of IOS tested (iTero, Trios, True Definition) was significantly different, and decreased with increasing distances between the scanbodies.

Some of the included studies explored the influence of angulated implants on the accuracy of DII[33–36,42,43,46,47]. Reference models in these studies had implants angulated from 10°[47] to 45°[36]. The clinically acceptable threshold for the angle deviations generated during impression procedure is not defined in the literature. However, based on simple trigonometrical calculations (and assuming that the maximal lateral apex movement of 50 µm is acceptable), one study[32] suggested that up to 0.4° angle deviation between implants could be acceptable, with total length of the implant of 14.8 mm. The majority of *in vitro* studies included in this systematic review

used shorter implants for the reference models. In the case of shorter implants, larger inter-implant angle deviation can possibly be accepted, as this angle can be defined by the formula: 2× arctan (0,05/L implant length in mm). Two studies have reported higher deviations in angulation (up to 1.6°)[37,46], while recent studies using newer generation of IOS indicated much smaller angle deviations (0.07 to 0.3°)[36,43,39].

The depth of implant placement as a factor was also considered in the included studies. Supragingival[46], equigingival[33–35,37,42,43] and 2 to 4 mm subgingival[33–35,42,43] implant positions were used.

In summary, the included studies reported that DII accuracy was influenced by implant angulation[46], distance between the implants[43], implant placement depth[33,43], and scanning mode[42]. Most studies investigating impact of operator experience concluded that this aspect was of significant importance[33,34,42,43].

Studies comparing accuracy of newer generation IOS (True Definition, Trios) with conventional impressions for partial- and full-arch implant-supported dental restorations, indicated that the accuracy of DII did not significantly differ from CII and could serve as a viable alternative[36,47,39]. Accuracy of implant-level, non-splinted CII was reported as being even less accurate compared with DII[47].

■ Discussion

To our knowledge, this is the first systematic review addressing DII accuracy. Results of this review are important, as intraoral implants and IOS are both used extensively in practitioners' clinical practice. IOS offers many new diagnostic and treatment workflows. Originally aimed at making the optical impression from the teeth, IOS has now become multifunctional instruments, which are able to measure the shade and work as intraoral cameras etc. Keeping the patient data unchanged for a long time, sharing it with treatment team members, following-up the patient condition objectively, integrating IOS data with data from CBCT, laboratory scanner, face scanner and photos, are among the few options IOS can offer today.

The number of publications related to the various uses of IOS is rapidly increasing. Patient- and dentist-centred and efficiency outcomes are also being investigated[52,53]. However, one of the main goals is to improve the accuracy of the digital workflow and to achieve aesthetic and functional restorations with minimal effort.

Digital workflow is still susceptible to errors, which can come from the digital impression and CAD/CAM software, as well as production (subtractive or additive) processes. Although manufacturing techniques have become very accurate, they still depend on the accuracy of the impression and master model. IOS are an integral part of the digital workflow; therefore accuracy is an essential requirement.

As the evidence on accuracy of DII is lacking, a thorough search was conducted in order to identify relevant publications. Strict criteria were applied for the studies, with accuracy measuring methodology described in detail. Despite the growing popularity of IOS devices, only one *in vivo* and 15 *in vitro* studies evaluating the accuracy of DII were identified.

While the *in vivo* study showed that accuracy of DII is not adequate for clinical applications, the majority of *in vitro* studies showed less than 100 µm deviations. This could also indicate significantly different conditions for *in vitro* and *in vivo* environments.

The only *in vivo* study used an older generation scanner. According to the *in vitro* results, newer versions of the scanners performed considerably better. Accuracy of these scanners was evaluated with partial- and full-arch models containing from two to six implants. A study comparing DII (obtained by True Definition and Trios) with a reference model containing six implants, reported values for trueness and precision ranging from 28 µm to 35 µm[48]. DII (True Definition) from four parallel mandibular implants did not statistically significantly differ from CII, however with distal implants tilted, statistically significant differences were detected[36]. As absolute values of these differences were approximately 30 µm, it can be concluded these differences could be of limited clinical significance. Based on this, IOS seem to become a reliable alternative to conventional impressions for the selected indications. However, results of this review should be interpreted with caution, as there are several limiting factors. Only one *in vivo* study satisfied inclusion criteria[32]. iTero IOS was used for DII and stitching problems leading to the

deformed image of the scan abutment, as described by the authors. The information is lacking if the accuracy of definitive models was rechecked by again fitting the bar to the model, as the true reference is difficult to obtain in *in vivo* studies, and this remains one of the challenges for the clinical evaluations. Hypothetically, trueness of the DII data could be better, but still deviate from the potentially less accurate model fabricated from the conventional impression. Moreover, at the time of this systematic review, a new version of the scanner used in this *in vivo* study became available, claiming much faster and more accurate scanning in colour. As the older version of the scanner and software were used, the findings of the study are therefore less relevant today.

In vivo use of IOS could be compromised by many aspects: movements of the object, saliva, fogging of the optics, and other patient-, operator- and device-related limiting factors. Scanning location can be important, as distant regions could be difficult to reach in a real clinical situation. Length of the edentulous ridge, lack of attached gingiva, tongue and cheek mobility could also negatively affect the ability to stitch the images. Scanning strategy and mode were also proved important aspects[42,55]. A recent study showed that intraoral scanning was less precise than model scanning[54].

Comparison of the results of the *in vitro* studies could also be limited by disparities in study design, the models and techniques used. IOS can utilise several different technologies: confocal microscopy, optical coherence tomography, active and passive stereovision/triangulation, phase-shift principles, accordion fringe interferometry, etc[36]. Different IOS systems with different software versions compromise the comparisons further. Moreover, no studies have been published with other new IOS systems – DWIOS, Condor, CS3600, Aadva, Trios 3 and many others. In this regard, there is a big difference between DII and CII, as the principles of conventional impression taking do not change that dramatically with time, and features of the products from different companies are relatively less different compared with IOS.

Accuracy of DII can also be affected by other factors. Characteristics of the scanbodies could be another source of errors. Shorter and less visible scanbodies can negatively influence the accuracy[56]. It was recommended that longer scanbodies should be used with deep-placed implants[43]. One of the studies included in the systematic review used longer scanbodies, which could also contribute to better-measured accuracy[47]. Sharp angles of the scanbodies could negatively influence scan accuracy. One study was excluded from the review, as healing abutments instead of scanbodies were used, making the results of this study less relevant[38].

Spraying of the scanbodies with powder is still needed for some of the IOS to reduce the reflections and aid the stitching of the images. Powdering could potentially influence the accuracy of scanning through homogeneity and thickness of spray. It was reported that experienced clinicians achieved greater homogeneity and thinner coatings[57]. Therefore it is recommended to use only light dusting on the surfaces to be scanned. As powder could be inhaled by the patient and clinician or swallowed by patient, more information is needed about the effect of it on human health[58].

Similarly, as with conventional impressions, type of the implant-abutment connection can influence the accuracy. External implant – abutment connection was reported to provide more consistent accuracy for CII[25]. Only one of the included studies investigated DII accuracy with external connection implants[48].

A potential effect of embedment relaxation and manufacturing tolerances should be taken into consideration when selecting prosthetic components[59]. Repositioning accuracy of scanbodies could have an effect on the accuracy of the DII. It was reported that the ability of repositioning of the scanbody is better on lab analogues than on original implants[60]. However, other authors suggested that the precision of implant scanbody scanning was not significantly influenced by detachment and repositioning of the scanbody[56]. Not all the studies standardised the use of the scanbodies (eg, tightening ranged from finger tightening to 15 Ncm) and this could act as an additional variable. Also, it could be hypothesised, that scanbodies with metallic base should have better repositioning accuracy as compared with fully plastic scanbodies.

Three studies evaluated accuracy of milled models obtained from DII[44–46]. It appeared that milling and positioning of implant analogues resulted in bigger deviations as compared with reference model. None of these studies described milling parameters they have used to fabricate the models. Also, information

about implant analogues dedicated for milled models was lacking. No publication was identified, utilising 3D printing to fabricate the model from DII data. As models are necessary for layered restorations, occlusal adjustments etc., more research is needed to define milling and printing parameters in order to avoid inaccuracies and increase applications of IOS.

Despite good accuracy results reported by *in vitro* studies, digital workflow based on DII is still lacking some reliable conventional solutions – use of verification jigs to validate the master model, easy and reliable recording of the emergence profile, validated techniques to record static and dynamic occlusal relationships, etc. Recent studies also identify the significance of inaccuracies of occlusal contacts of stereolithographic models fabricated, based on data from IOS[61].

Although scientific literature is struggling to keep up with the newest IOS developments, due to positive clinical experience, constantly increasing opportunities with digital workflow and marketing, its use in clinical practice is growing fast. Further IOS improvements need to be done in order to replace conventional techniques and increase the potential of digital workflow, especially in partially and fully edentulous patients.

Conclusions

1. Within the limitations of this systematic review (one *in vivo* and 15 *in vitro* studies identified), it can be concluded that digital implant impressions offer a valid alternative to conventional impressions for single- and multi-unit implant-supported restorations;
2. *In vivo* studies investigating the accuracy of newest available IOS are needed to further define their clinical indications;
3. Factors potentially affecting accuracy of digital implant impressions should be more extensively described and investigated in clinical studies;
4. Due to the constant changes in IOS hardware and software, reliable methodology, representing less forgiving *in vivo* situations should be defined to timely evaluate and compare trueness and precision of modern IOSs, and to provide clinical guidelines;
5. Digital implant impression techniques still have to be improved in order to fully substitute conventional ones;
6. Further studies are needed to investigate the accuracy of digital interocclusal records and master model production methods (milling, 3D printing) to ensure clinically acceptable results.

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