EVALUATION OF THE PRECISION OF INTRAORAL SCANNERS IN CAPTURING DIGITAL IMPLANT IMPRESSIONS: A COMPREHENSIVE REVIEW AND META-ANALYSIS OF IN VIVO RESEARCH.

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Annotation

Ensuring a passive fit of implant-supported frameworks is crucial for long-term treatment success, as superstructural misfits can lead to both mechanical and biological complications. Accuracy, comprising trueness and precision according to the International Organization for Standardisation (ISO5725-1), plays a pivotal role. Trueness refers to the measurement's ability to align with a true or acceptable reference, while precision signifies the consistency of repeated measurements.

The standardization of clinical and laboratory procedures remains incomplete, contributing to variations that influence prosthesis accuracy. These procedural steps, susceptible to varying degrees of error, cumulatively result in mismatches in the implant superstructure. Given that impression accuracy is the initial phase in restoration production, it stands as a primary determinant of ultimate outcomes.

In recent years, the continuous development of digital implant impressions through intraoral scanners (IOS) has been noteworthy. Leveraging technologies like triangulation, confocal lasers, and active wavefront sampling, IOS aims to ascertain the relative position of the implant. In comparison to traditional methods, IOS impressions streamline workflows, significantly reducing time and material costs. Theoretically, this approach may mitigate model deviation associated with traditional methods, leading to improved accuracy and suitability for final restorations. Clinical indications for IOS impressions are expanding, particularly in cases of single tooth loss or dentition defects.

While numerous in vitro laboratory studies have scrutinized the accuracy of IOS impressions, the in vivo environment presents distinct challenges. In vitro studies often feature stable reference points for scanning, while in vivo conditions introduce variables such as mobile mucosa, saliva, oral humidity, and tongue movements, potentially impacting accurate digitization. Consequently, this systematic review aims to assess the in vivo accuracy of digital implant impressions obtained through IOS.

Methods

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist, a systematic review was undertaken. The PICO (Population, Intervention, Comparison, Outcome) question guiding the review was: "What are the accuracy outcomes of IOS implant impression?"

For comprehensive coverage, two independent reviewers conducted an electronic search of PubMed, EMBASE, and the Cochrane Library spanning from 1989 to August 2023, adhering to PRISMA guidelines. Additionally, a manual search of reference lists and conference

proceedings was conducted to identify potential studies not captured in the electronic search. The search codes utilized are detailed in Table 1.

PICO	Codes
Population	#1 (single implant) OR (multiple/multi-unit implants)OR (partially edentulous arch/jaw) OR (complete arch/jaw) OR (full arch/jaw) OR (oral implant) OR (dental implant) OR (implant prosthesis/restorations/rehabilitation)
Intervention	#2 (digital impression) OR (intraoral scan) OR (optical impression) OR (inraoral digitizer) OR (dental scanner) OR (dental impression) OR (digital scan) OR (digital dentistry)
Comparison	#3 (conventional impression) OR (traditional impression) OR (conventional technique)
Outcome	#4 (impression accuracy) OR (trueness) OR (precision) OR (in vivo study) OR (dimensional measurement accuracy)
Search	(#1) AND (2#) AND (3#) AND (4#)

This analysis incorporated in vivo studies exploring the accuracy (trueness, precision, or both) of intraoral scanner (IOS) impressions in cases involving a single implant, partial edentation, and/or full edentation. The inclusion criteria encompassed studies published in peer-reviewed journals and presented in the English language. Exclusions were made for in vitro studies, literature reviews, case reports, and technical reports. The eligibility of chosen studies underwent independent assessment by two reviewers, with any disparities resolved by a third reviewer. For randomized control trials (RCTs), the Cochrane risk of bias tool was employed to assess risk, while the methodological index for nonrandomized studies was used to evaluate the quality of comparative studies and single-arm clinical trials.

Data extraction focused on the following parameters:

1. Study model details (jaw; number, position, angle, depth, connection type, and impression level of implants).
2. Scan particulars (IOS type, scan body type, strategy, and operator experience).
3. Study design attributes (sample size, methodological strategy for accuracy evaluation).
4. Accuracy results.
5. Relevant variables.
6. Peri-implant crestal bone loss.
7. Time required for the impression procedure.

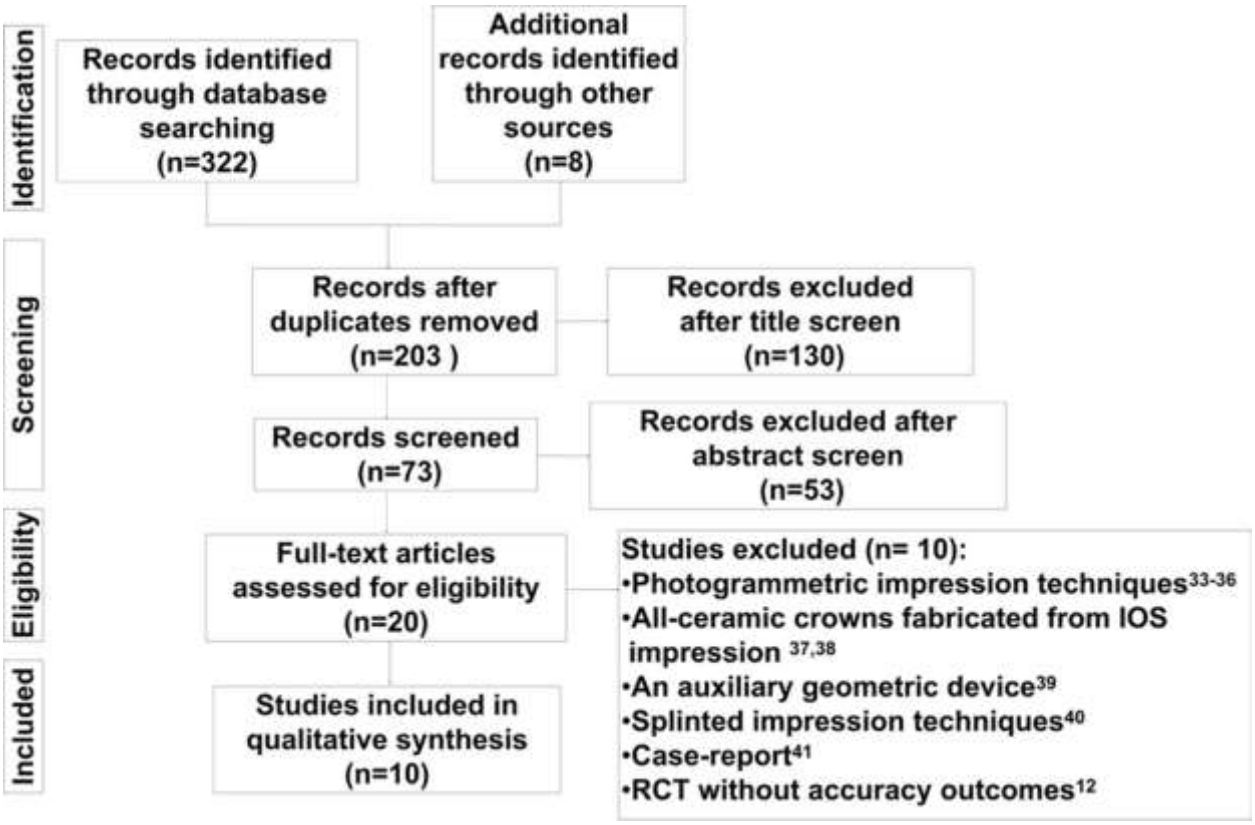
To synthesize information on bone loss and time costs, RevMan version 5.3 was emplo

Results

The initial search yielded a total of 322 citations (refer to Fig. 1). After a thorough review, 20 articles were selected for full-text examination. Among them, ten studies [12, 33,34,35,36,37,38,39,40,41] were excluded based on reasons outlined in the PRISMA flow diagram. The remaining ten studies met the inclusion criteria and underwent analysis in this

systematic review [30, 42,43,44,45,46,47,48,49,50]. It is noteworthy that all studies included in this review were conducted in vivo.

The detailed characteristics of the selected studies are summarized in Table 2. These encompassed seven comparative studies [30, 42,43,44,45,46,47], one single-arm clinical trial [48], and two randomized controlled trials (RCTs) [49, 50]. The risk of bias assessment is depicted in Fig. 2. Notably, all comparative studies and clinical trials explicitly stated their aims, and the methods for measuring accuracy were adequately described. However, the two RCTs exhibited an unclear risk of bias in terms of selection bias (random sequence generation). Across all studies, the primary risk was associated with the absence of blinding.



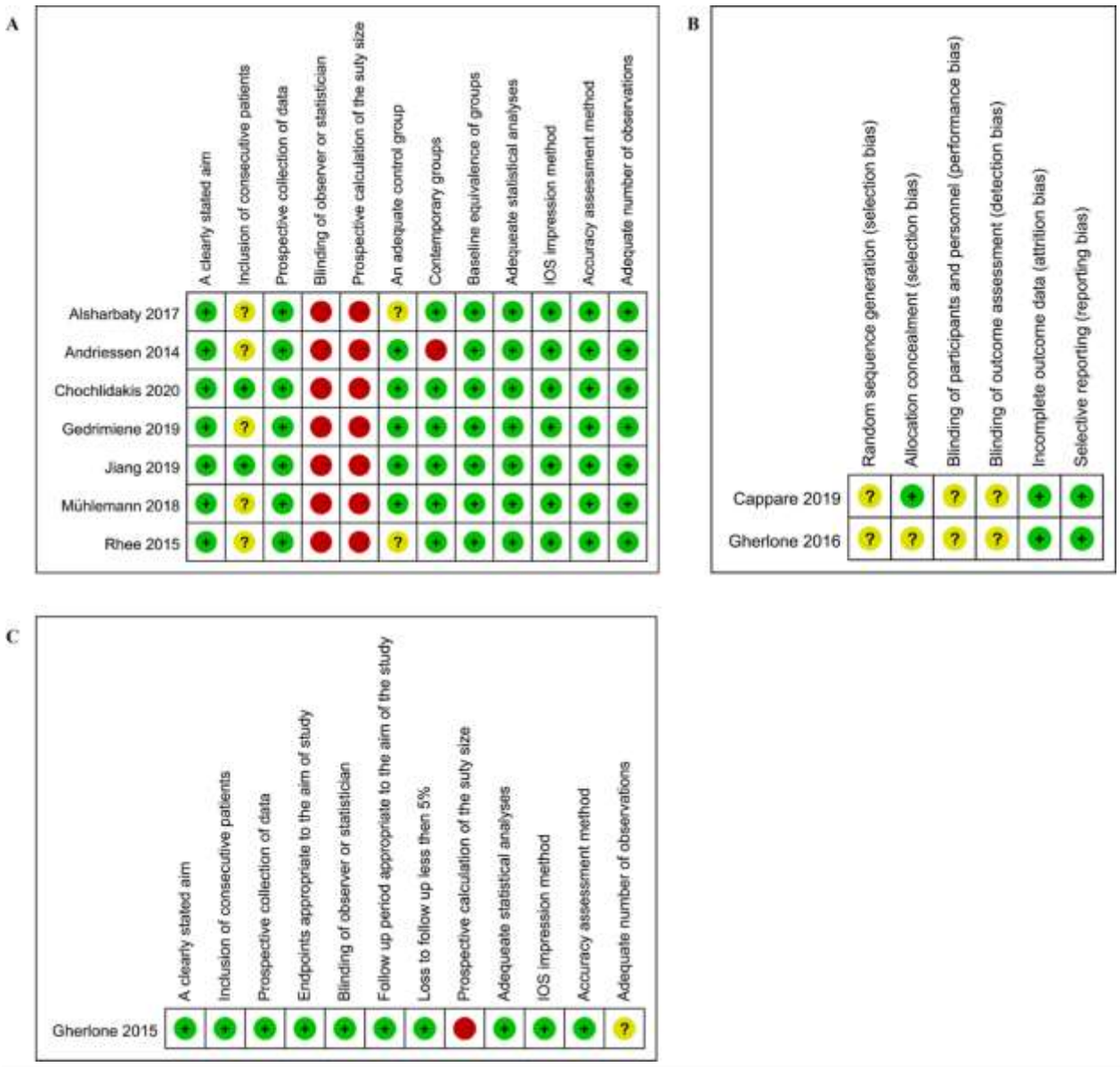
PRISMA flow diagram of search strategy

Table 2 Characteristics of the included studies

Study (author and year)	Edentulous	Implant				Jaw
		System	No.	Position	Connection	
Rhee 2015 [42]	Single tooth loss	NA	1	36, 46	External Internal	Mandible
Mühlemann 2018 [43]	Single tooth loss	Straumann RN	1	14–17,24–27,34–37,44–47	Internal	Maxilla Mandible

Study (author and year)	Edentulous	Implant				Jaw
		System	No.	Position	Connection	
Alsharbaty 2017 [44]	Partial	Dentium	2	Posterior region	Internal	NA
Gedrimiene 2019 [45]	Partial	AnyOne	2	Posterior region	NA	NA
Jiang 2019 [46]	Partial	Camlog Screw-Line	2 ~ 4	17–15,25–27,37–47	NA	Maxilla Mandible
Andriessen 2014 [30]	Complete	Straumann RN	2	NA	Internal	Mandible
Chochlidakis 2020 [47]	Complete	Straumann, BLT	4 ~ 6	NA	Internal	Maxilla
Gherlone 2015 [48]	Complete	Winsix	4	NA	NA	Maxilla Mandible
Gherlone 2016 [49]	Complete	IDI Evolution	4	NA	NA	Maxilla Mandible
Cappare 2019 [50]	Complete	CSR	6	NA	NA	Maxilla
Study (author and year)	**Sample size**	**Impression**	**Operator**	**Scan body**	**IOS device**	
		Convention	**Level**			
Rhee 2015 [42]	24	Dual-arch; full arch	Implant	NA	3Shape; Raphabio	Trios mono cart
Mühlemann 2018 [43]	5	Closed-tray	Implant	One	Straumann	iTero Cadent ;Lava True Definitio

Study (author and year)	Edentulous	Implant				Jaw
		System	No.	Position	Connection	
						n;Trios
Alsharbaty 2017 [44]	36	Open-tray; closed-tray	Implant	One	Dentium	Trios
Gedrimiene 2019 [45]	24	Splinted open-tray	Implant	NA	NA	Trios 3
Jiang 2019 [46]	34	Splinted open-tray	Implant	NA	Camlog	Trios
Andriessen 2014 [30]	25	NA	Implant	One	Straumann	iTero Cadent (software version 3.5.0)
Chochlidakis 2020 [47]	16	Open-tray	Abutment	NA	Straumann	True Definition
Gherlone 2015 [48]	14	NA	NA	NA	NA	Lava COS (software version 2.1)
Gherlone 2016 [49]	30	Open-tray	NA	NA	NA	Trios
Cappare 2019 [50]	50	Splinted open-tray	NA	One	CSR	CS 3600 (software version 3.1.0)



A The risk of bias for included comparative studies. B The risk of bias for included RCTs. C The risk of bias for included one single-arm study.

Evaluation methods for accuracy assessment

Two primary methods were employed for accuracy assessment: the best-fit algorithm and absolute linear/angular deviation methods [51].

In five studies [42, 43, 45,46,47], the three-dimensional (3D) superimposition deviations between intraoral scanner (IOS) and conventional impressions were examined. Utilizing the best-fit algorithm, these studies superimposed the standard tessellation language (STL) files of the IOS impressions onto reference STL data to determine 3D deviations. The root-mean-square value, derived from the mean positive and negative deviations, was calculated to describe the overall mean difference [51].

In one study [30], the absolute linear/angular deviation of IOS impressions was assessed. Distances and angulations between implants were measured using IOS and conventional impression STL files, respectively. The average value of the linear/angular discrepancies was then used to evaluate accuracy [51].

An exception was noted in one study [44], where a "true" reference model was fabricated. The impression transfers, hand-tightened and splinted intraorally, were removed and impressed in wet gypsum. The splinted transfers in gypsum served as the reference model, and coordinate measurement machines were utilized to obtain the reference data. This approach differed from other in vivo studies where implant coordinates did not align with the world coordinate system.

Accuracy outcomes

A total of six studies [30, 42, 44,45,46,47] focused on evaluating the trueness of intraoral scanner (IOS) impressions, while one study [43] specifically assessed the precision of IOS.

In terms of the trueness of IOS impressions for a single implant, an in vivo study [42] calculated tooth deviation at specific points near the implant, revealing measurements such as 118.9 μm at the second premolar buccal cusp and 80.7 μm at the second molar buccal cusp.

For partially edentulous arches, three studies [44,45,46] investigated trueness. Alsharbaty et al. [44] found that IOS impressions (n = 36) resulted in a 360 ± 46 μm 3D linear displacement, significantly differing from the 160 ± 25 μm displacement observed with pick-up impressions. Gedrimiene et al. [45] reported mean differences (n = 24) of 70.8 ± 59 μm, falling below the clinical threshold of 100 μm. However, they underscored the limited clinical relevance of the measured means. In contrast, Jiang et al. [46] reported a 3D deviation of 27.43 ± 13.47 μm (n = 34), asserting its acceptability within clinical standards.

The trueness of IOS impressions for the full arch was explored in two studies [30, 47]. Anderiessen et al. [30] reported a mean distance deviation of 226 μm (range: 21–638 μm) in 25 edentulous mandibles with two implants, noting four instances where IOS impressions could not be completed due to stitching challenges. Chochlidakis et al. [47] found a 3D deviation of 162 ± 77 μm in 16 edentulous maxillaries with 4–6 implants, asserting the 3D accuracy of IOS for the full arch fell within the clinically acceptable range.

As for precision, one study by Mühlemann et al. [43] focused on posterior single implants. They reported mean precision values of 57.2 ± 32.6 μm (iTero Cadent), 88.6 ± 46.0 μm (Trios 3Shape), 176.7 ± 120.4 μm (Lava True Definition), and 32.7 ± 11.6 μm for conventional impressions. Conclusively, they determined that conventional impressions exhibited the greatest reproducibility in implant placement.

Clinical studies with follow-up

Four clinical studies, including two prospective studies [46, 48] and two randomized controlled trials (RCTs) [49, 50], examined the accuracy of intraoral scanner (IOS) impressions for implant restorations over a follow-up period ranging from 1 to 2 years. In one study by Jiang et al. [46], the time cost for IOS impressions in partially edentulous patients was reported as 17.9 ± 2.77 minutes. Additionally, two RCTs [49, 50] revealed that IOS impressions for the full arch required significantly less time than conventional impressions, with a mean difference in procedure time of 8.59 minutes (6.78, 10.40 minutes; $P < 0.001$, Fig. 3) and a mean difference in additional time of 4.32 minutes (3.66, 4.97 minutes; $P < 0.001$, Fig. 4).

All studies reported implant and prosthetic survival rates of 100%. For full arch cases, three studies [48, 49, 50] found that the bar-implant connections of all definitive prostheses exhibited accuracy, assessed through intraoral digital X-ray. In the follow-up evaluation, the

two RCTs [49, 50] for the full arch reported no significant difference in marginal bone loss between the IOS and conventional impression groups. The mean difference at the 6-month evaluation was -0.04 mm (− 0.12, 0.04 mm; P = 0.34, Fig. 5), and at the 12-month evaluation, it was 0.03 mm (− 0.08, 0.14 mm; P = 0.55, Fig. 6).

Fig 3

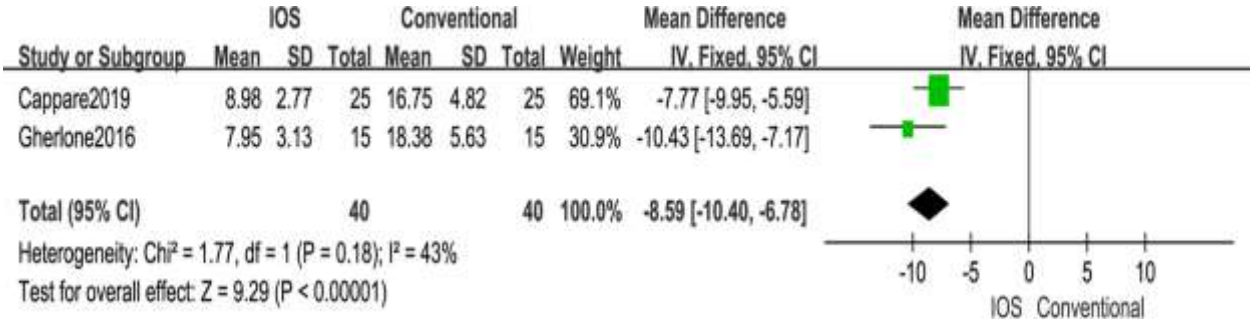


Fig 4

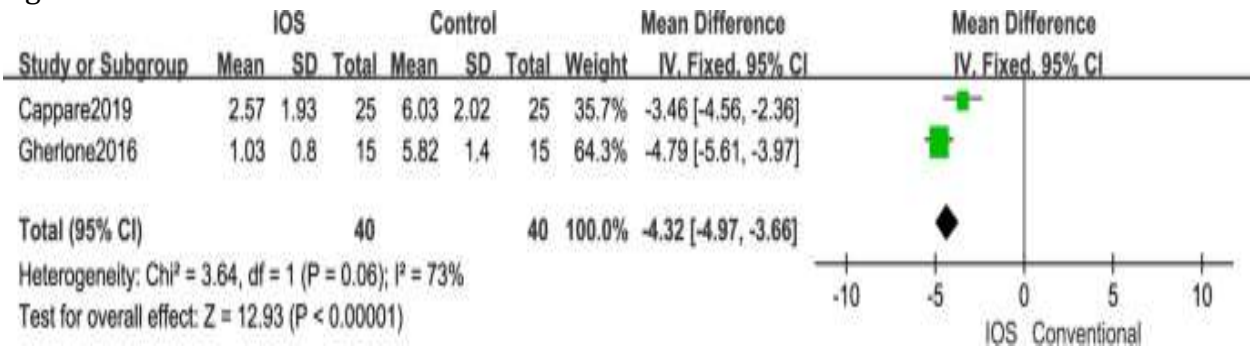


Fig 5

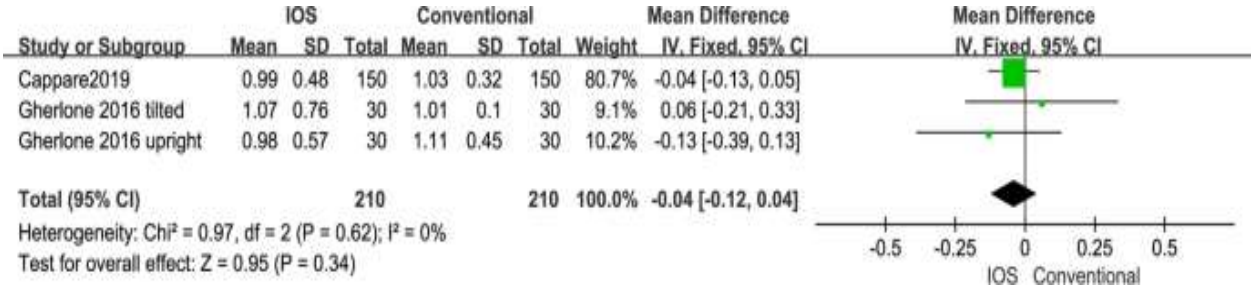
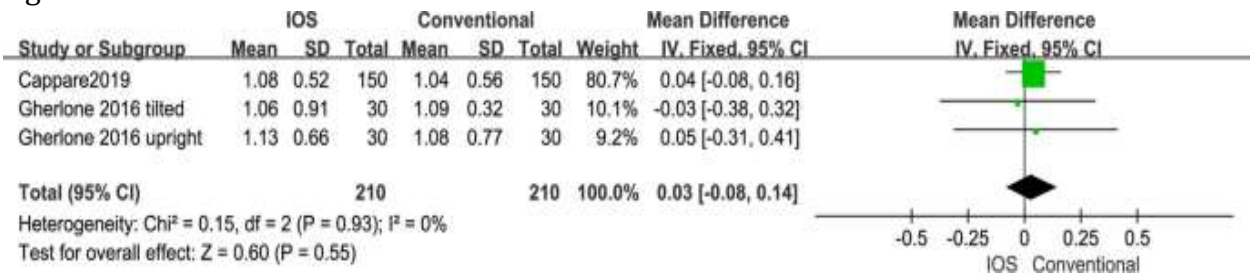


Fig 6



Discussion

This systematic review aimed to evaluate the accuracy of intraoral scanner (IOS) implant impressions through an analysis of ten included in vivo studies, assessing both the outcomes' precision and clinical results over a follow-up period.

The scarcity of scientific and clinical literature highlights the challenge of using in vitro equipment for measuring actual reference data in in vivo settings. The best-fit algorithm and absolute linear/angular deviation methods were the main accuracy assessment approaches, with some debate around the best-fit algorithm equalizing entire surface distances.

Comparing methods, Lyu et al. [51] argued that the absolute linear deviation method proved more effective in detecting inaccuracies.

Among the six studies exploring trueness, five used master models from conventional impressions as accepted references, verified through passive fit evaluation techniques. However, one study [44] introduced a "true" reference model, emphasizing the need for future verification in in vivo settings.

Evaluating precision in IOS implant impressions proved challenging due to the necessity of repeated intraoral impressions. Only one study [43] reported precision for three IOS devices and conventional impressions, requiring an extended research period and breaks between impression procedures.

Diverse opinions on acceptable misfit levels added complexity. This review noted variations in accuracy outcomes, particularly in partially edentulous arches, influenced by different evaluation methods, implant distributions, IOS devices, operator experience, and scan strategies. The contrasting results in fully edentulous cases could be attributed to participant differences and distinct scanning strategies.

Limited in vivo studies explored related variables' impact on IOS accuracy. Notably, Gedrimiene et al. [45] linked inter-implant angulation to trueness, while Mühlemann et al. [43] identified the significant effect of IOS type on precision. The varied working principles of the IOSs in the review suggested the need for future in vivo studies to assess the effects of different IOS strategies and related variables.

Four clinical studies with 1–2 years of follow-up reported that IOS impressions required less time than conventional methods, exhibited 100% prosthetic survival rates, and maintained stable marginal bone levels. While these studies generally supported the clinical accuracy of IOS impressions, the need for additional research centers and randomized controlled trials (RCTs) was emphasized to strengthen the evidence base.

Limitations of this study include the limited number of in vivo studies, diverse methodological strategies, and a concentration of clinical studies from the same research group. Addressing these limitations requires further research centers' involvement and additional RCTs to substantiate the accuracy of IOS implant impressions.

Conclusion

The precision of intraoral scanner (IOS) impressions for implant-supported restorations displays considerable variation contingent on the scanning strategy employed. The degree of trueness and precision for IOS in both partial and complete arches remains uncertain, necessitating further investigation. While clinical studies with follow-up periods suggest that IOS impressions are accurate for practical clinical applications, it's crucial to interpret these results cautiously. Notably, some of the evidence originates from studies conducted by the same research group, prompting the need for additional diverse research and independent validation of the findings.

Abbreviations

IOS:
Intraoral scanning
PRISMA:
Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PICO:

Population, Intervention, Comparison, Outcome

RCT:

Randomized control trial

3D:

Three-dimensional

STL:

Standard tessellation language

References:

1.Buzayan MM, Yunus NB. Passive fit in screw retained multi-unit implant prosthesis understanding and achieving: a review of the literature. J Indian Prosthodont Soc. 2014;14(1):16–23.

2.Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: current status. Implant Dent. 2001;10(2):85–92.

3.Michaels GC, Carr AB, Larsen PE. Effect of prosthetic superstructure accuracy on the osteointegrated implant bone interface. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1997;83(2):198–205.

4.Katsoulis J, Takeichi T, Sol Gaviria A, Peter L, Katsoulis K. Misfit of implant prostheses and its impact on clinical outcomes. Definition, assessment and a systematic review of the literature. Eur J Oral Implantol. 2017;10(Suppl 1):121–38.

5.Flügge T, van der Meer WJ, Gonzalez BG, Vach K, Wismeijer D, Wang P. The accuracy of different dental impression techniques for implant-supported dental prostheses: A systematic review and meta-analysis. Clin Oral Implants Res. 2018;29(Suppl 16):374–92.

6.Wee AG, Aquilino SA, Schneider RL. Strategies to achieve fit in implant prosthodontics: a review of the literature. Int J Prosthodont. 1999;12(2):167–78.

7.Heckmann SM, Karl M, Wichmann MG, Winter W, Graef F, Taylor TD. Cement fixation and screw retention: parameters of passive fit. An in vitro study of three-unit implant-supported fixed partial dentures. Clin Oral Implants Res. 2004;15(4):466–73.

8.Al Quran FA, Rashdan BA, Zomar AA, Weiner S. Passive fit and accuracy of three dental implant impression techniques. Quintessence Int. 2012;43(2):119–25.

9.Abduo J, Judge RB. Implications of implant framework misfit: a systematic review of biomechanical sequelae. Int J Oral Maxillofac Implants. 2014;29(3):608–21.

10.Ahlholm P, Sipilä K, Vallittu P, Jakonen M, Kotiranta U. Digital versus conventional impressions in fixed prosthodontics: a review. J Prosthodont. 2018;27(1):35–41.

11.Mangano FG, Hauschild U, Veronesi G, Imburgia M, Mangano C, Admakin O. Trueness and precision of 5 intraoral scanners in the impressions of single and multiple implants: a comparative in vitro study. BMC Oral Health. 2019;19(1):101.

12.Joda T, Brägger U. Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial. Clin Oral Implants Res. 2016;27(12):e185–9.

13.Wulfman C, Naveau A, Rignon-Bret C. Digital scanning for complete-arch implant-supported restorations: a systematic review. J Prosthet Dent. 2020;124(2):161–7.

14.Abdel-Azim T, Zandinejad A, Elathamna E, Lin W, Morton D. The influence of digital fabrication options on the accuracy of dental implant-based single units and complete-arch frameworks. Int J Oral Maxillofac Implants. 2014;29(6):1281–8.
15.Basaki K, Alkumru H, De Souza G, Finer Y. Accuracy of digital vs conventional implant impression approach: a three-dimensional comparative in vitro analysis. Int J Oral Maxillofac Implants.
16.Tallarico M, Xhanari E, Kim YJ, Cocchi F, Martinolli M, Alushi A, et al. Accuracy of computer-assisted template-based implant placement using conventional impression and scan model or intraoral digital impression: a randomised controlled trial with 1 year of follow-up. Int J Oral Implantol (Berl). 2019;12(2):197–206.
17.Kihara H, Hatakeyama W, Komine F, Takafuji K, Takahashi T, Yokota J, et al. Accuracy and practicality of intraoral scanner in dentistry: a literature review. J Prosthodont Res. 2020;64(2):109–13.
18.Wismeijer D, Joda T, Flügge T, Fokas G, Tahmaseb A, Bechelli D, et al. Group 5 ITI consensus report: digital technologies. Clin Oral Implants Res. 2018;29(Suppl 16):436–42.
19.Joda T, Katsoulis J, Brägger U. Clinical fitting and adjustment time for implant-supported crowns comparing digital and conventional workflows. Clin Implant Dent Relat Res. 2016;18(5):946–54.
20.Zhang Y, Tian J, Wei D, Di P, Lin Y. Quantitative clinical adjustment analysis of posterior single implant crown in a chairside digital workflow: a randomized controlled trial. Clin Oral Implants Res. 2019;30(11):1059–66.
21.Zhang YJ, Shi JY, Qian SJ, Qiao SC, Lai HC. Accuracy of full-arch digital implant impressions taken using intraoral scanners and related variables: a systematic review. Int J Oral Implantol (Berl). 2021;14(2):157–79.
22.Ribeiro P, Herrero-Climent M, Díaz-Castro C, Ríos-Santos JV, Padrós R, Mur JG, et al. Accuracy of implant casts generated with conventional and digital impressions-an in vitro study. Int J Environ Res Public Health. 2018;15(8):1599.
23.Amin S, Weber HP, Finkelman M, El Rafie K, Kudara Y, Papaspyridakos P. Digital vs. conventional full-arch implant impressions: a comparative study. Clin Oral Implants Res. 2017;28(11):1360–7.
24.Alikhasi M, Siadat H, Nasirpour A, Hasanzade M. Three-dimensional accuracy of digital impression versus conventional method: effect of implant angulation and connection type. Int J Dent. 2018;2018:3761750.
25.Papaspyridakos P, Gallucci GO, Chen CJ, Hanssen S, Naert I, Vandenberghe B. Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. Clin Oral Implants Res. 2016;27(4):465–72.
26.Menini M, Setti P, Pera F, Pera P, Pesce P. Accuracy of multi-unit implant impression: traditional techniques versus a digital procedure. Clin Oral Investig. 2018;22(3):1253–62.
27.Kim KR, Seo KY, Kim S. Conventional open-tray impression versus intraoral digital scan for implant-level complete-arch impression. J Prosthet Dent. 2019;122(6):543–9.
28.Chia VA, Esguerra RJ, Teoh KH, Teo JW, Wong KM, Tan KB. In vitro three-dimensional accuracy of digital implant impressions: the effect of implant angulation. Int J Oral Maxillofac Implants. 2017;32(2):313–21.
29.Vandeweghe S, Vervack V, Dierens M, De Bruyn H. Accuracy of digital impressions of multiple dental implants: an in vitro study. Clin Oral Implants Res. 2017;28(6):648–53.

30.Andriessen FS, Rijkens DR, van der Meer WJ, Wismeijer DW. Applicability and accuracy of an intraoral scanner for scanning multiple implants in edentulous mandibles: a pilot study. J Prosthet Dent. 2014;111(3):186–94.
31.Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343: d5928.
32.Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg. 2003;73(9):712–6.
33.Peñarrocha-Diago M, Balaguer-Martí JC, Peñarrocha-Oltra D, Balaguer-Martínez JF, Peñarrocha-Diago M, Agustín-Panadero R. A combined digital and stereophotogrammetric technique for rehabilitation with immediate loading of complete-arch, implant-supported prostheses: a randomized controlled pilot clinical trial. J Prosthet Dent. 2017;118(5):596–603.
34.Zhang YJ, Qian SJ, Lai HC, Shi JY. Accuracy of photogrammetric imaging versus conventional impressions for complete arch implant-supported fixed dental prostheses: A comparative clinical study. J Prosthet Dent. 2023;130(2):212–8.
35.Revilla-León M, Att W, Özcan M, Rubenstein J. Comparison of conventional, photogrammetry, and intraoral scanning accuracy of complete-arch implant impression procedures evaluated with a coordinate measuring machine. J Prosthet Dent. 2021;125(3):470–8.
36.Tohme H, Lawand G, Chmielewska M, Makhzoume J. Comparison between stereophotogrammetric, digital, and conventional impression techniques in implant-supported fixed complete arch prostheses: An in vitro study. J Prosthet Dent. 2023;129(2):354–62.
37.Syrek A, Reich G, Ranftl D, Klein C, Cerny B, Brodesser J. Clinical evaluation of all-ceramic crowns fabricated from intraoral digital impressions based on the principle of active wavefront sampling. J Dent. 2010;38(7):553–9.
38.Berrendero S, Salido MP, Valverde A, Ferreiroa A, Pradíes G. Influence of conventional and digital intraoral impressions on the fit of CAD/CAM-fabricated all-ceramic crowns. Clin Oral Investig. 2016;20(9):2403–10.
39.Iturrate M, Eguiraun H, Etxaniz O, Solaberrieta E. Accuracy analysis of complete-arch digital scans in edentulous arches when using an auxiliary geometric device. J Prosthet Dent. 2019;121(3):447–54.
40.Papaspyridakos P, Benic GI, Hogsett VL, White GS, Lal K, Gallucci GO. Accuracy of implant casts generated with splinted and non-splinted impression techniques for edentulous patients: an optical scanning study. Clin Oral Implants Res. 2012;23(6):676–81.