Systematic Review

Accuracy of the digital implant impression with splinted and non-splinted intraoral scan bodies: A systematic review

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Abstract

Introduction: Accurate implant impressions are crucial for successful prosthetic rehabilitation. Digital impressions using intraoral scanners (IOS) have emerged as an alternative to conventional techniques. Various factors influence the accuracy of digital implant impressions, including scan body design, scanning protocol, and splinting techniques.

Aim and Objective: To evaluate the difference between splinted and nonsplinted scan bodies in the accuracy of digital impressions for single or multiple implants by measuring distance and angular deviations between superimposed digital impressions.

Materials and Methods: PRISMA guidelines were followed in this systematic review. Electronic databases were searched for relevant studies published up to January 2024. Inclusion criteria encompassed clinical trials, *in vivo* and *in vitro* studies on scan bodies in partially or fully edentulous arches. Two reviewers independently assessed abstracts, titles and full texts. Data extraction included distance deviation, angular deviation, trueness, and precision measurements.

Discussion: Most studies found that scan body splinting improved the accuracy of digital implant impressions, particularly for complete-arch cases. Splinting techniques varied, including light-cured resin, pattern resin, dental floss, and custom-made splints. Factors such as the inter-implant distance, number of implants and choice of IOS also influenced accuracy. However, some studies reported no significant improvement or even negative effects of splinting on accuracy.

Conclusion: Splinting scan bodies generally improves the accuracy of digital implant impressions, especially for complete-arch cases. It enhances the stitching process in digital workflows and provides more stable reference points. However, the effectiveness may vary depending on the specific clinical situation, scanning protocol, and IOS used. Further research is needed to establish standardized protocols and evaluate long-term clinical outcomes of digitally fabricated implant restorations based on splinted scan body impressions.

Keywords: Digital implant impression, intraoral scanner, scan body, splinting

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INTRODUCTION

Dental implants have become a popular solution for replacing missing teeth. The success of implant treatment depends heavily on accurate prosthetic rehabilitation, which starts with precise impressions to capture the implant position. Conventionally, elastomeric materials were used for conventional implant impressions, but these methods can be prone to errors leading to prosthetic misfit and complications.[1-7]

Multiple studies have evaluated various conventional impression techniques. In general, open-tray methods, especially with splinted impression copings, have shown superior accuracy.[8-10] Factors such as implant angulation and the number of implants also influence impression accuracy.[11,12] For angled implants and multiple implant cases, pick-up impressions with splinted copings tend to yield the best results.[13,14]

In recent years, digital dentistry has introduced intraoral scanners (IOS) as an alternative to conventional impressions.[15-19] These systems use optical technology to create digital models of the oral environment. Many studies have compared digital and conventional implant impressions, with digital methods often achieving comparable or even better accuracy.[20-25]

Scan bodies play a crucial role in digital implant impressions.[26] These attachments connect to the implant and provide a scannable surface for the IOS. Various scan body designs exist, differing in material, shape, and surface coating. Scan body wear can affect impression accuracy, potentially necessitating regular replacement.[27,28]

Several factors influence the accuracy of digital implant impressions, including implant angulation and depth, the IOS system used, scan body design, and operator experience.[29-31] Increased implant angulation and depth tend to adversely affect accuracy, while experienced operators generally achieve better results.

Clinical studies comparing conventional and digital impression techniques for implant restorations have shown mixed results.[32,33,35,36] Some found no significant difference in marginal fit between the two methods, while others reported superior accuracy with conventional techniques, particularly for full-arch cases.

Systematic reviews analyzing the accuracy of conventional versus digital implant impression techniques have yielded varied conclusions.[34,37,39-41] In general, digital methods show promising results, especially for short-span restorations. However, the accuracy of digital complete-arch impressions may still need improvement. For conventional impressions, splinted impression copings, medium-body materials, and open-tray techniques typically provide the highest accuracy.

The choice between splinted and nonsplinted techniques applies to both conventional and digital impressions.[38] In conventional methods, splinted impression copings often yield better results. For digital impressions, some studies have explored splinting scan bodies, though this practice is less common.

While digital impressions offer many advantages, such as patient comfort and time efficiency, their accuracy compared to conventional methods remains a topic of ongoing research. The performance of different IOS systems varies, and factors such as scan strategy and software processing can influence outcomes.[25]

This systematic review aims to compare the trueness of digital implant impressions' STL files where the intraoral scan bodies were splinted and nonsplinted and to evaluate the overall accuracy of splinted scan bodies. The null hypothesis the trueness of the scans was not affected by different splinting techniques.

METHODOLOGY

The review was registered at PROSPERO under registration code CRD42023427147 and PRISMA guidelines were followed while reporting this systematic review. The focused PICO question was: Is there a difference between splinted and nonsplinted scan bodies in the accuracy of digital impressions for single or multiple implants? The inclusion criteria is studies including patients undergoing treatment for replacement of missing teeth using implant supported prosthesis, digital implant impressions were recorded of multiple implants using scan bodies which are splinted and nonsplinted and studies providing information about distance deviation, angular deviation, trueness and precision in the position of the scan bodies before and after splinting of the scan bodies. Literature and narrative reviews, case reports, and case series articles, those with duplicated data and without informed patient consent were excluded.

Search strategy

A concept Table 1 was prepared based on PICOS criteria of review question. According to this concept table, search strategy was formulated.

Primary outcomes measured were distance deviation, angular deviation, trueness, and precision. The databases searched were ScienceDirect, Scopus, Google Scholar, PubMed MEDLINE, and Proquest databases. Articles published till January 2024 were searched, with restriction concerning the publication's language to be in English only. Additional hand searching was done of the following journals: *Clinical Oral Implants Research*, *Journal of Prosthetic Dentistry and Journal of Implantology*. The used search terms in Pubmed, ScienceDirect and Scopus are as follows: (digital implant impression ([MeSH term]) AND (((splinting [MeSH term]) OR (splint)) AND ((scan body [MeSH term]) OR (scan body))). Boolean operators AND and OR were used. A total of 244 articles were obtained from these three databases. Entry terms used in Google Scholar and Proquest were splinting OR splinted AND scan body/scan bodies AND digital implant impression. The Boolean operator used was AND. A total of 54 articles were obtained from these two databases.

Article eligibility criteria

All the articles were evaluated by two reviewers individually after reading the titles and abstracts of the selected articles in the electronic database. These articles were further read in detail by both reviewers independently. If any discrepancy or disagreement was noted in inclusion exclusion criteria, then a third reviewer/author was consulted.

Study article selection.

Selection of articles

While selecting articles for this systematic review, duplicate articles were removed and irrelevant articles were deleted, full text of the relevant articles were obtained and added to the database. Full text of these articles was examined by 2 independent reviewers based on the inclusion and exclusion criteria.

Data extraction

The final 9 articles were again independently reviewed and listed according to their authorship, date of publication, the study design and the distance of deviation, angular deviation, thickness of impression and precision of impressions made with splinted and nonsplinted scan bodies [Table 2].

Table 1: Concept table

Population	Intervention	Comparison	Outcome	Study design
Adults with missing teeth undergoing rehabilitation with single or multiple implants	Digital impressions using splinted intraoral scan bodies	Digital impressions using nonsplinted scan bodies	Distance and angular deviation in the position of the scan bodies Trueness Precision Scan time	RCT *In vivo* studies *In vitro* studies

RCT: Randomized controlled trial

Risk of bias

This assessment followed the recommended approach for evaluating the risk of bias in studies included in Cochrane Reviews, utilizing the RevMan 5.4.1 tool. The two-part tool was applied to assess the domains outlined in Figures 1 and 2. Each domain includes one or more specific entries in a Risk of Bias table. The reviewers described what was reported to have occurred in the study, in the first part of the tool. They then assigned a judgment regarding the risk of bias for each entry, in the second part, categorizing it as either low risk, unclear risk, or high risk [Table 4]. Each study was addressed with a single entry for each domain in the tool. The agreement between the two reviewers was strong, with a high kappa coefficient (k > 0.89).

RESULTS

Out of the 298 articles obtained by searching the five databases, nine were included in the systematic review. The PRISMA flowchart [Figure 3] shows the various articles excluded at each stage of the review and the reason for their exclusion. Detailed characteristics of the included studies are mentioned in Table 3. Among the nine studies, three were conducted in the USA, one in Japan, one in France, one in Italy, one in Sweden, one in Switzerland, and one in Lithuania. All the studies included were published in the English language. Of these, three were *in vivo* studies where ethical approvals and informed consent was obtained. The IOS used between all the included studies are: Cerec Primescan (Dentsply Sirona), Cerec Omnicam (Dentsply Sirona), 3Shape Trios 4 (3Shape, Copenhagen, Denmark), 3Shape Trios 3 (3Shape), Planmeca Emerald (Planmeca, Helsinki, Finland), Medit i500 (Medit, Seoul, South Korea), and Carestream 3600 (Carestream Health,

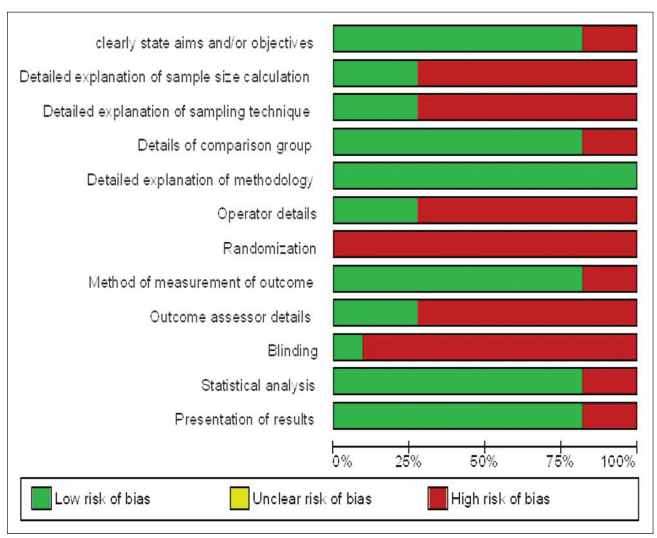

Figure 1: Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies (original)

Table 2: Data of clinical parameters

Study	Distance deviation (mm)		Angular deviation (mm)		Trueness		Precision	
	Control	Test	Control	Test	Control	Test	Control	Test
Retana *et al*. (2023)	0.3921±0.19	0.248±0.08	-	-	39.3±2.7	24.5±2.7	-	-
Mizumoto *et al*. (2020)	0.173±0.05	0.197±0.04	0.80±0.43	0.86±0.30	-	-	-	-
Masu *et al*. (2021)	0.198±0.06	0.128±0.02	-	-	-	-	-	-
Denneulin *et al*. (2023)	0.366±0.03	0.385±0.02	0.34±0.18	0.20±0.14	-	-	-	-
Ali (2022)	-	-	-	-	-	-	-	-
Pozzi *et al*. (2021)	0.155±0.05	0.090±0.05	0.33±0.20	0.38±0.18	-	-	-	-
Rutkunas (2022)	±	0.327±0.19		0.22±0.18	-	-	-	-
Nedelcu (2022)	-	-	-	-	-	22.22±7.11	9.3±1	47.67±6.67
Azevedo *et al*. (2023)	-	-	-	-	47.4±7.8	49.4±7.2	-	-

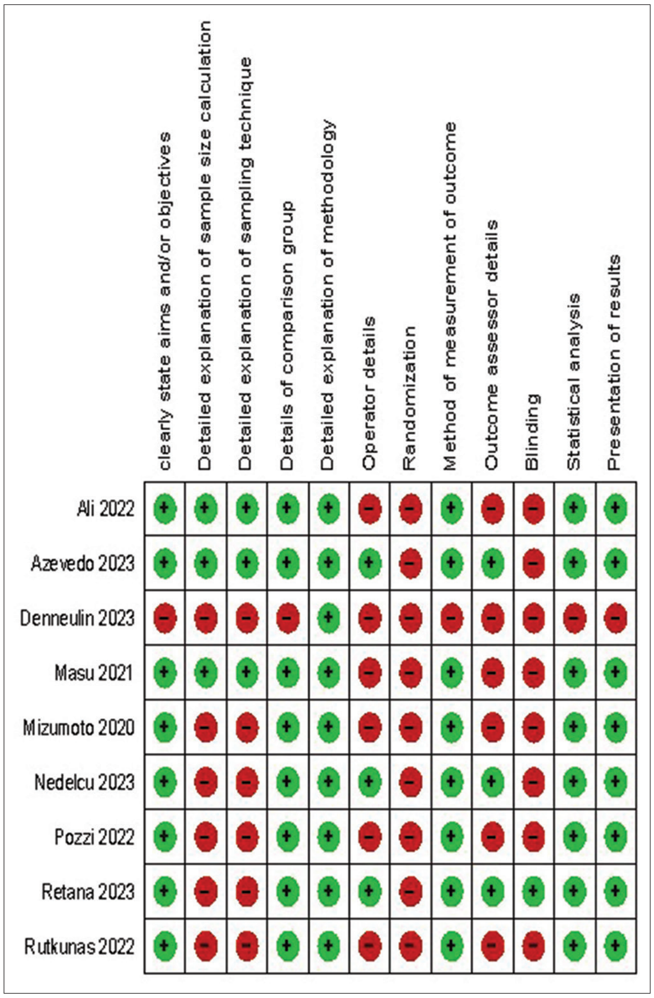

Figure 2: Risk of bias summary: review authors' judgements about each risk of bias item for each included study (original)

Rochester, NY, USA), Atlantis I-Flo (AF), Core3D (C3D), Nt-Trading (NT), Dess-USA (DE), Zimmer Biomet (ZI), 3M True Definition scanner (TDS; 3M ESPE, Seefeld, Germany), ATOS Core 80 5MP; GOM, Braunschweig, Germany, iTero Element 5D (Align Technology), i700 (Medit Corp), and Virtuo Vivo (Dental Wings). All the studies analyzed the accuracy of digital implant impressions before and after splinting of the intraoral scan bodies. The materials used for splinting were orthodontic wire, pattern resin, dental floss (DF), bis-acrylic composite splint, 3D-printed splints, modular chain, and suture thread. The parameters measured were distance deviation, angular deviation, trueness, and precision. The results obtained in each study are mentioned in Table 3.

DISCUSSION

Implant restorations encompassing a full arch fabricated using the digital technique have been studied to explore various factors influencing their precision. Splinting scan bodies, components attached to implants for scanning, have emerged as a technique with significant benefits. Studies by Azevedo *et al*.,[47] Retana *et al*.[42] and Pozzi *et al*.[50] all found that splinting the scan bodies generally improved the accuracy of digital scans for all IOS tested. The investigations by Azevedo *et al*.,[47] Retana *et al*.[42] and Pozzi *et al*.[50] explored the influence of splinting scan bodies on the accuracy (trueness) of digital scans for full-arch implant restorations, utilizing five, seven, and three distinct IOS, respectively. Two sets of digital scans were captured for each of the IOS devices tested: One scan with the scan bodies secured together (splinted). Another scan with the scan bodies unattached (individual). The space between implants (inter-implant distance) was varied to analyze its effect on accuracy. They saw that splinting the scan bodies generally enhanced the accuracy of digital scans for all the IOS devices evaluated. This improvement stemmed from better alignment during the software's process of stitching together multiple scans (used for capturing a full arch). Increased space between implants (greater inter-implant distance) led to a decrease in accuracy for both splinted and non-splinted scans. The specific IOS used also influenced the overall accuracy, with some scanners performing significantly better than others. The overall conclusion was that the accuracy of digital impressions for complete-arch implant restorations was enhanced by splinting the scan bodies, regardless of the specific IOS employed. This improved accuracy arises from providing the scanning software with clearer reference points during image stitching. Their studies also highlighted that the choice of IOS itself can impact the final impression's precision.

Table 3: Characteristics of included studies

Study	Country	Study design	Sample size Control	Sample size Test	Scanner/ISBs used	Splinting method	Population	Outcomes measured	Conclusion
Retana *et al*. (2023)	USA	*In vitro* study	70	70	Cerec Primescan (Dentsply Sirona), Cerec Omnicam (Dentsply Sirona), 3 Shape Trios 4 (3Shape, Copenhagen, Denmark), 3Shape Trios 3 (3Shape), Planmeca Emerald (Planmeca, Helsinki, Finland), Medit i500 (Medit, Seoul, South Korea), and Carestream 3600 (Carestream Health, Rochester, NY, USA)	3D printed splinting bars secured with clear polyvinyl siloxane material	A polyurethane cast of an edentulous mandible with four dental implant analogs was prepared	Distance deviation and trueness	Based on the present findings, splinting the scan bodies can improve the trueness of complete arch digital implant scans due to the improvement in morphologic landmarks by the stitching process, regardless of the type of IOS or the inter-implant distance
Mizumoto *et al*. (2020)	USA	*In vitro* study	5	5	AF, C3D, NT, Dess-USA (DE), Zimmer Biomet (ZI)	Dental floss	Edentulous maxillary model with 4 dental implant analogs	Distance deviation and angular deviation	Based on the findings of this *in vitro* study, the following conclusion was drawn: More distance deviation was noted when the scan bodies were splinted with floss
Masu *et al*. (2021)	Japan	*In vitro* study	15	Test 1–15 Test 2–15	PS; Dentsply Sirona, USA, 3M TDS; 3M ESPE, Seefeld, Germany, and Trios scanner 3 (TR; 3Shape, Copenhagen, Denmark)	Two assistive devices were designed using a CAD software. The designs were input to a CAM device and milled from a polymethyl methacrylate disk	A reference model representing an edentulous maxilla with four implants	Surface deviation	The results of this study showed that an assistive device significantly improved impression precision, but the effect varied depending the assistive device used and the IOS
Denneulin *et al*. (2023)	France	*In vitro* study	3	Test 1–10 Test 2–10	Trios 3 (3Shape) and Primescan (Dentsply Sirona)	Suture thread	A resin-based model of an edentulous mandible with six implants	Distance deviation and angular deviation	The study concluded that splinting with a suture thread did not improve the accuracy of digital scanning with either device, especially with the Trios 3
Ali (2022)	USA	*In vivo* study	19	19	3Shape D900L; 3Shape Inc, NJ, USA	Dental floss and pattern resin	Patients with maxillary or mandibular edentulous arches with 4–6 dental implants	Distance deviation and angular deviation	The findings suggest that trueness of full arch edentulous implant digital impressions is not affected by splinting scan bodies. However, scan time is reduced drastically
Pozzi *et al*. (2021)	Italy	*In vitro* study	30	30	Trios3, 3Shape A/S, Copenhagen, Denmark	Modular chain secured with light cured resin	An edentulous mandibular model with 4 analogues was fabricated	Distance deviation and angular deviation	The investigated implant scan body splinting technique reduced angular and linear deviations at the posterior most implant position hence improving the accuracy of full arch digital impression
Rutkunas (2022)	Lithuania	*In vitro* study	80	2 h - 80 24 h - 80	E4, 3Shape, Copenhagen, Denmark	Type I impression plaster (PLA), autopolymerizing acrylic resin, cut and rejoin technique (PTR), light-cured acrylic resin, cut and rejoin technique (ILC), light-cured acrylic resin,	Two steel bars were milled in which ten pairs of implant analogs were fixed with autopolymerizing acrylic resin	Distance deviation and angular deviation	Splinting techniques with rigid materials, proper polymerization and compensating for material shrinkage seemed to produce the best results. The dimensional accuracy was best in the light cure acrylic resin group

Contd...

Table 3: Contd...

Study	Country	Study design	Sample size Control	Sample size Test	Scanner/ISBs used	Splinting method	Population	Outcomes measured	Conclusion
						no cutting and rejoining (ILN), VPS bite registration material (SBR), bis-acryl bite registration material (LXB), bis-acryl composite resin (PTP), 3D printed splint (3DP)			
Nedelcu (2022)	Sweden	*In vivo* study	15	15	Trios 3 (Trios), (3Shape, Copenhagen, Denmark), ATOS Core 80 5MP; GOM, Braunschweig, Germany	Dental floss and bis-acrylic composite splint	Patients with edentulous maxillae with 6 implants	Trueness and precision	The results of this study were that the dental floss group and splinted group showed overall lesser trueness and precision than the control group
Azevedo *et al*. (2023)	Switzerland	*In vivo* study	50	50	iTero Element 5D (Align Technology), Trios 4 (3Shape A/S), Cerec Primescan (Dentsply Sirona), i700 (Medit Corp), and Virtuo Vivo (Dental Wings)	Orthodontic wire and pattern resin	Patients with an edentulous arch with 6 tissue level implants	Trueness	The conclusion drawn was splinting ISBs did not affect the trueness of the digital scans with Virtuo Vivo, Medit i700, and Primescan. However, the trueness of the complete arch digital implant scans on splinting was improved with Trios4

ISBs: Intraoral scan bodies, 3D: Three-dimensional, IOS: Intraoral scanner, AF: Atlantis I-Flo, C3D: Core 3D, NT: Nt-Trading, DE: Dess, ZI: Zimmer, PS: Primescan, TDS: True definition scanner, CAD: Computer aided design, 3DP: 3D printed, 5D: Five-dimensional

Nedelcu *et al*.[43] studied the accuracy (precision and trueness) of capturing full-arch implant scans using IOS with three distinct acquisition protocols. Five participants with six implants each in their maxilla were included. A high-precision laboratory scanner provided a reference scan for comparison. With a commercially available IOS, three different scanning protocols were employed: Control (CT): Standard scanning procedure. DF assisted: Used DF to retract soft tissues and improve scan capture. Acrylic splint (SP): Employed a custom-made splint around the scan bodies for added stability. Scans were repeated three times for each protocol on each participant. The CT protocol achieved the highest trueness, with an average deviation of 41 micrometers (μm) from the reference scan. The DF protocol showed slightly lower trueness with an average deviation of 49 μm. The SP protocol demonstrated the least deviation at 55 μm, though statistically similar to CT. Interestingly, all three protocols displayed similar precision, with an average variation of around 50 μm between repeated scans. This study suggested that using a CT protocol with careful soft tissue management can achieve highly accurate full-arch implant scans with an IOS. The use of a DF or an acrylic splint yielded comparable results, although the CT protocol remained the most favorable. The findings also indicate that all three protocols provided consistent (precise) repeated scans.

Rutkunas *et al*.[49] investigated how the dimensional accuracy of implant impressions was affected by different splinting techniques and time intervals, conducted in a controlled laboratory setting. A master model with four dental implant analogues was used, representing an edentulous jaw. High-precision reference scans served as the benchmark for accuracy assessment. The researchers evaluated three different splinting techniques for the impression copings: no splinting (control group), light-cure acrylic resin splinting, polytetrafluoroethylene (PTFE) tape splinting. In addition, they captured impressions at two different time points after splinting the copings: Immediately after splinting (2 h), After 24 h. Compared to the reference scans, all splinting techniques resulted in some degree of dimensional deviations. Light-cure acrylic splinting and PTFE tape splinting generally improved accuracy compared to the control group (no splinting). However, all splinting methods exhibited a slight decrease in accuracy after 24 h compared to the 2-h measurements. Among the splinting techniques, the Light-cure acrylic group displayed the lowest overall deviation in terms of distance, vertical positioning, angulation, and rotation. This study suggests that splinting impression copings with either light-cure acrylic resin or PTFE tape can enhance the accuracy of implant impressions compared to no splinting. However, some level of dimensional deviation occurs with all

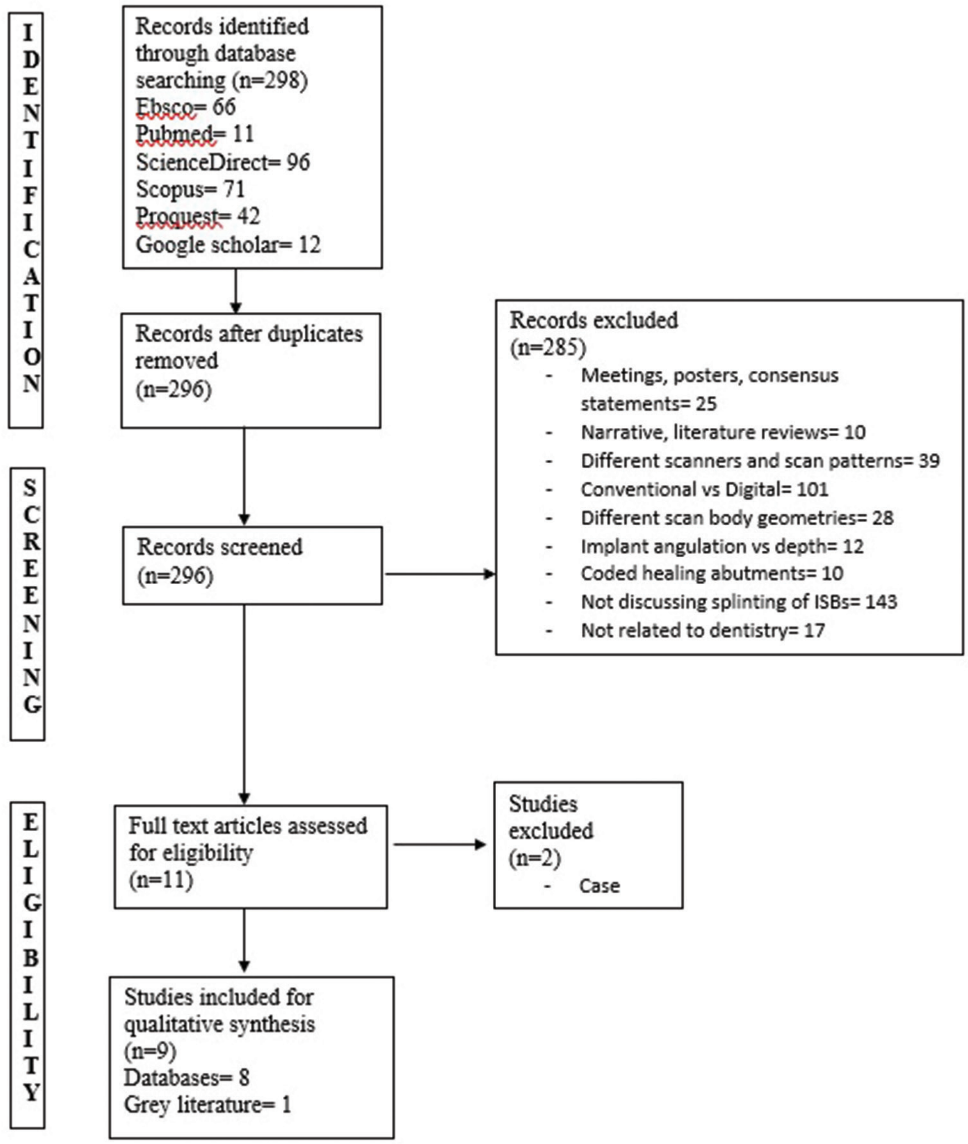

Figure 3: PRISMA flowchart (original)

techniques, and a slight decrease in accuracy was observed after 24 h. The findings suggest that light-cure acrylic splinting might offer the most favorable results, although all techniques require careful execution to minimize deviations.

However, Denneulin *et al*.[46] observed that splinting might not always be advantageous, reporting it negatively impacted accuracy in their study. They investigated how three factors affected the digital scans for implant restorations encompassing an entire dental arch (complete-arch): scan body splinting, number of implants and scanning protocol. Six implants were placed in a resin model replicating an edentulous jaw. High-precision scans generated by a coordinate measurement machine served as the benchmark for accuracy assessment. Two commercially available IOS were employed to capture digital scans: Trios 3 and Primescan. Three experiments were conducted to evaluate the effects of the aforementioned factors: The first experiment examined three scanning protocols (half-arch, zigzag and linear). The second experiment mimicked different clinical scenarios with varying implant numbers (4 implants in a long arch, 4 implants in a short arch and 6 implants). The third experiment assessed the influence of splinting the scan bodies with suture threads. They found no significant differences in accuracy between the three scanning protocols with either IOS device. Accuracy (measured by distance and angular deviations) significantly decreased for both IOS systems when using only four implants compared to six implants. Splinting the scan bodies negatively impacted the accuracy of scans acquired with both IOS devices. They concluded that the number of implants plays a more critical role in scan accuracy compared to the chosen scanning protocol within the tested options.

Table 4: Risk of bias

Author (year)	Clearly state aims and/or objectives	Explanation of sample size calculation	Explanation of sampling technique	Details of comparison group	Detailed explanation of methodology	Operator details	Randomization	Method of measurement of outcome	Outcome assessor details	Blinding	Statistical analysis	Presentation of results
Retana, 2023	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk	Low risk
Nedelcu, 2023	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	High risk	Low risk	Low risk
Mizumo-to, 2020	Low risk	High risk	High risk	Low risk	Low risk	High risk	High risk	Low risk	High risk	High risk	Low risk	Low risk
Masu, 2021	Low risk	Low risk	Low risk	Low risk	Low risk	High risk	High risk	Low risk	High risk	High risk	Low risk	Low risk
Denneulin, 2023	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	High risk	Low risk	Low risk
Azevedo, 2023	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	High risk	Low risk	Low risk
Ali, 2022	Low risk	Low risk	Low risk	Low risk	Low risk	High risk	High risk	Low risk	High risk	High risk	Low risk	Low risk
Pozzi, 2022	Low risk	High risk	High risk	Low risk	Low risk	High risk	High risk	Low risk	High risk	High risk	Low risk	Low risk
Rutkunas, 2022	Low risk	High risk	High risk	Low risk	Low risk	High risk	High risk	Low risk	High risk	High risk	Low risk	Low risk

In addition to that, six implants yielded the most favorable results for both Trios 3 and Primescan. Moreover, splinting the scan bodies with sutures seems to be less advantageous for achieving optimal accuracy.

Beyond splinting, other factors influencing accuracy include the scanning protocol used and the number of implants. Research undertaken by Mizumoto *et al*.[44] investigated the accuracy of various digital impression techniques for implant-supported prostheses spanning an entire arch. An edentulous maxillary jaw model with four implants was utilized. A high-precision extraoral scan served as the reference for accuracy comparisons. The following scanning methods were assessed: Intraoral scanning with various scan bodies (customized and prefabricated), Extraoral scanning of the model itself. Scan bodies with different angulations were also evaluated. They observed that intraoral scanning with customized scan bodies delivered the most accurate digital impressions. Extraoral scanning provided comparable accuracy but was less convenient for clinical use. Pre-fabricated scan bodies resulted in less precise scans compared to customized ones. Scan body angulation did not significantly influence accuracy. Mizumoto *et al*. emphasized the importance of selecting appropriate scan bodies, particularly customized ones, to achieve optimal accuracy in digital implant impressions for full-arch restorations. While extraoral scanning offered comparable precision, its practicality was deemed less favorable for clinical settings. This research suggests that intraoral scanning with customized scan bodies provides the most accurate and practical solution for these implant procedures.

Masu *et al*. studied the precision of digital impressions for implants when assistive devices were used.[45] In a resin model of an edentulous maxilla, four implants were placed. A high-precision laboratory scan served as the benchmark for evaluating accuracy. Three configurations of digital impressions were captured using various IOS: No assistive device (Type 0), An assistive device connecting only neighboring implants (Type 1), An assistive device connecting all four implants, with additional perpendicular branches for enhanced stability (Type 2). Five digital scans were obtained for each configuration with three different IOS devices. The study revealed that the type of assistive device and the IOS used significantly affected the precision of the digital impressions. Digital impressions obtained with assistive devices, particularly Type 2 (most comprehensive design), demonstrated improved precision compared to those captured without any assistive device (Type 0). The findings suggest that assistive devices aid in stabilizing the implant positions during scanning, leading to more accurate impressions. The precision of the digital scans also varied depending on the specific IOS employed.

Overall, these studies demonstrate that achieving optimal accuracy in digital impressions for complete-arch implant restorations requires careful consideration of various factors. Splinting scan bodies appears to be a generally beneficial technique, although its effectiveness might vary depending on the specific situation. The scanning protocol, number of implants and choice of IOS and scan bodies themselves also play a role.

CONCLUSION

Among all the included studies, it can be concluded that splinting scan bodies while recording digital implant impressions is a beneficial technique to record an accurate impression. A few techniques have been used for splinting the scan bodies including light cured resin, pattern resin, DF, PTFE tape, custom made splints, and assistive devices. Splinting ensures that the precise positions and angulations of the implants or abutments are accurately transferred from their intraoral position to the digital model. By accurately capturing the implant positions, splinting contributes to a better fit of the implant- retained restoration, reducing the risk of complications such as prosthetic screw loosening, implant fractures or bone resorption. It minimizes potential discrepancies between the digital model and the clinical situation. Splinting streamlines the digital workflow by providing a single, unified digital model that can be seamlessly used for virtual design, planning, and manufacturing processes. It eliminates the need for manual alignment or registration of individual scan bodies, saving time and reducing the potential for human error.

However, in complete arch cases involving multiple implants and natural teeth, splinting scan bodies across a large span can amplify even small registration errors or discrepancies in the digital impression.[48-53] In cases with severely undercut areas, deep subgingival margins, or other complex anatomical features, the rigidity of the splinted scan bodies may hinder the scanner's ability to capture these areas accurately. To mitigate these potential negative impacts, some digital impression systems employ alternative strategies for complete arch cases, such as segmented or quadrant-based scanning approaches, or hybrid techniques that combine digital and conventional impression methods. In addition, ongoing advancements in scanning technology, software algorithms, and operator training continue to address these challenges and improve the reliability of full arch digital impressions involving splinted scan bodies.

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Reporting guidelines:

This study has been reported as per the PRISMA reporting guidelines.

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Conflicts of interest
There are no conflicts of interest.

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