Intraoral Scanning Versus Conventional Impression for Implant Prostheses: A Systematic Review

Keywords

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ABSTRACT

Purpose: To analyze and compare conventional and digital impressions, the effectiveness in implant-supported fixed prosthesis cases regarding accuracy, time, and patient preference. Methods: This review followed PRISMA guidelines and was registered in PROSPERO. Two independent reviewers searched PubMed/MEDLINE, Scopus, Embase, Web of Science, and gray literature (ProQuest) for studies published until September 2023. Risk of bias was assessed using RoB 2.0 and ROBINS-I tools. Meta-analysis was performed using RevMan 5.4 software. A total of 27 studies were selected, including 737 patients. Results: Qualitative analysis showed similar prosthetic results and precision for both procedures. Adjustment and impression durations were shorter with digital impressions. Twelve studies that evaluated patients' perceptions were unanimous about their preference for digital impressions. The meta-analysis revealed a significant difference in scanning time in single crowns (P =.001; MD: -7.16; CI: -10.21 to -4.10; heterogeneity P <.001; I2 =98%). Additionally, significant differences were observed in the analyses of adjustment duration (P =.04; MD: -3.33; CI: -6.52 to -0.13; heterogeneity P < .001; I^2 =90%) and patient preference (P =.003; MD: 19.02; CI: 6.36 to 31.68; heterogeneity P <.001; I^2 =95%) favoring the digital impression. Conclusion: Intraoral scanning provides better results concerning patient perception, impression time, and duration of adjustments.

INTRODUCTION

Dental implants replace missing teeth and support prosthetic structures such as single crowns, fixed partial dentures (FPDs), and complete dentures, whether fixed or removable.[1] To ensure the long-term success of implant-supported prostheses, impressions must be highly accurate to achieve a passive fit of the framework.[2] Inaccuracies can compromise both mechanical stability and biological integration.[2,3] Unlike natural teeth, the bone-implant interface lacks a periodontal ligament, meaning that any uncompensated occlusal load is directly transferred to the bone tissue. Therefore, obtaining an exact three-dimensional impression of the implant position is important for fabricating a precise and reliable prosthesis.[4,5]

Impressions can be obtained using either conventional or digital techniques.[3] With technological advancements, the introduction of digital impressions through intraoral optical scanners (IOS) has enabled a fully digital workflow, leading to the emergence of computer-aided design and manufacturing (CAD/CAM) systems.[6] Digital technology provides an alternative to conventional impressions,[7] allowing the clinical situation to be recorded digitally without physical contact. IOS capture information by projecting light,[2] digitally recording intraoral conditions and generating a virtual model.[8]

Compared to the traditional workflow, the fully digital workflow offers several advantages, including increased efficiency for both dentists and dental laboratories, elimination of disinfection and cast shipping requirements, and ease of duplication and storage of scanned files.[9] However, the accuracy of digital scanning is influenced by multiple factors, including the scanning protocol, operator experience and training, type of prosthesis, arch scanning, distance, angulation between implants, scan body characteristics, number of implants, and ambient lighting conditions,[4,3,9,10] Furthermore, adopting new technologies involves significant costs, time for installation and configuration, periodic upgrades, maintenance, and a learning curve that requires patience from the operator.[11-13]

Previous studies have primarily focused on comparing the accuracy and precision of conventional and digital impressions.[2,3,14-18] However, few studies have evaluated their overall effectiveness, particularly in terms of patient perception, impression-taking duration, and adjustment time. A previous systematic review[6] evaluated 17 studies, of which 10 assessed patient-reported outcome measures (PROMs) and work time efficiency between digital and conventional impressions for implant-supported prostheses. Recently, new clinical studies have been published on this topic,[19-35] highlighting the need to reassess these findings to determine their consistency. Additionally, the type of prosthesis (single crowns or FPD), along with different outcomes such as precision and adjustment duration, were not thoroughly explored in the previous review, making them relevant factors in assessing effectiveness. Therefore, this systematic review aims to compare the effectiveness of conventional and digital impression procedures for implant-supported prostheses. The null hypothesis is that there is no difference in effectiveness between conventional and digital impression techniques.

MATERIAL AND METHODS

REGISTRY PROTOCOL

This systematic review was conducted based on the guidelines of the Cochrane Handbook of Systematic Reviews.[36] The Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA)[37] checklist was used to structure the systematic review. This research was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42024585840.

ELIGIBILITY CRITERIA

The studies were selected according to the PICO strategy, where (P) refers to the population, including patients rehabilitated with implant-supported prostheses; (I) refers to the intervention, considering digital scanning; (C) refers to the comparison, considering conventional impressions; and (O) refers to the outcome, including effectiveness (impression time, patient preference, and precision). The research question guiding this review was: "Does digital scanning present better effectiveness in cases of implant-supported prostheses compared to conventional impressions?"

The inclusion criteria were (a) in vivo studies, (b) randomized clinical studies, (c) prospective studies, (d) samples with more than ten patients, and (e) studies comparing digital and conventional impressions in terms of time, patient preference and accuracy. No restrictions were applied regarding the year of publication or language. Conversely, the exclusion criteria were (a) *in vitro* or animal studies, (b) case reports, (c) case series, (d) pilot studies, (e) systematic reviews, and (f) studies that did not compare digital and conventional impressions.

INFORMATION SOURCES

An electronic search strategy was conducted by two authors (CSCR and CAAL) in the databases PubMed/MEDLINE, Scopus, Embase, Web of Science, and gray literature (ProQuest) for articles published until September 2023. In each database, the retrieved studies were exported to Rayyan QCRI,[38] where duplicates were removed, and the studies were screened based on their title and abstract. For inclusion, full-text were assessed. Study selection was performed independently by two authors (CSCR and GCM). In cases of disagreement, a third author (RFC) conducted a blind reassessment, and discrepancies were resolved through discussion among the three reviewers until a unanimous consensus was reached on the eligibility criteria.

RISK OF BIAS

The risk of bias in non-randomized prospective studies was assessed using the ROBINS-I tool,[39] which evaluates the risk of bias across five domains: randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of the reported outcome. This tool assesses the comparative effectiveness (harm or benefit) of interventions in studies without randomization, classifying studies as having a low risk, some concerns, or a high risk of bias. For randomized trials, the RoB 2.0 tool[40] was used, examining the risk of bias in five domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in outcome measurement, and bias in the selection of the reported outcome. Each domain is categorized as having a "low risk," "high risk," or "some concerns" risk of bias.

The risk of bias assessment was conducted by one reviewer (CSCR), with a second reviewer (GCM) verifying the findings to ensure consistency.

CERTAINTY OF EVIDENCE

The certainty of the evidence was assessed using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) framework.[41] This approach allows for the systematic assessment of the reliability of the evidence for each outcome, considering study design, publication bias, inconsistency, indirect evidence, and imprecision. Outcomes were then categorized as having high, moderate, low, or very low certainty of evidence.

SUMMARY MEASURES

A qualitative analysis was conducted for all studies. The mean time and age were calculated. In studies that used more than one type of scanner, the groups were combined to obtain a single average using the online tool (https://www.statstodo.com/CombineMeansSDs.php). The meta-analysis was performed using Reviewer Manager 5.4 software (Cochrane Group), based on inverse variance method. Duration, adjustment duration, and patient preference data from the included studies were continuous and were assessed using mean differences (MD) with corresponding 95% confidence intervals (CI). MD values were considered statistically significant when P <.05. When the meta-analysis revealed high heterogeneity (P <.10), a random-effects model was adopted.

RESULTS

STUDY SELECTION

The electronic search provided 3,296 articles: 566 from PubMed/Medline, 470 from Scopus, 340 from Embase, 733 from Web of Science, and 1187 from ProQuest. The search strategy can be consulted in Supplementary File 1. After removing the duplicate articles, 1035 articles remained. Titles and abstracts were screened, and eligibility criteria were applied, resulting in 42 articles. During full-text evaluation, 15 studies were excluded for not meeting the eligibility criteria, with specific reasons for exclusion detailed in Supplementary File 2. Additionally, one article[42] was excluded due to the unavailability of the full-text, despite efforts to obtain it through institutional resources or contact with the authors. In total, 27 studies were included in the analysis *(Figure 1)*. The characteristics of the included studies can be found in Supplementary File 3, and the evaluated outcomes in Table 1.

Of the 27 included articles, thirteen[19-28,43-45] were randomized controlled trials, and fourteen[29-35,46-52] were prospective studies. The total study population consisted of 737 participants, with an average age of 53.46 years. Six studies[21,28, 32,33,46,49] did not report the average age.

Regarding the type of prosthesis, seventeen studies,[20-23,25,27,31,32,34,35,43,44,47-51] reported impressions for single-unit implant crowns, nine studies,[19,23,24,28-30,33,45,52] reported impressions for fixed partial dentures (FPD), and one study[46] analyzed both types. The model of IOS used varied among the selected studies, with greater prevalence of TRIOS 3, CEREC Omnicam, iTero, Carestream CS 3600, Virtuo Vivo, True Definition Scanner, and TRIOS Color scanners.

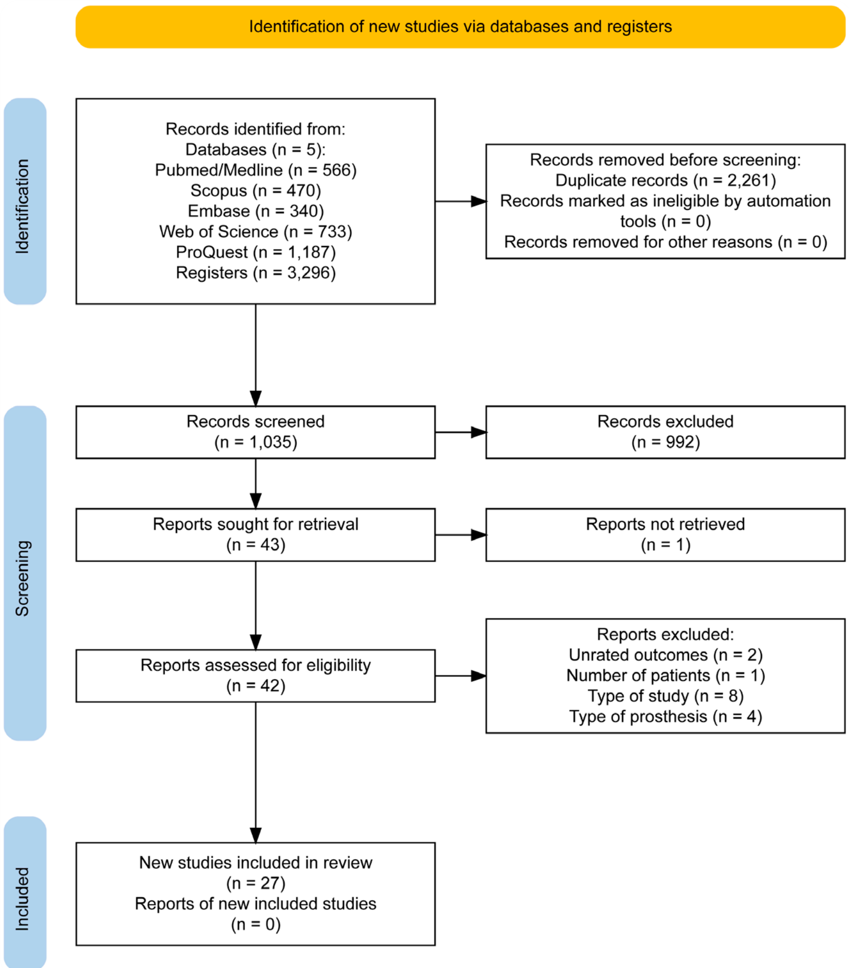

Figure 1: Flowchart describing the search and selection strategies.

Table 1. Evaluation of outcomes.

Author/Year	Type of crown	Treated area	Time of procedure	Retake	Prosthetic outcomes	Patients' preference	Used scale
Wismeijer et al 2014	Single crown and 3-unit FPD	Quadrant	C: 12.4 min; D: 19.7 min (Single)/ C: 12,44 min; D: 30,77min (3-unit FPD)	X	X	Preference for digital (p=0.006)	7 questionnaire questions, rated on a scale from 1 (negative) to 10 (positive).
Schepke et al 2015	Single crown	Full arch	D: 6. 39 min (±1:51); C: 12.13 min (±1:24)	X	X	Preference for digital: 82%	VAS (0-100)
Joda e Bragger (a) 2015	Single crown	Quadrant	D: 14.8 min (±2.2); C: 17.9 min (±1.1)	X	X	Preference for digital: 77.3% (SD 15.2%, median 79%)	VAS (0-100) (12 affirmations)
Guo et al	Single crown	Full arch	D: 10.6 min (±2.5); C: 14.45 min (±3.0)	X	X	Preference for digital: 85% (n=17)	VAS
Di Fiore et al 2018	Single crown	x	D: 9.57 min ±2.5 ; C: 18.1±1.78 min	D: 2:52 min; C: 05:46 min	x	The digital technique was more comfortable than the conventional technique (mean discomfort score: 15.5 vs. 62, respectively; P < .001). The mean patient evaluation score for the esthetic outcome was 73 for digital and 69 for conventional (P = .07)	VAS
Lee et al 2021	Single crown	Quadrant	C: 14.16 min (±1.65); D: 11.28 min (±2.30)	C: 0.17, additional time: 0.56 min/ retake times D: 1.27, additional time: 2.27 min	In terms of accuracy, the analysis revealed no differences in the intaglio or marginal fit, as no adjustments were required for either technique.	Preference for digital: 89% (D: 79.5 ± 21.6; C: 39.9 ± 31.7)	VAS (0-100)
Delize et al 2019	Single crown		X	X	Both crowns demonstrated acceptable and comparable clinical precision in interproximal contact and occlusion.	Six domains were assessed: duration, comfort, anxiety, nausea, pain, and taste (D: 52.7 ± 5.88; C: 49.4 ± 6.88).	VAS (0-10)
Pan et al 2019	Single crown	Full arch	D: 10.9 min (CI 10.4, 11.5); C: 14.3 min (CI 13.4, 15.1)	X	The evaluation of occlusal and interproximal contacts showed that the quality of results for posterior implant crowns was similar.	X	X
Kunavisarut et al 2022	Single crown	X	X	X	The Functional Implant Prosthodontic Score (FIPS) instrument showed similar results for digital and conventional protocols, as well as for different restorative materials.	Digital impressions were associated with less gustatory irritation (P = 0.036). Conventional protocol: 0.65 (0.03–4.98); Digital protocol: 0.05 (0–1.05). Homogeneous results were observed in five of the six assessed domains: duration, comfort, anxiety, nausea, and pain.	VAS (0-10)
Derksen et al 2020	Single crown	Full arch	X	X	One-year follow-up showed a high success rate for both techniques, with 100% survival. Adjustment time: C: 6.09 min (±4.63, range: 0–18 min); D: 3.35 min (±3.38, range: 0–11 min).	X	X
Ren et al 2021	Single crown	Quadrant	D: 13.75 min (±2,45); C: 13.50 min (±2.62)	X	Average crown adjustment duration: D: 6.45 min (±2.21 min); C: 13.15 min (±3.84 min).	X	X
Joda e Bragger (b) 2015*	Single crown	X	D: 14.8 min; C: 17.9 min	X	Average interproximal and occlusal adjustment duration: D: 2.6 min; C: 5.4 min. The fabrication process did not affect the success rate of the final crown placement.	X	X
Mühlemann et al 2022	Single crown	Full arch	D: 9.5 min (±3.5); C: 15.1 min (±4.6)	X	In both groups, a substantial improvement in the anatomical form parameter was observed between try-in and crown delivery. The prosthetic outcomes of implant crowns were similar for both workflows.	X	X
Cappare et al 2021	Single crown	X	X	X	X	Preference for digital regarding discomfort (VAS): D: 96.8 (±6.42); C: 72.8 (±16.57), P = 0.007. Absolute patient satisfaction was nearly equivalent between the two groups (VAS): D: 94.32 (±8.61); C: 92.02 (±8.87), P = 0.363.	VAS (0-100)
Mangano e Veronesi 2018	Single crown	Posterior	D: 20 min (±5); C: 50 min (±7)	X	One-year follow-up: The tested and control groups showed no significant differences in complications or probability of success.	Discomfort: D: 96.8 (±4.7); C: 72.8 (±18.6). Nausea/Gag reflex: D: 97.2 (±5.4); C: 84.0 (±21.7). Comfort: D: 97.6 (±4.3); C: 69.2 (±13.8).	VAS (0-100)
Seth et al 2023	Single crown	X	Students perceived the digital technique as taking longer and less practical (subjective view)	X	Using the Copenhagen Index Score (CIS) scale, no significant differences in esthetic results were recorded. The interproximal contact ratio and occlusal contacts did not depend on the type of registration technique and were all acceptable.	Preference for digital: 80% Preference for conventional: 2% Without preference: 18%	VAS (0-100)
Joda and Bragger 2014	Single crown	Quadrant	D: 27.3 min; C:33.2 min	X	X	X	X
Joda et al 2016	Single crown	Quadrant	X	X	The sum of interproximal and occlusal adaptation times: D: 2.2 min ± 2.1; C: 6.0 min ± 3.9.	X	X
Joda et al 2021	3-unit FPD	X	D: 12.95 min (±5.2); C: 12.9 min (±1.6)	X	X	X	X
Cappare et al 2019	Hybrid (full arch)	Full arch	C: 16.45 min (±4:49); D: 8:59 min (±2:46)	C: Retakes: 2, time: 6.02 min (±2.01). D:Retakes: 7, time: 2.34 min (±1.02).	Intraoral digital X-ray examinations revealed precision in the bar-implant connection. All hybrids demonstrated precision and achieved 100% success.	X	X
Gherlone et al 2016	Hybrid (full arch)	Full arch	D: 7.57 min (±3.08); C: 18.23 min (±5.38)	D: retake 9, 1.02 min (±0.48); C: retake 3, 5.49 min (±1.24)	100% survival rate of implants and hybrids.	X	X
Ferrini et al 2018	3- or 4-unit FPD (immediate loading)	Quadrant (superior and inferior)	C: 6.41 min; D: 3.32 min	No retake needed for both techniques	Radiographic examination confirmed the accuracy of the prosthesis-implant connection. 100% implant survival rate.	X	X
Hashemi et al 2022	3-unit FPD	Full arch	C: 41.4 min; D: 43.3min	X	There was no statistically significant difference in passivity between digital and conventional techniques. There was also no significant difference in rotational displacement between the two impression techniques (P = 0.759).	X	VAS
Gintaute et al (a) 2022	3-unit FPD	Full arch	X	X	X	D: Preference in perceptions regarding overall convenience, unpleasant oral taste, and nausea sensation. C: 54.4 (±24.42); D: 80.75 (±16.35).	VAS (0-100)
Gintaute et al (b) 2022	3-unit FPD: Seven FPDs were evaluated in edentulous areas posterior to the remaining natural teeth, and three FPDs in edentulous spaces with two adjacent teeth.	Full arch	X	X	Based on the clinical adjustment duration in the present study, it can be concluded that all three workflows were successful. Average interproximal adjustment duration and occlusal changes in the pontic area: C: 2.59 (±2.51); D: 3.37 (±2.94).	X	X
Chochlidakis et al 2020	FPD	Full arch	X	x	The 3D accuracy of digital scans of full-arch implants falls within the previously reported clinically acceptable limit (up to 200 µm).	X	X
Derksen et al 2021 (b)	FDP	Full Arch	X	X	The average adjustment time: D: 6.92 min ± 10.84; C: 2.38 min ± 14.52.	X	X

FPD: fixed partial denture; VAS: visual analogue scale; C: conventional; D: digital; CI: confidence interval

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IMPRESSION TIME

The time analysis of single crown impression procedures was conducted in twelve studies,[22,26,31,32,33,43,44,46-49,51] while one study[27] evaluated the operator's perception of time. The average impression time was 13.47 minutes for digital impressions and 20.05 minutes for conventional impressions. Most studies,[26,31,32,33,43,44,47-49,51] reported a shorter time for digital impressions, except for two studies[22,46] that found shorter time for conventional impressions. For FPD impressions, in six studies, [19,29,30,45,46,52] the average time was 18.29 minutes for conventional impressions and 17.75 minutes for digital impressions. Three studies,[19,30,46] reported a shorter time for conventional impressions.

Regarding the meta-analysis, digital impressions presented a significantly shorter time than conventional impressions (P=.001; MD: -6.84; CI: -9.41 to -4.27; heterogeneity P<.001, I^2=97%). When considering the types of prostheses, this difference remained favorable for digital impressions (P =.001; MD: -7.16; CI: -10.21 to -4.10; heterogeneity P <.001; I^2 =98%). However, in the FPD analysis, there was no significant difference between the groups evaluated (P =.07; MD: -6.07; CI: -12.54 to 0.40; heterogeneity P <.001; I^2=96%) *(Figure 2)*.

ACCURACY

Among the studies that included patients with an implant-supported single crown, eleven studies,[20-23,26,27,31,32,44,50,51] evaluated their prosthetic outcomes using one of the following methods: adjustment, adjustment duration, marginal adaptation, instruments, or follow-up. These studies found similar results for both techniques.

For the studies evaluating FPD impressions, seven studies[24,28,29,30,34,45,52] assessed prosthetic outcomes using radiographs, adjustment duration, or image superimposition, also reporting similar results between techniques. A meta-analysis was performed using five included studies [21,22,24,28,34] to evaluate the adjustment duration between conventional and digital groups. The results showed a significant difference in favor of digital impressions compared to conventional impressions (P =.04; MD: -3.33; CI: -6.52 to -0.13; heterogeneity P < .001; I^2 =90%) *(Figure 3)*.

PATIENT PREFERENCE

Ten studies,[20,25-27,43,44,47-50] evaluated patients' preference for single crown impressions. In most studies, there was a preference for digital impressions.

For studies that evaluated FPD impressions, Gintaute *et al.*,[23] assessed patients' preference regarding the impression procedure. Their results revealed significant differences in patients' perceptions of general convenience, bad oral taste, and nausea, favoring digital techniques.

Wismeijer *et al.*,[46] evaluated prostheses fabricated using conventional and digital techniques for both single-unit and FPD prostheses. A preference for digital impressions was observed in five domains: preparation, taste, bite registration, scanning head, gag reflex, and general preference. However, regarding procedure time, participants preferred conventional impressions.

A meta-analysis including five studies[23,25,26,44,50] was performed to compare patients' preferences between groups. The analysis revealed that patients preferred digital impressions over conventional impressions (P =.003; MD: 19.02; CI: 6.36 to 31.68; heterogeneity P <.001; I^2 =95%) *(Figure 4)*.

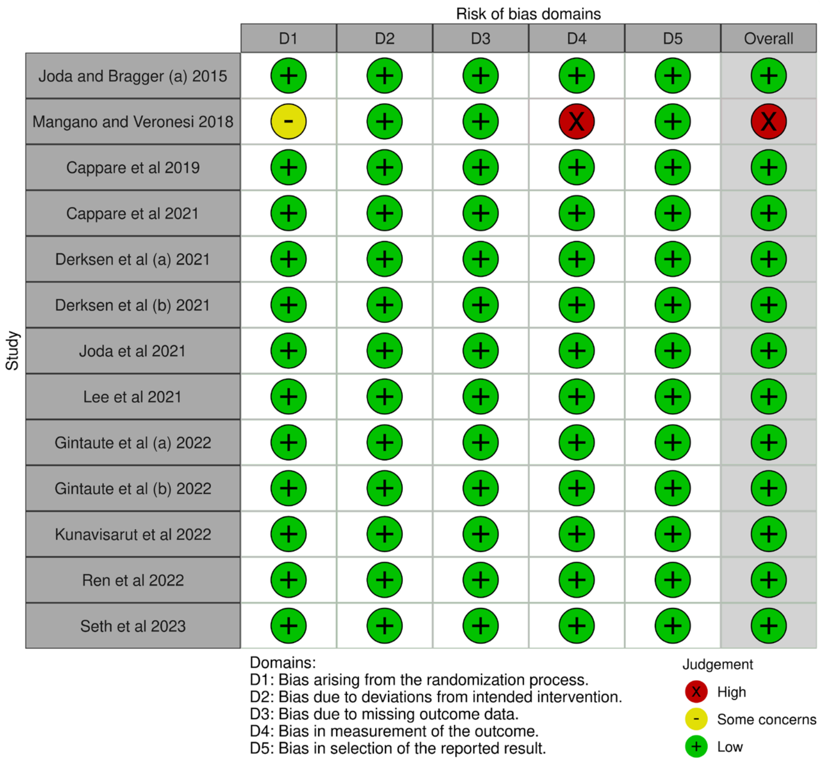

Figure 2: Assessment of risk of bias according to the RoB 2.0 tool.

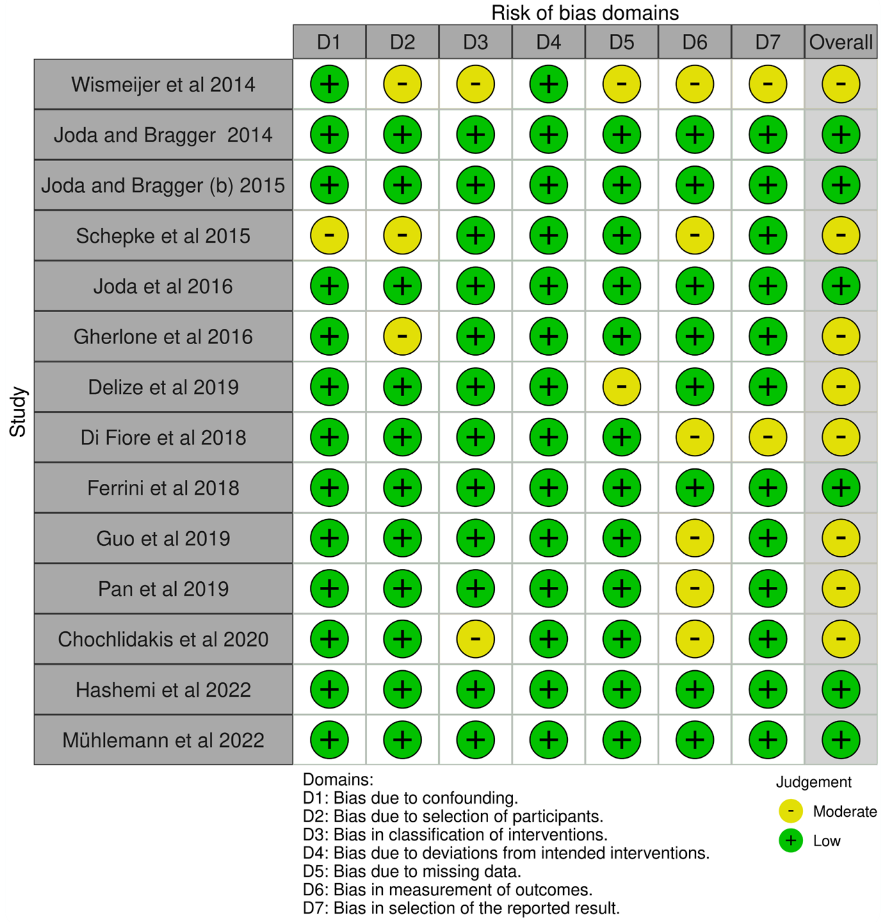

Figure 3: Assessment of risk of bias according to the ROBINS-I tool.

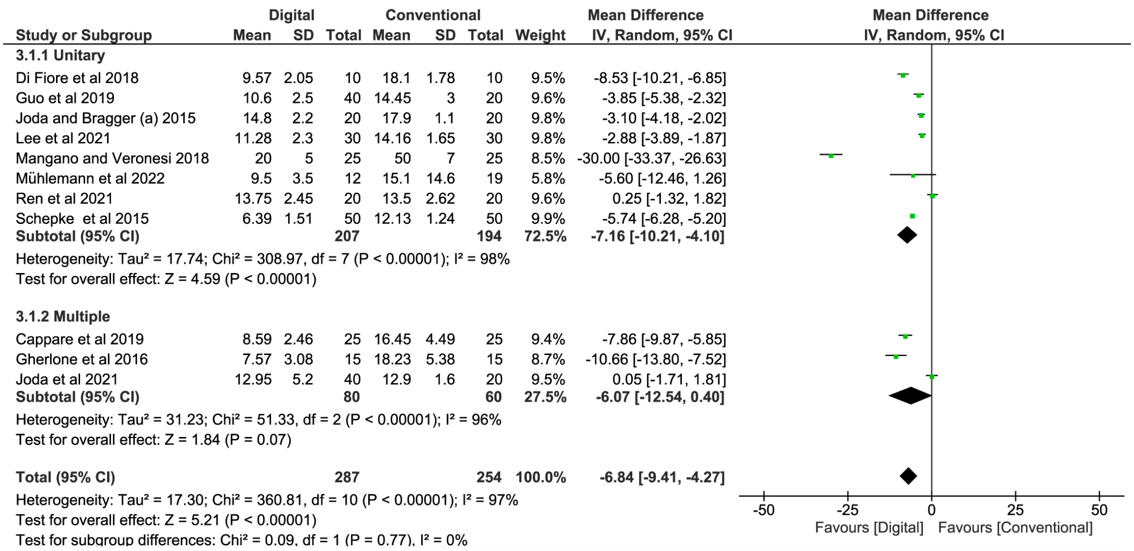

Figure 4: Forest plot for procedure duration analysis.

RISK OF BIAS AND CERTAINTY OF EVIDENCE

Randomized clinical trials were evaluated using the RoB 2.0 tool. One study,[26] presented an uncertain risk of bias in the randomization process and a high risk of bias in outcome measurement and overall risk. All other domains showed a low risk of bias for all studies *(Figure 5)*. Prospective studies were evaluated using the ROBINS-I tool. One study[47] presented a moderate risk of bias in the confounding domain. Three studies[46,47,52] were classified as having a moderate risk of bias in the study participant selection domain. Two studies[33,46] had a moderate risk of bias for the intervention classification domain. Two studies,[26,50] were classified as having a moderate bias due to missing data. Six studies[33,46,47,48,49,51] were assessed as having a moderate risk of bias in outcome measurement. Two studies[46,49] were assessed as having moderate risk of bias in outcome selection.

Eight studies[33,46-52] were considered to have moderate overall risk of bias. All other domains and studies were assessed as having low risk of bias *(Figure 6)*.

Certainty of evidence was considered as low for the outcomes: procedure time, patient preference, and precision, for both RCT and prospective studies, due to high heterogeneity and use of different instruments to assess the same outcome. The adjustment duration outcome was classified as having very low certainty of evidence, as results varied significantly across different operators, in addition to high heterogeneity *(Table 2)*.

DISCUSSION

SUMMARY OF FINDINGS

The study's null hypothesis, that there would be no differences in the effectiveness of digital scanning and conventional impressions, was rejected. Although accuracy did not differ between the evaluated methods, a shorter impression time and greater patient preference for the digital technique were observed.

Our results align with a previous review,[6] which indicated that IOS can reduce working time and improve subjective patient parameters. Based on the studies included, it was possible to assume that digital impressions improve the patient experience, causing less discomfort, anxiety, and nausea. The patient preference for the digital impression technique was corroborated by the meta-analysis, which showed a favorable result for digital impressions.

FACTORS INFLUENCING ACCURACY

The precision of both techniques was evaluated through image superimposition, radiographs, occlusal and interproximal contacts for single-unit and FPD crowns. Clinically acceptable precision was observed in both techniques, with similar success rates. Digital impressions are influenced by the scanning protocol, software model, and procedure steps, all of which affect accuracy. According to Flügge *et al.*,[53] evidence shows that the scanning protocol impacts the accuracy of digital scans. Additionally, factors like reflections, metallic restorations, excess saliva,[45] or hard-to-reach areas affect image quality.[54] On the other hand, conventional impression techniques can be affected by factors such as the impression technique itself, the quality and compatibility of the impression material, and the gypsum pouring technique.[55] Digital impressions prevent material deformation errors and gypsum pouring issues, ensuring better detail reproducibility and faster treatment. However, they may struggle to capture hard-to- reach areas and rely on calibration and operator expertise to prevent acquisition failures. Conversely, conventional impressions are subject to manual variations and dimensional changes in the material, which may impact the final accuracy of the rehabilitation.

In the last International Team for Implantology (ITI) consensus related to digital technologies in 2018,[56] the authors stated that intraoral digital impressions of implants in edentulous patients could not be recommended for routine clinical use. However, three studies[33,45,52] have since concluded that the digital workflows for fixed maxillary dentures may be clinically viable due to IOS advancements. Although there is no definitive evidence that IOS has been proven to be more accurate than conventional impression methods, current scientific data indicate a trend toward improved accuracy and clinically acceptable outcomes in the edentulous jaw region.[57]

CLINICAL IMPLICATIONS

The assessment of working time is an essential factor when comparing both techniques. Most of the included studies have shown that digital impressions can reduce working time,[29,26,31-33,43-45,47-49,51,52] which may influence patient preference. In contrast, one study,[46] reported that although digital impressions were perceived as more comfortable in several aspects, the

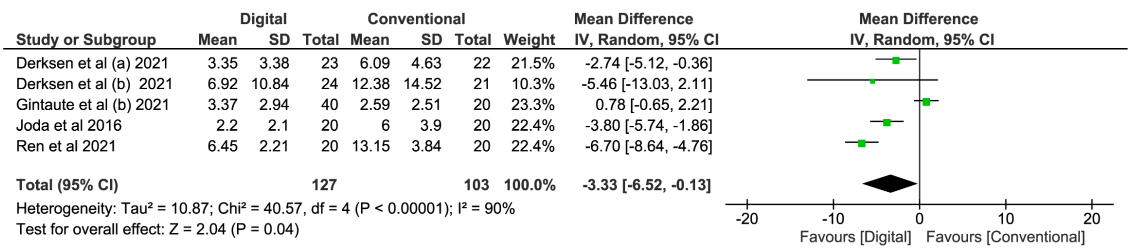

Figure 5: Forest plot for adjustment duration analysis.

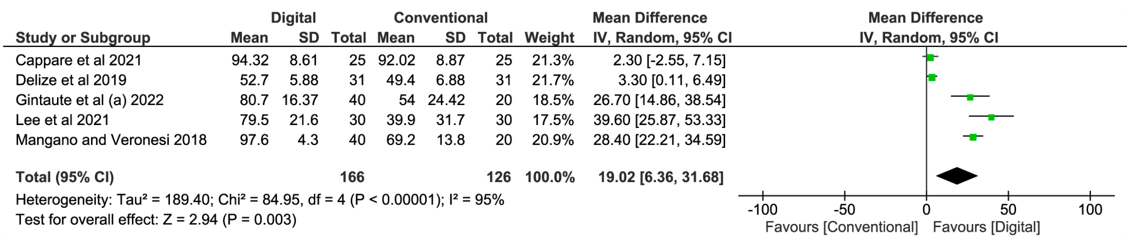

Figure 6: Forest graph for patients' preference analysis.

Table 2. Certainty of evidence.

Certainty assessment							
Number of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirect evidence**	**Imprecision**	**Other Considerations**	**Certainty**
Impression time							
6	randomized clinical trials	Not Serious	Serious[a]	Not Serious	Serious[b]	None	⊕⊕OO Low
11	observational study	Not Serious	Serious[a]	Not Serious	Serious[a]	None	⊕⊕OO Low
Patient preference							
5	observational study	Not Serious	Serious[c]	Not Serious	Serious[b]	None	⊕⊕OO Low
6	randomized clinical trials	Not Serious	Serious[a]	Serious	Serious[d,e]	None	⊕OOO Very low
Adjustment duration							
4	randomized clinical trials	Not Serious	Serious[a]	Serious	Serious[d,e]	None	⊕OOO Very low
2	observational study	Not Serious	Serious[a]	Serious	Serious[d,e]	None	⊕OOO Very low
Accuracy							
5	randomized clinical trials	Not Serious	Serious[a]	Not Serious	Serious[f]	None	⊕⊕OO Low
6	observational study	Not Serious	Serious[a]	Not Serious	Serious[f]	None	⊕⊕OO Low

[a]High heterogeneity between studies; [b]Large confidence interval; [c]Assessment of outcomes using different questionnaires; [d]Small number of patients; [e]The result may vary depending on who the operator is; [f]Assessment using different methods

total impression time was longer, negatively impacting patient perception. However, this difference may be attributed to study-specific factors. The authors highlighted technical difficulties during scanning, such as challenges in merging images when scanning multiple implants and difficulties in capturing the proximal areas of adjacent teeth.[46] The meta-analysis revealed that for single-crown impressions, the digital workflow resulted in significantly shorter working time compared to conventional impressions. However, in the FDP analysis, the difference was not statistically significant. This could likely be explained by the limited number of studies included in the FDP working time analysis (only three studies). Therefore, further research is recommended to better evaluate this effect in FDP prostheses. The reduction in time observed with the digital workflow can be attributed to the simplification of protocols,[43] such as eliminating the need for disinfection and the shipment of physical models to the laboratory.[9] Moreover, the digital technique allows for an immediate preview of the scanned area, enabling the rescanning of specific regions when necessary, without the need to repeat the entire impression procedure, as required in the conventional technique.[44]

Furthermore, rescanning time for digital impressions was evaluated. The digital technique had a shorter time for both single-unit and FPD crowns. According to Cappare *et al.*,[45] one advantage of digital impressions is the 3D preview, which allows for verification and correction, possibly explaining the shorter impression time observed.

When comparing digital and conventional impression techniques, adjustment duration must also be considered. The present study observed a shorter adjustment duration for crowns made using digital scanning, and the meta-analysis also favored the digital technique. However, these results must be interpreted with caution, as only a limited number of studies were included in the analysis.

Digital dentistry is becoming increasingly prevalent in daily clinical practice, though conventional methods are widely used. The choice between digital and conventional impressions for implant-supported rehabilitations did not influence accuracy or the success rate. However, digital impressions were preferred by patients and had a short impression time, allowing the technique to be selected based on dentist preference or patient acceptance.

LIMITATIONS AND FUTURE DIRECTIONS

The present study has some limitations, including the significant heterogeneity of the data, explained by the inclusion of different study designs. Methodological variations hinder standardization and result comparison. Among the studies evaluating subjective parameters, most did not use a standardized and validated questionnaire to assess patient preference. Furthermore, many studies were conducted by the same group of researchers, which may introduce bias. Other limitations include the inability to include all studies in the meta-analysis due to the lack of standardization in analysis method, use of different instruments to assess outcomes, which prevented subgroup analyses, and the reduced number of studies limited the interpretation of meta-analyses. The evaluated outcomes presented low or very low certainty of evidence. Future well-designed clinical studies are needed to reassess these findings.

CONCLUSION

Based on the results of this systematic review, the following conclusions were drawn. Both conventional and digital impression techniques demonstrate clinically acceptable precision for the fabrication of single and FPD crowns. However, the digital impression offers a shorter working time and is more favorably evaluated based on patient perception.

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Supplementary File 1: Search strategy.

Databases	Strategy
PubMed	#1 ((((((((((“Dental Implants”[Mesh])) OR (“Dental Implants”)) OR (“Dental Implant”)) OR (“Implant”)) OR (“Dental Implantation”)) OR (“Dental Implant Abutment Connection”)) OR (“Implant-supported Denture”)) OR (“Tooth Implantation”)) OR (“Dental Prosthesis, Implant-Supported”[Mesh])) OR (“Dental Prosthesis, Implant-Supported”)) OR (“Implant-Supported Dental Prosthesis”)) OR (“Implant-Supported Dental Prostheses”) #2 ((((((((((((“Digital Impression”) OR (“Intraoral Scanning”)) OR (“Intraoral Scanner”)) OR (“Intraoral Scan”)) OR (“Digital Implant Impression”)) OR (“Digital Impression”)) OR (“Digital Scan”)) OR (“Dental Scanner”)) OR (“Implant Impressions”)) OR (“Digital Techniques”)) OR (“Digital Dentistry”)) OR (“Scanner”)) OR (“Digital”)) OR (“Digital Workflow”) #3 ((((((((((((“Conventional Impression”) OR (“Analog Impression”)) OR (“Analog Technique”)) OR (“PVS impression”)) OR (“Implant Impression”)) OR (“Dental Impression Technique”[Mesh])) OR (“Dental Impression Technique”)) OR (“Impression”)) OR (“Conventional”)) OR (“Conventional Implant Impression”)) OR (“Conventional Impression”)) OR (“Traditional Impression”)) OR (“Dental Impression Materials”[Mesh])) OR (“Dental Impression Materials”) #4 ((((((((((((((((((((((((((((((“Precision”) OR (“Patient Satisfaction”[Mesh])) OR (“Patient Satisfaction”)) OR (“Patient Preference”)) OR (“Patient Perception”)) OR (“Patient Reported Outcome Measures”[Mesh])) OR (“Patient Reported Outcome Measures”)) OR (“Patient Reported Outcomes”)) OR (“Patient Reported Outcome”)) OR (“Patient-Reported Outcome”)) OR (“Patient-Reported Outcomes”)) OR (“Patient Outcome Assessment”[Mesh])) OR (“Patient Outcome Assessment”)) OR (“Patient Outcomes Assessment”)) OR (“Patient Outcome Assessments”)) OR (“Patient-Centered Outcome”)) OR (“Time efficiency”)) OR (“Operative Time”[Mesh])) OR (“Operative Time”)) OR (“Operative Times”)) OR (“Accuracy”) #5#1 AND #2 AND #3 AND #4
Web of Science	#1 ((((((((ALL=(“Dental Implants”)) OR ALL=(“Dental Implant”)) OR ALL=(“Implant”)) OR ALL=(“Dental Implantation”)) OR ALL=(“Dental Implant Abutment Connection”)) OR ALL=(“Implant-supported Denture”)) OR ALL=(“Tooth Implantation”)) OR ALL=(“Dental Prosthesis, Implant-Supported”)) OR ALL=(“Implant-Supported Dental Prosthesis”)) OR ALL=(“Implant-Supported Dental Prostheses”) #2 (((((((((((ALL=(“Digital Impression”)) OR ALL=(“Intraoral Scanning”)) OR ALL=(“Intraoral Scanner”)) OR ALL=(“Intraoral Scan”)) OR ALL=(“Digital Implant Impression”)) OR ALL=(“Digital Scan”)) OR ALL=(“Dental Scanner”)) OR ALL=(“Implant Impressions”)) OR ALL=(“Digital Techniques”)) OR ALL=(“Digital Dentistry”)) OR ALL=(“Scanner”)) OR ALL=(“Digital”)) OR ALL=(“Digital Workflow”) #3 (((((((ALL=(“Conventional Impression”)) OR ALL=(“Analog Impression”)) OR ALL=(“Analog Technique”)) OR ALL=(“PVS impression”)) OR ALL=(“Implant Impression”)) OR ALL=(“Dental Impression Technique”)) OR ALL=(“Impression”)) OR ALL=(“Conventional”)) OR ALL=(“Conventional Implant Impression”)) OR ALL=(“Conventional Impression”)) OR ALL=(“Traditional Impression”)) OR ALL=(“Dental Impression Materials”) OR ALL=(“Conventional Workflow”) #4 (((((((((((((((((((((((ALL=(“Precision”)) OR ALL=(“Patient Satisfaction”)) OR ALL=(“Patient Preference”)) OR ALL=(“Patient Perception”)) OR ALL=(“Patient Reported Outcome Measures”)) OR ALL=(“Patient Reported Outcomes”)) OR ALL=(“Patient Reported Outcome”)) OR ALL=(“Patient-Reported Outcome”)) OR ALL=(“Patient-Reported Outcomes”)) OR ALL=(“Patient Outcome Assessment”)) OR ALL=(“Patient Outcomes Assessment”)) OR ALL=(“Patient Outcome Assessments”)) OR ALL=(“Patient-Centered Outcome”)) OR ALL=(“Time efficiency”)) OR ALL=(“Operative Time”)) OR ALL=(“Operative Times”)) OR ALL=(“Accuracy”) #5 #1 AND #2 AND #3 AND #4
Scopus	#1 TITLE-ABS-KEY(“Dental Implants”) OR TITLE-ABS-KEY (“Dental Implant”) OR TITLE-ABS-KEY (“Dental Implantation”) OR TITLE-ABS-KEY(“Dental Implant Abutment Connection”) OR TITLE-ABS-KEY (“Implant-supported Denture”) OR TITLE-ABS-KEY(“Tooth Implantation”) OR TITLE-ABS-KEY (“Dental Prosthesis, Implant-Supported”) OR TITLE-ABS-KEY (“Implant-Supported Dental Prosthesis”) OR TITLE-ABS-KEY(“Implant-Supported Dental Prostheses”) # 2 TITLE-ABS-KEY (“Digital Impression”) OR TITLE-ABS-KEY (“Intraoral Scanning” “Intraoral Scanner”) OR TITLE-ABS-KEY (“Intraoral Scan”) OR TITLE-ABS-KEY (“Digital Implant Impression”) OR TITLE-ABS-KEY (“Digital Impression”) OR TITLE-ABS-KEY (“Digital Scan”) OR TITLE-ABS-KEY (“Dental Scanner”) OR TITLE-ABS-KEY (“Implant Impressions”) OR TITLE-ABS-KEY (“Digital Techniques”) OR TITLE-ABS-KEY (“Digital Dentistry” “Scanner”) OR TITLE-ABS-KEY (“Digital”) OR TITLE-ABS-KEY (“Digital Workflow”) #3 TITLE-ABS-KEY (“Conventional Impression”) OR TITLE-ABS-KEY (“Analog Impression”) OR TITLE-ABS-KEY (“Analog Technique”) OR TITLE-ABS-KEY (“PVS impression”) OR TITLE-ABS-KEY (“Implant Impression”) OR TITLE-ABS-KEY (“Dental Impression Technique”) OR TITLE-ABS-KEY (“Impression”) OR TITLE-ABS-KEY (“Conventional”) OR TITLE-ABS-KEY (“Conventional Implant Impression”) OR TITLE-ABS-KEY (“Conventional Impression”) OR TITLE-ABS-KEY (“Traditional Impression”) OR TITLE-ABS-KEY (“Dental Impression Materials”) OR TITLE-ABS-KEY (“Conventional Workflow”) #4 TITLE-ABS-KEY (“Precision”) OR TITLE-ABS-KEY (“Patient Satisfaction”) OR TITLE-ABS-KEY (“Patient Preference”) OR TITLE-ABS-KEY (“Patient Perception”) OR TITLE-ABS-KEY (“Patient Reported Outcome Measures”) OR TITLE-ABS-KEY (“Patient Reported Outcomes”) OR TITLE-ABS-KEY (“Patient Reported Outcome”) OR TITLE-ABS-KEY (“Patient-Reported Outcome”) OR TITLE-ABS-KEY (“Patient-Reported Outcomes”) OR TITLE-ABS-KEY (“Patient Outcome Assessment”) OR TITLE-ABS-KEY (“Patient Outcomes Assessment”) OR TITLE-ABS-KEY (“Patient Outcome Assessments”) OR TITLE-ABS-KEY (“Patient-Centered Outcome”) OR TITLE-ABS-KEY (“Time efficiency”) OR TITLE-ABS-KEY (“Operative Time”) OR TITLE-ABS-KEY (“Operative Times”) OR TITLE-ABS-KEY (“Accuracy”) #5 #1 AND #2 AND #3 AND #4
Embase	#1 ‘dental implants’:ab OR ‘dental implant’:ab OR ‘implant’:ab OR ‘dental implantation’:ab OR ‘dental implant abutment connection’:ab OR ‘implant-supported denture’:ab OR ‘tooth implantation’:ab OR ‘dental prosthesis, implant-supported’:ab OR ‘implant-supported dental prosthesis’:ab OR ‘implant-supported dental prostheses’:ab #2 ‘intraoral scanning’:ab OR ‘intraoral scanner’:ab OR ‘intraoral scan’:ab OR ‘digital implant impression’:ab OR ‘digital impression’:ab OR ‘digital scan’:ab OR ‘dental scanner’:ab OR ‘implant impressions’:ab OR ‘digital techniques’:ab OR ‘digital dentistry’:ab OR ‘scanner’:ab OR ‘digital’:ab OR ‘digital workflow’:ab #3 (‘conventional impression’:ab OR ‘analog impression’:ab OR ‘analog technique’:ab OR ‘pvs impression’:ab) AND ‘implant impression’:ab OR ‘dental impression technique’:ab OR ‘impression’:ab OR ‘conventional’:ab OR ‘conventional implant impression’:ab OR ‘conventional impression’:ab OR ‘traditional impression’:ab OR ‘dental impression materials’:ab OR ‘conventional workflow’:ab #4 ‘patient satisfaction’:ab OR ‘patient preference’:ab OR ‘patient perception’:ab OR ‘patient reported outcome measures’:ab OR ‘patient reported outcomes’:ab OR ‘patient reported outcome’:ab OR ‘patient-reported outcome’:ab OR ‘patient-reported outcomes’:ab OR ‘patient outcome assessment’:ab OR ‘patient outcomes assessment’:ab OR ‘patient outcome assessments’:ab OR ‘patient-centered outcome’:ab OR ‘time efficiency’:ab OR ‘operative time’:ab OR ‘operative times’:ab OR ‘accuracy’:ab OR ‘operation duration’:ab #5 #1 AND #2 AND #3 AND #4
ProQuest	#1 noft(“Dental Implants” OR “Dental Implant” OR “Implant” OR “Dental Implantation” OR “Dental Implant Abutment Connection” OR “Implant-supported Denture” OR “Tooth Implantation” OR “Dental Prosthesis, Implant-Supported” OR “Implant-Supported Dental Prosthesis” OR “Implant-Supported Dental Prostheses”) #2 noft(“Digital Impression” OR “Intraoral Scanning” OR “Intraoral Scanner” OR “Intraoral Scan” OR “Digital Implant Impression” OR “Digital Impression” OR “Digital Scan” OR “Dental Scanner” OR “Implant Impressions” OR “Digital Techniques” OR “Digital Dentistry” OR “Scanner” OR “Digital” OR “Digital Workflow”) #3 noft(“Conventional Impression” OR “Analog Impression” OR “Analog Technique” OR “PVS impression” OR “Implant Impression” OR “Dental Impression Technique” OR “Impression” OR “Conventional” OR “Conventional Implant Impression” OR “Conventional Impression” OR “Traditional Impression” OR “Dental Impression Materials” OR “Conventional Workflow”) #4 noft(“Precision” OR “Patient Satisfaction” OR “Patient Preference” OR “Patient Perception” OR “Patient Reported Outcome Measures” OR “Patient Reported Outcomes” OR “Patient Reported Outcome” OR “Patient-Reported Outcome” OR “Patient-Reported Outcomes” OR “Patient Outcome Assessment” OR “Patient Outcomes Assessment” OR “Patient Outcome Assessments” OR “Patient-Centered Outcome” OR “Time efficiency” OR “Operative Time” OR “Operative Times” OR “Accuracy” OR “Operation Duration”) #5 #1 AND #2 AND #3 AND #4

Supplementary File 2. Excluded studies.

Author/Year	DOI	Title	Justificative
Alibrahin and Aslan 2020	10.33808/clinexphealthsci.675276	Comparison of the Accuracy and Time Efficiency of Two Different digital Impressions of Single Tooth Implant Treatments	Type of study (cross-sectional)
De Angelis et al. 2020	10.3390/ma13122781	Patient and Operator Centered Outcomes in Implant Dentistry: Comparison between Fully Digital and Conventional Workflow for Single Crown and Three-Unit Fixed-Bridge	Type of study (retrospective)
Gjelvold et al. 2015	10.1111/jopr.12410	Intraoral Digital Impression Technique Compared to Conventional Impression Technique. A Randomized Clinical Trial	Evaluated conventional and implant-supported fixed prostheses
Hanozin et al. 2022	10.1186/s40729-022-00406-6	Digital vs. conventional workflow for one-abutment one-time immediate restoration in the esthetic zone: a randomized controlled trial	Did not evaluate any of the study outcomes
Joda et al. 2016	10.1111/clr.12982	Time efficiency, difficulty, and operator's preference comparing digital and conventional implant impressions: A randomized controlled trial	Type of study (Impressions made on typodonts)
Karasan et al. 2023	10.1016/j.jdent.2022.104365	Occlusal adjustment of 3-unit tooth-supported fixed dental prostheses fabricated with complete-digital and -analog workflows: A crossover clinical trial	Evaluated tooth supported FPD
Liu et al. 2021	10.3290/j.cjdr.b2440831	Time Efficiency of Immediate Loading of Full-arch Implant Reconstructions Using Prefabricated Prostheses Located by an Anchor Pin: a Pilot Study.	Type of study (pilot study)
Neha et al. 2021	ISSN2515-8260	Evaluating accuracy of digital impressions and conventional impression in implant placement	Number of patients (less than ten patients evaluated)
Pennarocha et al. 2017	10.1016/j.prosdent.2016.12.015	A combined digital and stereophotogrammetric technique for rehabilitation with immediate loading of complete-arch, implant-supported prostheses: A randomized controlled pilot clinical trial	Type of study (pilot study)
Pereira et al. 2022	10.4047/jap.2022.14.4.212	Conventional and digital impressions for complete-arch implant-supported fixed prostheses: time, implant quantity effect and patient satisfaction	Type of study (cross-sectional)
Rattapanich et al. 2019	10.3390/jcm8050622	Comparative Study Between an Immediate Loading Protocol Using the Digital Workflow and a Conventional Protocol for Dental Implant Treatment: A Randomized Clinical Trial	Did not evaluate any of the study outcomes.
Sakornwimon and Leevailoj 2016	10.1016/j.prosdent.2016.10.019	Clinical marginal fit of zirconia crowns and patients' preferences for impression techniques using intraoral digital scanner versus polyvinyl siloxane material	Evaluated tooth-supported FPD
Zeltner et al. 2016	10.1016/j.prosdent.2016.04.028	Randomized controlled within-subject evaluation of digital and conventional workflows for the fabrication of lithium disilicate single crowns. Part III: marginal and internal fit	Evaluated tooth-supported FPD
Alsharbaty et al 2019	10.1111/jopr.12764	A Clinical Comparative Study of 3-Dimensional Accuracy between Digital and Conventional Implant Impression Techniques	Type of study (cross-sectional)
Rutkunas et al 2020	10.1922/EJPRD_02028Rutkunas09	Comparison of the Clinical Accuracy of Digital and Conventional Dental Implant Impressions.	Type of study (cross-sectional)

Supplementary File 3. Descriptive results of included studies.

Author/Year	Type of crown	Type of study	# of patients / (# of impressions)	Gender and proportion (%)	Treated area	Implant brand	Conventional impression technique	Material used	Scanner brand
Wismeijer et al 2014	Single crown and 3-unit FPD	Prospective	30/ (D: 30; C: 30)	x	Posterior Maxilla or Mandible	Straumann	Open tray	Impregum (3M Espe)	Cadent Itero (AlingTechnology Inn)
Schepke et al 2015	Single crown	Prospective	50/ (D: 50; C: 50)	66% F, 34% M	Pre-molar Maxilla or Mandible	Astra OsseoSpeed TX (Dentsply Implants)	Closed tray	Impregum (3M Espe)	Cerec Omnicam (Sirona)
Joda e Bragger (a)* 2015**	Single crown	RCT	20/ (D: 20; C: 20)	47% F, 52% M	Posterior	Straumann TL RN/WN, (Institut Straumann AG)	Open tray	Impregum Penta (3M Espe)	iTero (Align Tech Inc.)
Guo et al 2019	Single crown	Prospective	20/ (D: 40, C: 20)	55% F, 45% M	Posterior	x	Closed tray	Impregum Penta (3M Espe)	Trios 1 (3 Shape Trios)
Di Fiore et al 2018	Single crown	Prospective	10/ (D: 10; C: 10)	x	Posterior	x	Open tray	Impregnum, (3M Espe)	CEREC Omnicam; (Sirona)
Lee et al 2021	Single crown	RCT	30/ (D: 30; C: 30)	50% F, 50% M	Posterior Maxilla or Mandible	Straumann	Closed tray	PVS Aquasil Ultra Monophase Light Viscosity (Dentsply Sirona)	iTero Element (Align Technology Inc)
Delize et al 2019	Single crown	Prospective	31/ (D: 31; C: 31)	X	Posterior Maxilla	M-center (MIS Implants Technologies)	Closed tray	Imprint 4 (3M)	TRIOS Second generation (3Shape)
Pan et al 2019**	Single crown	Prospective	40/ (D: 20; C: 20)	52.5% F, 47.5% M	Posterior Maxilla or Mandible	Straumann Bone, (Institut Straumann AG) or Straumann Tissue level, (Institut Straumann AG)	Closed tray	Impregum Penta (3M Espe)	Trios 3 (3Shape)
Kunavisarut et al 2022	Single crown	RCT	40 / (D: 20; C: 20)	60% F, 40% M	Posterior Maxilla or Mandible	LS2, N!CE (Institut Straumann AG) or PICN, Enamic (Vita)	Closed tray	Impregum Penta, (3 M Espe)	TRIOS3 (3Shape)
Derksen et al 2021	Single crown	RCT	32 / (D: 23; C: 22)	x	Posterior	Straumann	Open tray	Impregum (3M Penta)	True Definition Scanner (3M)
Ren et al 2021	Single crown	RCT	40 / (D: 20; C: 20)	50% F, 50% M	Posterior	Camlog Screw Line (Camlog Biotechnologies GmbH)	Closed tray	VPS	TRIOS Color (3Shape)
Joda e Bragger *(b) 2015**	Single crown	Prospective	20 / (D: 20; C: 20)	47.4% F, 52.6% M	Posterior (pre-molar or molar)	Straumann	x	Impregum Penta (3M Espe)	iTero Scanner (Align Tech Inc)
Mühlemann et al 2022	Single crown	Prospective	31/ (D: 12; C: 19)	x	Posterior	ASTRA TECH OsseoSpeed EV (Dentsply Sirona)	Open tray	Permadyne (3M)	TRIOS 3 (3Shape)
Cappare et al 2021	Single crown	RCT	50/ (C:25; D: 25)	62% F, 38% M	Esthetic area (2nd pre-molar to 2nd pre-molar)	CSR (System, Sweden & Martina)	Open tray	Impregum Penta (3M ESPE)	Cerec Omnicam, (Dentsply Sirona)
Mangano and Veronesi 2018	Single crown	RCT	50 / (D: 25; C: 25)	56% F, 44% M	Posterior Maxilla or Mandible	Exacone, (Leone Implants)	Closed tray	PVS Elite HDPlus (Zhermack)	CS 3600, (Carestream Dental)
Seth et 2023	Single crown	RCT	40 / (D: 40; C: 40)	45% F, 55% M	Anterior and posterior Maxilla or Mandible	Astra Tech Implant System, EV (Dentsply Sirona)	Closed tray	Impregum (3M Espe)	CEREC Omnicam (Dentsply Sirona)
Joda and Bragger 2014	Single crown	Prospective	20/(D:20; C:20)	47.4% F; 52.6%	Posterior (pre-molar or molar)	Straumann	X	X	iTero Scanner (Align Tech Inc)
Joda et al 2016	Single crown	Prospective	20/(D:20; C:20)	47.4% F; 52.6%	Posterior (pre-molar or molar)	Straumann	X	X	iTero Scanner (Align Tech Inc)
Joda et al 2021	FPD	RCT	20 / (C: 20; D: 40)/	55% F, 45% M	Posterior Maxilla or Mandible	VITA YZ ST (Super Translucent Multicolor)	Open tray	Impregum, (3M Espe,)	TRIOS 3 (3Shape) and Virtuo Vivo (Straumann)
Cappare et al 2019	Hybrid (full arch)	RCT	50/ (D: 25; C: 25)	X	Maxilla	CSR implant system (Sweden & Martina)	Conventional impression	Plaster (Éclair Classe II, Ultima)	CS 3600, (Carestream Dental LLC)
Gherlone et al 2016	Hybrid (full arch)	Prospective	25/ (D: 15; C: 15)	60% F, 40% M	Maxilla e Mandible	X	X	Permadyne (Espe)	TRIOS (3Shape)
Ferrini et al 2018	3- or 4-unit FPD (immediate loading)	Prospective	24/ (D: 12; C: 12)	37.5% F, 62.5% M	Posterior Maxilla	Winsix, (Biosafin)	Conventional impression at implant level	Permadyne, (Espe)	3MTM True Definition Scanner (3M)
Hashemi et al 2022	3-unit FPD	Prospective	10 (C: 10; D: 10)	70% F, 30% M	Posterior Mandible	Dentium Co.	Open tray	VPS (Panasil, Kettenbach GmbH & Co.)	TRIOS 3 (3Shape)
Gintaute et al* (a) 2022	3-unit FPD	RCT	20/ (C: 20; D: 40)	55% F, 45% M	Posterior	Tissue Level Implant System RN/ WN (Institut Straumann AG)	X	Polyether	Trios 3 (3Shape), and Virtuo Vivo (Straumann)
Gintaute et al* (b) 2022	3-unit FPD	RCT	20/ (C: 20; D: 40)	55% F, 45% M	Posterior	Tissue Level Implant System RN/ WN (Institut Straumann AG)	Open tray	Impregum, (3M ESPE)	Trios 3 (3Shape), and Virtuo Vivo (Straumann)
Chochlidakis et al 2020	FPD	Prospective	16/(C: 16;D:16)	X	Maxilla	BLT, Roxolid, SLActive, (Institute Straumann AG)	Open tray	VPS (3M)	True Definition(3M)
Derksen et al 2021	FPD	RCT	38/(C:21; D:24)	X	Posterior	Straumann	Open tray	polyether	True Definition(3M)

FPD: fixed partial denture; C: Conventional, D: Digital; F: Female, M: Male; VPS: polylsiloxane; * same sample different outcomes; ** sample of 40 patients; however, only 20 were included in the analysis; the other 20 are in the article by Guo et al. 2019, * same sample.**