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SYSTEMATIC REVIEW

Digital Versus Conventional Impression Techniques in Children: A Systematic Review and Meta-Analysis of Efficiency, Comfort and Patient Preference

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ABSTRACT

Background: Conventional alginate impressions are widely used in paediatric dentistry but present several limitations. Digital intraoral scanning has emerged as a promising alternative, potentially improving patient experience and clinical efficiency.

Aim: Evaluate whether digital intraoral impressions differ from conventional alginate impressions in efficiency, comfort and acceptance among paediatric patients.

Design: Systematic review and meta-analysis following PRISMA 2020. PubMed, Scopus, Web of Science and SIGLE were searched to February 2025. Eligible studies enrolled children receiving both digital and conventional full-arch impressions. Risk of bias was assessed with Cochrane RoB-1, and data pooled using random-effects models.

Results: Seven studies with 337 children were included. Digital impressions were faster than conventional (mean difference 165.48 s; 95% CI 157.74–173.21; $p < 0.00001$). Patient-reported outcomes also favoured digital scanning: lower pain (MD 13.03 mm), greater comfort (MD −34.02 mm) and less breathing difficulty (MD 32.51 mm) and gag reflex (MD 38.07 mm), all $p < 0.00001$. Children were over four times likelier to prefer digital scanning (RR 4.28; 95% CI 1.47–12.44; $p = 0.008$). Heterogeneity was high but directionally consistent.

Conclusions: Digital intraoral scanning is faster, more comfortable and better accepted than conventional impressions, supporting wider use in paediatric dentistry.

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1 | Introduction

At the end of the eighties, the first chairside computer-assisted design and computer-assisted manufacturing (CAD/CAM) system became commercially available, providing dental professionals with a new way to design and create restorations directly in the clinic [1]. Since then, digital technologies have significantly transformed dental practices, impacting everything from diagnosis to treatment planning and even communication between dental teams and patients [2]. Nevertheless, the integration of digital tools into everyday dental practice remains a work in progress. A recent survey revealed that only 50% of dentists in

Summary

- Why this paper is important to paediatric dentists
  - Digital dentistry is increasingly present in paediatric care, and this review evaluates its impact at the very first clinical step: impression taking.
  - Understanding whether digital impressions are more comfortable and better tolerated by children helps paediatric dentists tailor their workflow to improve cooperation.
  - Identifying which technique is more time-efficient allows clinicians to optimise appointment scheduling and reduce chairside time.
  - This review highlights how gag reflex, breathing difficulty and pain influence impression tolerance—key aspects for behavioural management strategies.
  - As intraoral scanning becomes more widespread, this paper provides timely, evidence-based insight into its advantages in paediatric settings.

North America routinely use dental scanners, with even lower adoption rates in northern Europe (35%) and other regions of the world (under 15%) [3].

Paediatric dentistry has not been immune to the impact of digital technologies, but the extent of their implementation in this field is still unclear. Unlike other dental specialties defined by specific conditions, paediatric dentistry focuses on the dental care of children and adolescents, addressing a wide variety of clinical situations related to growing patients. This characteristic, often referred to as the 'transversal' nature of paediatric dentistry, can affect how and to what extent digital tools are incorporated into everyday paediatric dental care [4].

Moreover, due to the unique behavioural and emotional characteristics of children, the outcome of dental procedures is not determined solely by the clinical technique used, but also by the practitioner's ability to ensure effective behavioural management [5]. A child's response is influenced not only by fear or anxiety, but also by the physical comfort of the procedure, which may shape their attitude toward future dental treatments.

Within digital dentistry, imaging—and particularly intraoral scanning—plays a pivotal role in initiating the digital workflow. Without the digitisation of patient records, the process cannot begin. Errors at this early stage may lead to cumulative inaccuracies throughout the workflow. However, when properly implemented, a digital workflow can greatly enhance efficiency, reduce clinical time and improve overall accuracy [6].

The accuracy and reliability of digital impressions are well documented, with numerous studies showing that the precision of digital and conventional methods is largely comparable, and differences, when present, are usually clinically insignificant [7]. Comparative studies evaluating comfort, preference and time have primarily focused on adult or young adult populations. Although some research includes adolescents and young adolescents [8], very few have assessed comfort specifically in children, and most involve small sample sizes [9–11]. These limitations may explain the divergent findings reported across studies. For these reasons, we decided to perform a systematic review to synthesise the existing evidence comparing digital and conventional impression techniques in paediatric patients.

The aims of this systematic review are defined by the following PICO question: in paediatric patients undergoing the full arch-impression taking process (P), is there any difference between digital impressions using intraoral scanners (I), compared to conventional alginate impression techniques (C), in terms of time, comfort and patient perceptions (O)?

2 | Materials and Methods

This systematic review and meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [12].

2.1 | Eligibility Criteria

The inclusion and exclusion criteria were defined according to the previously formulated PICO question.

2.1.1 | Inclusion Criteria

Controlled Clinical Trials (CCTs), Randomised Clinical Trials (RCTs) and observational studies (both retrospective and prospective); published or in press; written in English; involving paediatric patients who underwent a full-arch impression procedure using both conventional alginate and digital intraoral scanner techniques. Studies were required to report at least one of the following outcome variables: comfort, gag reflex, pain, breathing difficulty, thermal sensitivity (hot/cold) or impression-taking time.

2.1.2 | Exclusion Criteria

Studies including adult patients or patients with congenital craniofacial anomalies (e.g., cleft palate); narrative or systematic reviews; case reports; case series; and animal studies.

2.2 | Information Sources

An electronic search was conducted in the following databases: PubMed, Scopus, Web of Science and the System for Information on Grey Literature in Europe (SIGLE). The initial search was performed in June 2024 and updated in February 2025. No restrictions were applied regarding publication date; however, the search was limited to articles published in English, Spanish or Italian.

2.3 | Search Strategy

The search was performed using the advanced PubMed search tool with a combination of the following keywords, MeSH

(Medical Subject Headings), non-indexed terms and the corresponding Boolean operators:

(conventional OR alginate impression) AND (digital impression OR intraoral digital impression OR intraoral scanning OR intraoral scanner OR intraoral digital scanner OR IOS) AND (children [MeSH] OR adolescent [MeSH] OR young adult [MeSH]) AND (comfort [MeSH] OR discomfort OR gagging [MeSH] OR pain OR time [MeSH] OR efficiency [MeSH] OR comparison)

In all other databases, an advanced search was performed with the same combination of keywords, MeSH terms and free search terms. Additionally, a manual search was conducted on the references of the selected articles to identify further relevant studies not retrieved by the initial search. When necessary, corresponding authors were contacted by e-mail to request missing information.

2.4 | Study Selection

Two authors (D.G. and M.A.) simultaneously and independently conducted the search process, following PRISMA 2020 guidelines. Initially, titles and abstracts of the retrieved articles were screened to identify potentially eligible studies. Subsequently, the same reviewers assessed the full texts according to the predefined inclusion and exclusion criteria. In cases of disagreement, a third reviewer (R.A.) was consulted to reach consensus.

2.5 | Data Collection Process

One reviewer extracted the data from the selected articles and entered them into an Excel spreadsheet (Microsoft Office for Windows, 2023), structured according to the Cochrane Consumers and Communication Review Group's data extraction format. A second author independently reviewed the extracted data, and any discrepancies were resolved through consensus. During this stage, no authors were contacted, as all relevant numerical data were available in the published documents.

2.6 | Data Items

The following data were extracted: (a) Name of the authors; (b) year of publication; (c) study type; (d) sample size; (e) sex of the participants; (f) mean age and SD if available; (g) treatment procedure; (h) outcome variables analyzed; (i) measurement method of the variable; and (j) conclusions. When the same outcome variables were reported by at least two studies, data were quantitatively synthesised. Otherwise, results were just reported in the narrative synthesis. The following variables were considered for the quantitative evaluation: (a) time employed for the administration of alginate or digital impression taking; (b) comfort related to the procedure; (c) pain; (d) breathing difficulties; and (e) gag reflex.

For the outcome 'time', we extracted total chairside treatment time. When studies reported stepwise measures (e.g., tray selection, upper, lower, bite registration), we summed the reported intervals to obtain a total value. When only a total procedure time was available, that figure was used directly. For example, Glisic [13] included mixing, impression taking and retakes, while Aiuto [14] reported separate stepwise times which we aggregated. This harmonisation enabled comparison across studies.

2.7 | Quality Assessment

The quality assessment of the included studies was performed independently by two reviewers (D.G. and M.A.), and if necessary, any disagreements were discussed and resolved by consensus. Quality assessment was performed using the Cochrane Risk of Bias 1 tool (RoB-1) since all included studies were cross-over studies, a specific type of RCT in which all participants receive both interventions, but the order is randomised (Higgins et al. [15]). The tool assesses the following elements: (1) random sequence generation, (2) allocation concealment; (3) blinding of participants and personnel; (4) blinding of outcome assessment; (5) incomplete outcome data; (6) selective reporting bias; and (7) other bias. Every single item can be considered as having a low risk, unclear, high risk or no information.

2.8 | Statistical Analysis

Meta-analyses were performed using Review Manager (RevMan) version 5.4 following the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions [16]. For continuous outcomes—procedure time, comfort, breathing difficulty and gag reflex—means and standard deviations were extracted and pooled as mean differences (MDs) with 95% confidence intervals (CIs). Statistical significance was set at $p < 0.05$. Heterogeneity was assessed with the Cochran Q (Chi^2) test and quantified with the I^2 statistic. As I^2 exceeded 50%, a random-effects model was applied to all syntheses of continuous data.

Patient preference, a dichotomous outcome, was analysed by recording the number of participants who favoured digital scanning versus conventional impressions and computing risk ratios (RRs) with 95% CIs using the inverse-variance method. Studies were pooled with the DerSimonian–Laird random-effects model due to the observed heterogeneity ($\mathrm{Tau}^2 = 1.20$; $I^2 = 90\%$). The overall effect was tested using the Z statistic ($p < 0.05$), and Tau^2, Chi^2 and I^2 values were reported to describe heterogeneity.

3 | Results

A total of 580 records were retrieved through database searching, with one additional study identified through manual and grey literature search. After removing duplicates, 369 records remained and were screened by title and abstract. Thirteen full-text articles were assessed for eligibility, of which six were excluded: four for including adult participants, one review article and one that did not compare both impression

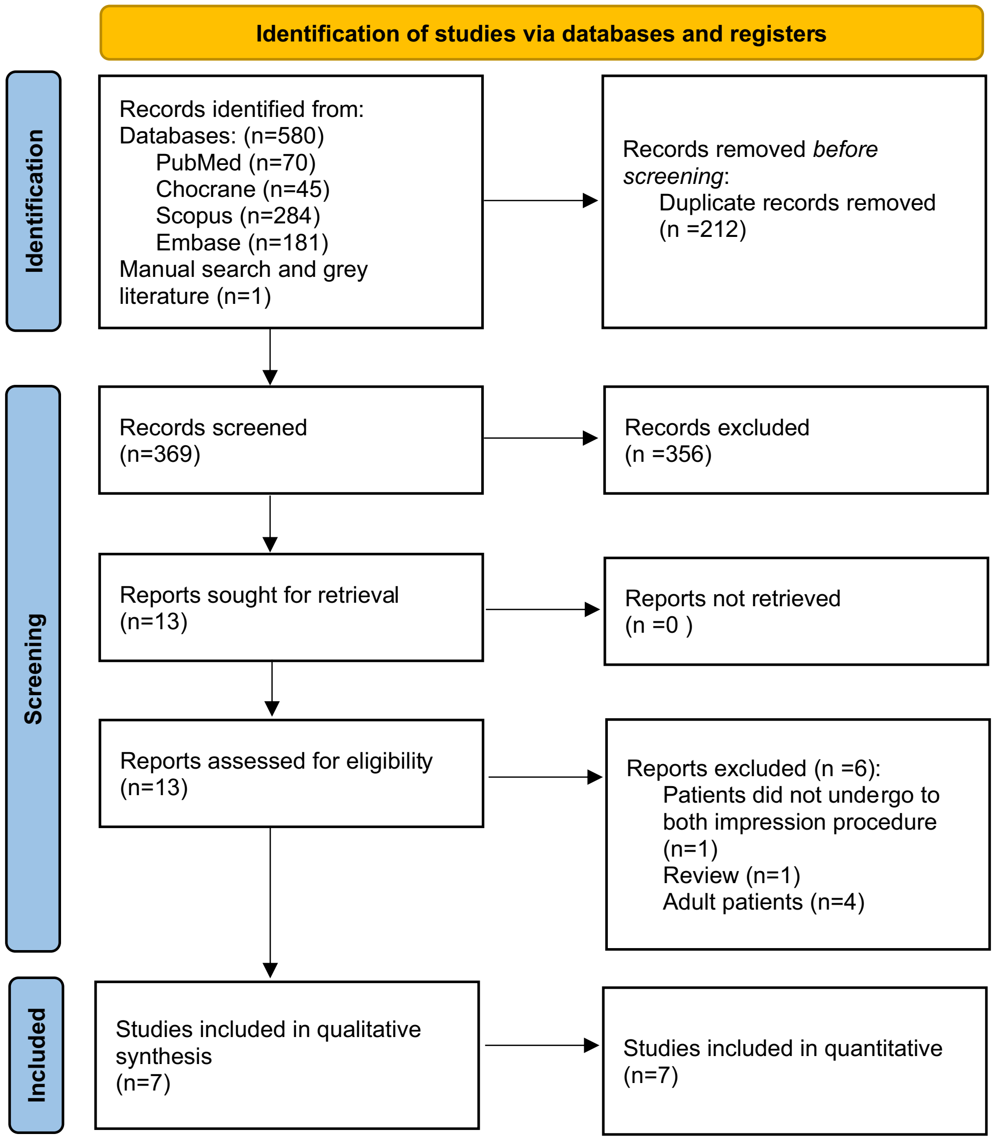

FIGURE 1 | PRISMA flow diagram showing the study selection process, from 580 records identified to seven studies included in the final quantitative synthesis. *Source:* Page et al. [12].

techniques. Seven studies met all inclusion criteria and were included in both qualitative and quantitative synthesis. The selection process is summarised in the PRISMA flow diagram (Figure 1).

The seven included studies were published between 2016 and 2025. Two were randomised controlled trials, and five were crossover studies. All included studies compared conventional alginate impressions with intraoral scanning procedures in paediatric patients. The main characteristics of each study are summarised in Table 1. The outcomes analysed included the time employed to perform the procedure, comfort, breathing difficulty, gag reflex and patient preference.

3.1 | Time Efficiency

Four of the seven included studies assessed the duration of the impression procedure, comparing the time required for conventional alginate impressions and intraoral digital scanning (Figure 2). The meta-analysis demonstrated that digital impressions were significantly faster than conventional ones. The pooled mean difference was 165.48 s in favour of the digital method (95% CI: 157.74 to 173.21, $p < 0.00001$), indicating that, on average, digital impressions took approximately 2.75 min less to perform. Heterogeneity was high ($I^2 = 98\%$).

3.2 | Patient Reported Pain

Reported Pain was assessed in three of the included studies, using 0–100 mm visual-analogue scales (VAS), completed immediately after each technique (Figure 3). A random-effects model was used due to substantial heterogeneity ($\text{Chi}^2 = 15.83$, $df = 2$, $p = 0.0004$; $I^2 = 87\%$). Digital scanning produced significantly lower pain scores, with a pooled mean difference of 13.03 mm in favour of the digital method (95% CI 8.62 to 17.44; $Z = 5.79$, $p < 0.00001$). Despite variation in effect size, all studies pointed

TABLE 1 | Main characteristics of the studies included in the qualitative and quantitative synthesis.

Author (year)	Country	Study design	Intervention	*N*	Sex	Mean age	Scanner type	Outcome variables	OMM	Conclusions
Bosoni et al. (2023) [11]	Italy	CRT	A Impr/D Impr	24	11M/13F	8.8 ± 1.0	3Shape, TRIOS3	Time; Comfort; Pain; Gag reflex; Breathing difficulties	VAS	In children aged 6 to 11, digital impressions were preferred by 75% of patients. The procedure with an intraoral scanner was significantly faster and offered greater comfort, with fewer issues related to gag reflex and breathing difficulty. No significant differences in pain or vomiting-related complications were observed.
Glisic et al. (2019) [13]	Denmark	Cross-over	A Impr/D Impr	59	31M/28F	NR (range: 9–15 years)	3Shape, TRIOS Classic, version 1.4.6.0	Time; Comfort; Anxiety; Dental arch measurements; Cost	VAS	Patient experience was statistically better with intraoral scanning. No significant differences in chairside time, but digital models showed slightly larger arch distances. The method became cost-effective over time despite higher initial costs.
Burhardt et al. (2016) [8]	Netherlands	Cross-over	A Impr/D Impr	38	16M/22F	NR (range: 10–17 years)	CEREC Omnicam, Sirona Dental Systems; Lava C.O.S. 3M ESPE	Time; Comfort; Preference	Likert scale	Young orthodontic patients preferred digital over traditional impressions, despite shorter chairside time with alginate. Further research should explore the effects of operator skill and the use of powder in digital impressions.

(Continues)

TABLE 1 | (Continued)

Author (year)	Country	Study design	Intervention	*N*	Sex	Mean age	Scanner type	Outcome variables	OMM	Conclusions
Yilmaz and Aydin (2019) [10]	Turkey	Cross-over	A Impr/D Impr	28	7M/17F	10.6 ± 1.78	3Shape, TRIOS3	Time; Comfort; Pain; Gag reflex; Breathing difficulties; Smell/taste; Heat/cold; Queasiness; Preference	VAS	While both techniques had different strengths, children and clinicians rated digital impressions as more comfortable. Most children preferred the digital method.
Serrano-Velasco et al. (2024) [17]	Spain	CRT	A Impr/D Impr	51	25M/26F	12.35 ± 2.57	iTero, Align Technology; Primescan, Sirona Dental System	Time; Comfort; Pain; Gag reflex; Breathing difficulties; Smell/taste; Heat/cold; Queasiness; Preference	VAS	Digital impressions were superior in overall comfort. Breathing, nausea, and gag reflex were worse with alginate. iTero was perceived as more painful than Primescan.
Garcovich et al. (2025) [14]	Italy/Spain	Cross-over	A Impr/D Impr	107	58M/49F	7.34 ± 1.42	3Shape, TRIOS3	Time; Comfort; Pain; Gag reflex; Breathing difficulties; Smell/taste; Heat/cold; Queasiness; Preference	VAS	Digital impressions were more time-efficient and preferred. Discomfort with alginate was associated with discomfort during digital impressions. Gag reflex was not strongly linked to discomfort, which was more related to dental fear.
Mangano et al. (2018) [9]	Italy	Cross-over	Alginate impression/ Digital impression	30	15M/15F	12.6 ± 1.9	CS 3600, Carestream	Time; Comfort; Gag reflex; Breathing difficulties; Smell/taste; Heat/cold; Preference; Anxiety	VAS State–Trait Anxiety Scale	Digital impressions were ≈2 min faster, markedly more comfortable on all VAS sub-scales, and preferred by 83% of paediatric patients compared with conventional alginate impressions.

Abbreviations: A Impr, Alginate, conventional, impression; CRT, Controlled Randomised Trial; D Impr, Digital impression; NR, Not Reported; OMM, Outcome Measurement Method; VAS, Visual Analogue Scale.

in the same direction. A reduction of ~13 mm on a 100 mm scale represents a clinically relevant improvement in patient comfort during impression taking.

3.3 | Patient-Reported Comfort

Comfort was evaluated in five studies using various patient-reported outcome measures, typically based on visual analogue scales (VAS) administered immediately after each impression technique (Figure 4). The meta-analysis revealed that intraoral scanners were significantly more comfortable than conventional impressions, with a pooled mean difference of −34.02 (95% CI: −37.01 to −31.04, $p < 0.00001$). This result is both statistically and clinically significant, indicating a consistent and notable improvement in patient experience. Heterogeneity was high ($I^2 = 83\%$).

3.4 | Breathing Difficulty

Four studies assessed breathing difficulty experienced by children during the impression procedures (Figure 5). The combined analysis showed significantly lower levels of breathing difficulty with intraoral scanners compared to alginate impressions. The pooled mean difference was 32.51 mm (95% CI: 29.19 to 35.84; $p < 0.00001$), strongly favouring the digital technique. Heterogeneity was high ($I^2 = 94\%$).

	Impression			Scanner				Mean difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Bosoni et al. 2023	301	31	24	182	38	24	15.5%	119.00 [99.38 , 138.62]
Burhardt et al. 2016	528	108	12	642	108	13	0.8%	-114.00 [-198.74 , -29.26]
Garcovich et al. 2025	316.1	40.9	107	128	20.9	107	79.0%	188.10 [179.40 , 196.80]
Yilmaz & Aydin 2019	450.25	60.08	28	465.89	76.71	28	4.6%	-15.64 [-51.73 , 20.45]
Total			**171**			**172**	**100.0%**	**165.48 [157.74 , 173.21]**

Test for overall effect: Z = 41.92 (P < 0.00001)
Test for subgroup differences: Not applicable
Heterogeneity: Chi² = 186.04, df = 3 (P < 0.00001); I² = 98%

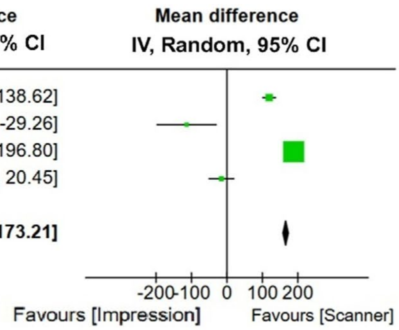

FIGURE 2 | Forest plot using a random-effects model comparing impression and scanner times; positive mean differences indicate shorter times with digital impressions. Random effects, inverse variance model.

	Impression			Scanner				Mean difference
Study or Subgroup	Mean [mm]	SD [mm]	Total	Mean [mm]	SD [mm]	Total	Weight	IV, Random, 95% CI
Bosoni et al. 2023	17	25	24	15	25	24	9.7%	2.00 [-12.14 , 16.14]
Garcovich et al. 2025	27.9	30.6	107	5.8	12.9	107	49.2%	22.10 [15.81 , 28.39]
Serrano-Velasco et al. 2024	13.55	22.32	51	8.76	11.41	51	41.1%	4.79 [-2.09 , 11.67]
Total			**182**			**182**	**100.0%**	**13.03 [8.62 , 17.44]**

Test for overall effect: Z = 5.79 (P < 0.00001)
Test for subgroup differences: Not applicable
Heterogeneity: Chi² = 15.83, df = 2 (P = 0.0004); I² = 87%

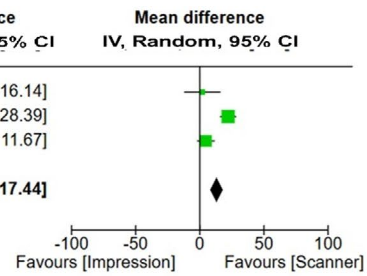

FIGURE 3 | Forest plot using a random-effects model comparing patient-reported pain between impression and scanner techniques; positive mean differences indicate greater comfort with scanners. Random effects, inverse variance model.

	Impression			Scanner				Mean difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Bosoni et al. 2023	60.6	20.7	24	80.3	10.8	24	10.2%	-19.70 [-29.04 , -10.36]
Garcovich et al. 2025	56.5	29.7	107	90.6	14.3	107	22.9%	-34.10 [-40.35 , -27.85]
Mangano et al. 2018	52.5	9.26	30	90.5	6.2	30	56.1%	-38.00 [-41.99 , -34.01]
Serrano-Velasco et al. 2024	81.63	19.21	51	91.24	51	51	4.0%	-9.61 [-24.57 , 5.35]
Yilmaz & Aydin 2019	56.12	29.85	28	92.86	7.22	28	6.9%	-36.74 [-48.12 , -25.36]
Total			**240**			**240**	**100.0%**	**-34.02 [-37.01 , -31.04]**

Test for overall effect: Z = 22.33 (P < 0.00001)
Test for subgroup differences: Not applicable
Heterogeneity: Chi² = 23.31, df = 4 (P = 0.0001); I² = 83%

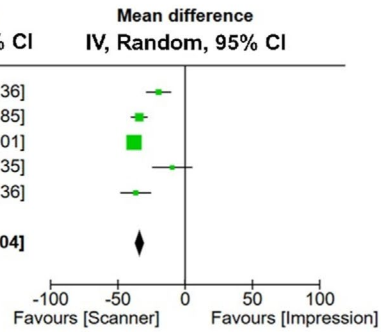

FIGURE 4 | Forest plot using a random-effects model comparing patient comfort scores between impression and scanner techniques; negative mean differences indicate greater comfort with scanners. Random effects, inverse variance model.

Study or Subgroup	Impression Mean	Impression SD	Impression Total	Scanner Mean	Scanner SD	Scanner Total	Weight	Mean difference IV, Random, 95% CI
Bosoni et al. 2023	24	23	24	9	18	24	8.1%	15.00 [3.32 , 26.68]
Garcovich et al. 2025	49	33.7	107	13.7	18.7	107	20.8%	35.30 [28.00 , 42.60]
Mangano et al. 2018	54.5	8.23	30	12.5	10.23	30	50.1%	42.00 [37.30 , 46.70]
Serrano-Velasco et al. 2024	18.58	24.96	51	4.72	8.77	51	21.0%	13.86 [6.60 , 21.12]
Total			**212**			**212**	**100.0%**	**32.51 [29.19 , 35.84]**

Test for overall effect: Z = 19.15 (P < 0.00001)
Test for subgroup differences: Not applicable
Heterogeneity: Chi² = 50.20, df = 3 (P < 0.00001); I² = 94%

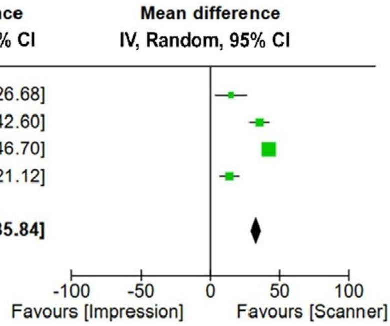

FIGURE 5 | Forest plot of four studies evaluating breathing difficulty during digital scanning versus conventional impressions; positive mean differences indicate substantially less breathing difficulty with scanners. Random effects, inverse variance model.

Study or Subgroup	Impression Mean	Impression SD	Impression Total	Scanner Mean	Scanner SD	Scanner Total	Weight	Mean difference IV, Random, 95% CI
Bosoni et al. 2023	25	37	24	1	4	24	3.9%	24.00 [9.11 , 38.89]
Garcovich et al. 2025	47.8	35.9	107	12.1	18.2	107	14.7%	35.70 [28.07 , 43.33]
Mangano et al. 2018	53.67	7.64	30	10	6.29	30	68.3%	43.67 [40.13 , 47.21]
Serrano-Velasco et al. 2024	23.89	22.32	51	8.19	19.19	51	13.1%	15.70 [7.62 , 23.78]
Total			**212**			**212**	**100.0%**	**38.07 [35.14 , 40.99]**

Test for overall effect: Z = 25.50 (P < 0.00001)
Test for subgroup differences: Not applicable
Heterogeneity: Chi² = 42.86, df = 3 (P < 0.00001); I² = 93%

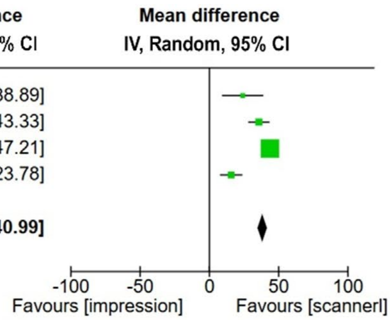

FIGURE 6 | Forest plot of four studies evaluating gag-reflex intensity during digital scanning versus conventional impressions; positive mean differences indicate markedly less gag reflex with scanners. Random effects, inverse variance model.

3.5 | Gag Reflex

Four studies reported outcomes related to the gag reflex during impression taking (Figure 6).

The pooled results indicated a significantly lower intensity or frequency of gagging with intraoral scanners. The mean difference was 38.07 mm on a VAS (95% CI: 35.14 to 40.99; $p<0.00001$), clearly favouring digital techniques in reducing this common and distressing response in paediatric patients. Heterogeneity was high ($I^2=93\%$).

3.6 | Patient Preference

Across the five studies, patients consistently preferred intraoral digital scanning over conventional impressions (Figure 7). The pooled random-effects meta-analysis showed that patients were more than four times as likely to favour the digital method (RR = 4.28; 95% CI: 1.47 to 12.44; $p=0.008$). However, substantial between-study heterogeneity was observed ($\tau^2=1.20$; $I^2=90\%$), suggesting that study design or participant characteristics influenced effect size.

3.7 | Risk of Bias Assessment

The quality assessment, conducted using the Cochrane Risk of Bias tool (RoB-1), revealed variability across the included studies. Most recent publications (from 2023 onwards) exhibited low or moderate risk of bias across domains, whereas older studies showed unclear or high risk in key areas such as random sequence generation and blinding of participants and personnel. Only two studies explicitly reported allocation concealment and blinding of outcome assessment. A summary of the risk of bias assessments is presented in Figure 8.

4 | Discussion

The results of this systematic review and meta-analysis provide robust evidence supporting the superiority of intraoral digital scanning over conventional alginate impressions in paediatric populations. The digital technique was not only significantly faster but also rated more favourably by patients in terms of comfort, gag reflex, breathing difficulty and overall preference. While these findings are consistent with much of the adult-based literature, the studies included in this review focus exclusively on children, a population with distinct physiological and behavioural traits that require a differentiated clinical interpretation [8, 11]. One of the most consistent findings was the superior time efficiency of digital impressions. The mean difference of 165.48 s in favour of scanning falls within the range reported in adult studies, such as that by Gjelvold et al. [18], which demonstrated a significant reduction in total procedural time with intraoral scanners. Similarly, Joda et al. [19] noted a clear temporal advantage in digital workflows for implant-supported crowns. However, other studies, such as Yılmaz and Aydın [10],

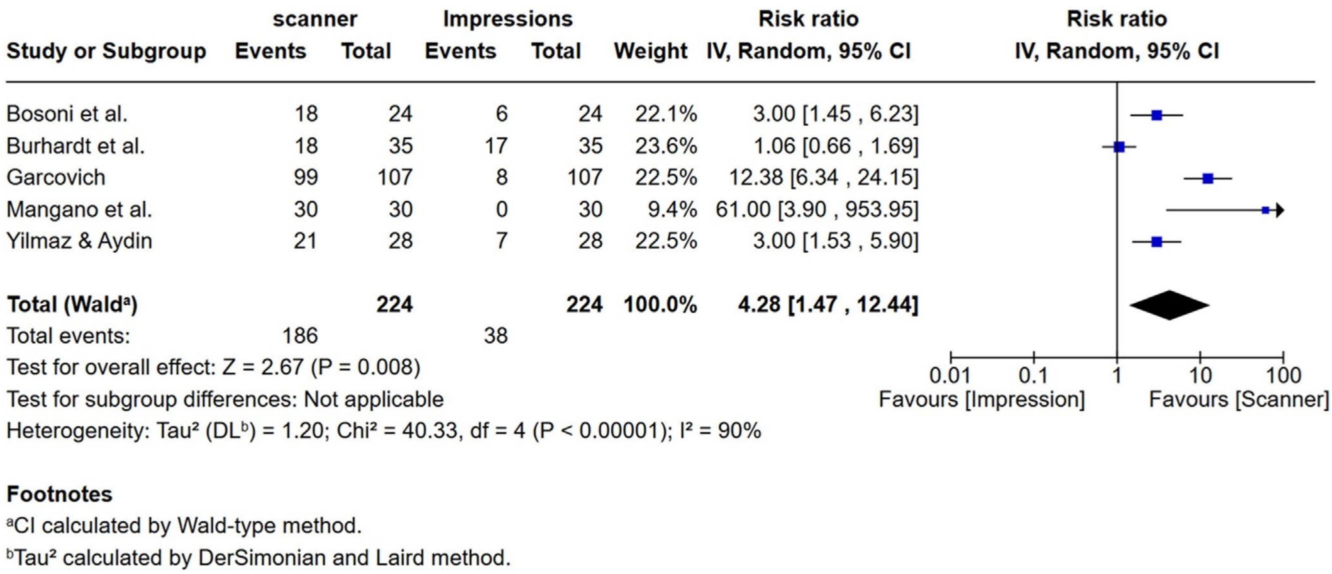

FIGURE 7 | Forest plot of five studies comparing digital intra-oral scanners with conventional impressions in terms of patient preference.

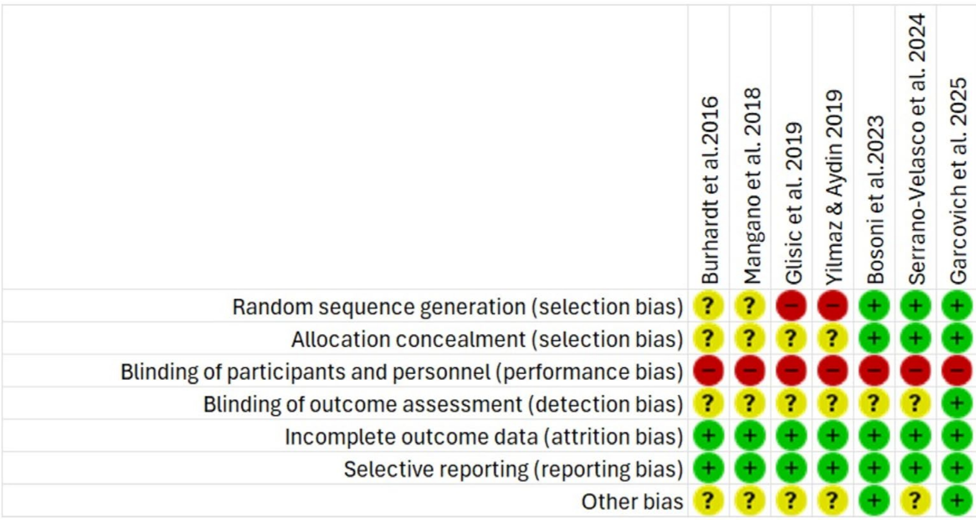

FIGURE 8 | Traffic-light plot of Cochrane Risk of Bias (ROB-1) assessments for the seven included trials; green (+) indicates low risk, yellow (?) unclear risk and red (–) high risk for each methodological domain.

reported no statistically significant time differences, suggesting that procedural time may be influenced by variables such as the type of restoration, scanning extent and operator experience.

Notably, the study by Burhardt et al. [8] differed from the pooled estimate, reporting shorter times with alginate compared to both digital systems tested. This result appears largely driven by the older, powder-requiring Lava C.O.S. scanner, which was considerably slower than both alginate and the powder-free CEREC Omnicam. More recent trials with modern scanners, and experienced operators consistently show the opposite pattern, with digital impressions being faster [11, 14], while others found no difference [10, 13]. These discrepancies likely reflect differences in scanner generation and operator experience.

Recent findings by Vavrickova et al. [20] further highlight that adults may perceive scanning to be more time-consuming, especially in extensive restorations. Our meta-analysis differs substantially from these previous approaches both in procedural scope and target population. While studies like those of Manicone et al. [21] and de Paris Matos et al. [22] focused on single-unit or partial restorations in adults, our review evaluates full-arch scans in paediatric patients. This methodological distinction is crucial: scanning full arches can be technically and temporally more demanding, yet our findings demonstrate that even under these conditions, digital scanning significantly outperforms conventional techniques in terms of efficiency. This likely reflects improvements in modern scanner hardware and software, as well as more established clinical learning curves. In terms of patient comfort, the superiority of digital scanning was more pronounced in children than in adults. De Paris Matos et al. [22] reported a mean difference of 15 points on the VAS for patient preference, whereas our analysis found a difference of 34.02 points. This discrepancy is not only statistically significant but clinically meaningful. Children's lower tolerance for foreign objects, strong tastes or stimuli that trigger the gag reflex may explain why conventional techniques are perceived as especially unpleasant in this age group [9, 13]. Moreover, in variables such as breathing difficulty and gag reflex, the beneficial effects of digital scanning have been previously documented in adult populations [23, 24], but our results suggest these effects may be even more pronounced in children. This could be related to anatomical factors (e.g., higher tongue-palate ratio, smaller oral cavity) and behavioural factors (e.g., greater anticipatory anxiety, limited prior dental experience). Another relevant aspect is the consistency of patient preferences. While some variability is seen in adults—as observed in studies by Sailer et al. [25] and Sakornwimon and Leevailoj [26], where some adults still favoured conventional methods due to familiarity—paediatric patients expressed a clearer and more unanimous preference for digital scanning. This homogeneity may stem from children having fewer preconceived expectations or a heightened sensitivity to discomfort caused by conventional materials.

For paediatric dentistry, the consistent advantages of digital scanning in comfort (including gag reflex and breathing difficulty) and preference may imply better cooperation and easier behavioural control. Even where time is equivalent, digital workflows avoid alginate taste/texture and may reduce retakes, which children find distressing. In settings with experienced operators and modern scanners, digital appears time-efficient as well, enabling tighter scheduling. Clinicians should consider device generation, team training and child factors (age, dental fear) when implementing scanning protocols.

From a methodological standpoint, it is important to emphasise that our work draws on low-risk-of-bias studies, many of which employed crossover designs and relies exclusively on clinical trials with direct technique comparisons. This represents a significant advancement over prior reviews that included observational or non-randomised studies [22]. Additionally, the consistent use of validated tools like the VAS enhances the reliability and comparability of the quantitative synthesis.

Therefore, this review not only contributes new evidence regarding the benefits of digital scanning but does so within a clinical context—paediatric dentistry—that has been underrepresented in the literature. Demonstrating that digital scanning is faster, more comfortable and clearly preferred by children supports its systematic adoption in settings where patient cooperation is a critical factor for clinical success. Nevertheless, it is important to acknowledge both the strengths and limitations of this review. Among its strengths are the exclusive inclusion of experimental studies (randomised and crossover trials), the focus on a paediatric population—often underrepresented in systematic reviews—and the analysis of clinically relevant variables such as comfort, respiratory difficulty and patient preference. Furthermore, the use of validated tools such as VAS scales for self-reported outcomes enhances data comparability and the robustness of quantitative synthesis. However, several limitations should be noted. The high statistical heterogeneity observed in the meta-analyses ($I^2 > 80\%$) reflects considerable variability across studies, likely due to differences in participant characteristics, devices used and clinical settings. This issue is not unique to our analysis: the systematic review by de Paris Matos et al. [22] also identified significant heterogeneity in preference analyses ($I^2 = 83\%$), attributing it to methodological differences, lack of standardisation in measurement tools, and the diversity of scanners. Similarly, Manicone et al. [21] reported high heterogeneity in operative time outcomes, which they interpreted as reflecting diverse clinical workflows and varying levels of user proficiency.

Although heterogeneity was substantial across most outcomes, formal subgroup analyses (by age band, scanner model or study design) were not feasible due to the limited number of eligible studies and heterogeneous outcome definitions. Likely contributors to heterogeneity include scanner generation (e.g., powder vs. powder-free systems), operator experience (novice vs. experienced), age range and setting. Future trials using harmonised definitions and reporting standards should enable informative subgroup/meta-regression analyses.

These findings suggest that, although overall effects favour digital scanning, the magnitude and consistency of the effect may vary depending on contextual factors. In addition, the inability to blind participants due to the nature of the interventions may introduce bias in subjective outcome assessments. Finally, although the included studies are relatively recent, the rapid evolution of scanning technologies means that some systems analysed may soon become outdated.

Future research should aim to better harmonise not the validated tools themselves (such as the VAS), but the conditions of their application and the interpretation criteria used, to improve cross-study comparability. Further studies should also stratify analysis based on moderating variables such as age, dental anxiety levels, prior treatment experience or scanner model. Lastly, multicentre studies, with broader geographic and socioeconomic representation, would enhance the generalisability of findings and guide stronger clinical recommendations.

Within the limitations of the present review, the available evidence suggests that digital intraoral scanning may offer advantages over conventional alginate impressions in paediatric patients.

Author Contributions

D.G. and M.A.M. conceived the study and defined the research question. D.G., A.A.L., M.D., M.A.M. and R.A. designed the search strategy and eligibility criteria. D.G., A.A.L., M.D., R.A. and J.B. conducted the literature search, screened the studies and extracted the data. D.G., M.A.M., A.A.L., M.D. and R.A. performed the risk of bias assessment and statistical analysis. D.G drafted the initial version of the manuscript. M.A.M., A.A.L., M.D. and R.A. contributed to the interpretation of results and critically revised the manuscript. All authors (D.G., M.A.M., R.A., A.A.L., M.D., J.B.) reviewed and approved the final version of the manuscript. All data relevant to the review are provided within the article.

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The authors have nothing to report.

Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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