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Systematic Review

Comparative evaluation of marginal and internal fit of multi-unit fixed dental prostheses: A systematic review and meta-analysis of conventional versus digital impressions

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ABSTRACT

Background: The incorporation of digital techniques has gained popularity in the fabrication of fixed dental prostheses (FDPs) over the last decade; however, limited evidence exists regarding the marginal and internal fit when using conventional versus digital impression techniques. This systematic review and meta-analysis aimed to compare the marginal and internal fit of tooth-supported multi-unit FDPs produced from conventional and digital impressions.
Materials and Methods: A comprehensive search was conducted in electronic databases, including Cochrane Library, PubMed, and Scopus. A meta-analysis was conducted using the standardized mean differences (SMDs) to quantify the effect sizes.
Results: Fourteen studies, three randomized controlled trials (RCTs) and 11 *in vitro* were included in the review, all complying with the inclusion criteria. The meta-analysis revealed that multi-unit FDPs fabricated using digital impressions generally exhibited improved marginal and internal fit compared with those produced using conventional impressions. In the RCT subgroup, digital impressions showed a trend toward improved marginal fit (SMD: −0.25; 95% confidence interval [CI]: −0.64–0.14) and statistically significant improvement for internal fit (SMD: −0.15; 95% CI: −0.55 to −0.24). In contrast, *in vitro* studies demonstrated statistically significant superiority of digital impressions for both marginal fit (SMD: −0.81; 95% CI: −1.06, −0.56) and internal fit (SMD: −0.52; 95% CI: −0.79 to −0.24).
Conclusion: Although digitalized impressions demonstrated statistically superior marginal and internal fit compared with conventional impressions, the observed differences should be interpreted with caution. Most outcomes remained within clinically acceptable limits. Among the intraoral scanners, the Trios system showed a trend toward improved marginal fit.

Key Words: Conventional impression, digital impression, fixed dental prostheses, marginal fit

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INTRODUCTION

Multiunit fixed dental prostheses (FDPs) are integral to contemporary dental practice and are routinely provided as the part of fixed prosthodontic treatments. While conventional impressions have long been used to fabricate these prostheses with consistent clinical success, they are not without limitations.[1] The challenges associated with the conventional technique

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include patient discomfort during impression-taking, difficulties in selecting appropriate trays, risk of dimensional changes due to delayed pouring, limited wettability of gypsum casts, and the potential for impression distortion during transport to the laboratory.[2] Such issues can contribute to inaccuracies in the marginal and internal fit of the final prosthesis.[3]

The integration of computer-aided design and computer-aided manufacturing technology has significantly enhanced the fabrication process of multi-unit FDPs. Digital impression techniques, employing laser or optical scanning, facilitate rapid and precise capture of both soft and hard tissues within the oral cavity, generating detailed digital impressions within minutes.[4] Two primary approaches to digital impression techniques exist: direct and indirect. The indirect method involves creating a gypsum cast from a conventional elastomeric impression, which is then scanned using a desktop scanner. In contrast, the direct method utilizes intraoral scanners (IOS) to capture the necessary anatomical structures directly from the patient's mouth. The direct digital approach offers several advantages, including reduced chairside time and the elimination of conventional steps such as tray selection, impression material use, and cast pouring, thereby increasing efficiency and patient comfort.[5]

IOS systems employ various image acquisition technologies to optimize accuracy. For instance, the Sirona Cerec Bluecam system, introduced in 1987, uses structured blue light and requires a light dusting of powder to capture the images via principle of triangulation, where three straight beams of light intersect at one point. In contrast, newer powder-free systems like the Cerec Omnicam allow for full-arch or quadrant scanning using continuous image capture.[6] The iTero scanner utilizes confocal imaging with a strobe light and a probe for focus, eliminating the need for powder. Similarly, the Trios system (3Shape) employs ultrafast optical sectioning and confocal microscopy for accurate, powder-free imaging.[7] The Lava Chairside Oral Scanner (3M ESPE) differs by using active wavefront sampling with continuous video capture, although it requires a thin layer of titanium dioxide for optimal accuracy.[8]

The internal and marginal fit of multi-unit FDPs is critical to their clinical success. Holmes *et al*. defined internal fit as the perpendicular distance between the intaglio surface of the restoration and the prepared tooth surface.[9] Poor internal adaptation can hinder proper seating of the prostheses, while marginal discrepancies may lead to recurrent caries, gingival discoloration, and prosthesis failure.[10,11] Both conventional and digital impression techniques have demonstrated the ability to reproduce sufficient detail for accurate fit. Studies suggest that a marginal discrepancy of ≤120 µm and an internal discrepancy of ≤200 µm at the occlusal surface are clinically acceptable.[12,13] The efficacy of IOS has been previously proven in single-unit FDPs[14] and completely edentulous arches.[15]

A previous systematic review by Morsy *et al*.[16] concluded that zirconia FDPs fabricated using digital impressions exhibited superior marginal and internal fit compared to those made with conventional techniques. However, with the continuous advancement of IOS technology, newer generations are overcoming the limitations of earlier models. Therefore, the present systematic review aims to incorporate the most recent evidence to reassess and update the comparative evaluation of conventional and digital impressions in the fabrication of multi-unit FDPs.

The null hypothesis stated that there is no significant difference in the accuracy of the marginal and internal fit of prostheses fabricated using conventional and digital impression techniques, nor is there a difference in the accuracy of the various IOS available on the market.

MATERIALS AND METHODS

This systematic review was conducted following the Preferred Reporting Items of Systematic Reviews and Meta-analyses guidelines and has been registered on the International Prospective Register of Systematic Reviews (PROSPERO) CRD42023458713.

The research question was formulated using the PICO format: Patient (P): Patients requiring multi-unit FDPs, Intervention (I): Digital impressions, Comparison (C): Conventional impressions, and Outcome (O): Accuracy of marginal and internal fit. The primary question is digital impressions a feasible and accurate alternative to conventional impressions in achieving optimal marginal and internal fit in multi-unit FDPs? A secondary question was also explored: Do differences exist in scanning accuracy among the various IOSs currently available on the market?

Search strategy

A comprehensive literature search was conducted to identify studies comparing the marginal and internal fit of multi-unit FDPs fabricated using conventional and digital impression techniques. Electronic databases searched included the Cochrane Central Register of Controlled Trials, MEDLINE (PubMed), Scopus, and Web of Science. The search encompassed both controlled *in vivo* and *in vitro* studies published between 2013 and January 2025.

In addition to electronic searches, a manual search was performed in leading prosthodontic journals such as the International Journal of Prosthodontics, Journal of Prosthetic Dentistry, Journal of Esthetic and Restorative Dentistry, European Journal of Esthetic Dentistry, and Journal of Prosthodontics. Reference lists and citations of selected articles were also screened to identify any additional relevant studies. A combination of free-text keywords and Medical Subject Headings terms was used, employing Boolean operators to optimize search sensitivity and specificity [Table 1].

Eligibility criteria

The review included *in vivo* and *in vitro* studies that focused on the quantitative measurement of internal and marginal gaps in multi-unit FDPs fabricated from conventional and digital impressions and published in English. The exclusion criteria were article where direct comparison of digital and conventional impression was not done. Case reports, case series, and systematic reviews were excluded.

Table 1: Search strategy

Component	Description
Focused question	Are digital impressions a feasible and accurate alternative to conventional impressions in achieving optimal marginal and internal fit in multi-unit FDPs?
Search strategy by PICO	Population (((Fixed dental prosthesis)) OR (FDP) OR ((multi-unit fixed dental prosthesis))) Intervention ((digital impression)) OR (optical impression)) OR (digital scanner)) OR (oral scanner)) OR (intraoral scanner)) OR (optical scanner) Comparison (Impression Technique OR conventional impression technique OR silicon impression material OR polyether impression material OR elastomeric impression material OR polyvinyl siloxane OR vinylpolysiloxane OR PVS OR addition silicone)) Outcome (precision of fit OR marginal fit OR internal fit OR marginal gap OR internal gap OR marginal accuracy OR internal accuracy OR (marginal discrepancy OR internal discrepancy OR marginal precision OR internal precision)
Database searched	Cochrane Central Register of Controlled Trials, MEDLINE (PubMed), Scopus, and Web of Science (WOS)

Initial screening of titles and abstracts identified through the electronic search was performed independently by two reviewers (G.S., A.S.) to determine eligibility. Articles were excluded based on abstract review; in cases of ambiguity, the full text was retrieved for further assessment. The full texts of all potentially relevant articles were obtained and evaluated by the reviewers based on the predefined inclusion criteria. Any disagreements between the two authors were resolved through the consensus with a third author (S.P.). Data extraction was performed for each qualified study, recording details such as author, year of publication, study type, sample size, number of units and region, impression system, marginal fit, and internal fit [Tables 2 and 3].

Risk of bias

Two reviewers (G.S., A.S.) independently assessed the risk of bias (ROB) and the quality of the included studies. The Cochrane collaboration tool was used to assess the ROB for randomized controlled trials (RCTs).[30] The studies were categorized under low ROB, unclear ROB, and high ROB.

The quality assessment tool for *in vitro* studies (QUIN tool) was used to evaluate the *in vitro* studies.[31] Each study was assessed based on 12 criteria [Table 4]. Scoring was as follows: 2 points for adequately specified criteria, 1 point for inadequately specified criteria, 0 points for unspecified criteria, and exclusion from calculation if not applicable. The total score for each study was computed and categorized as low (>70%), medium (50%–70%), or high ROB (<50%) using the formula: Final score = (Total score × 100)/(2 × number of applicable criteria).

Data analysis

The marginal and internal gap between the prostheses and the abutment was considered the primary outcome. Accuracy of different IOS was measured as the secondary outcome.

Extracted data were analyzed using a review manager software program RevMan 5.4.1 (Review Manager 5, Version 5.4. Cochrane Collaboration 2020; Copenhagen, Denmark)). Standardized mean difference (SMD) with 95% confidence interval (CI) was calculated for the effect size of each study as

Table 2: Characteristic of included *in vitro* studies

Author, year	Number of patients	Number of units and region	Impression system	Marginal fit (µm)	Internal fit (µm)	Fabrication material	Manufacturing method	Testing procedure for fit evaluation	Cement space thickness (µm)
Bandiaky *et al.*, 2023[17]	8	5, AP	CI: PVS DI: Trios	106.02±14.51 95.03±12.74	106.38±7.64 103.61±9.32	Zirconia	Five-axis milling machine	The silicone replica technique combined with micro-CT	50
Uluc *et al.*, 2022[18]	10	5, AP	CI: PVS DI1: Cerec DI2: Trios	83.5±9 82.2±8 81.2±9	120.75±17.5 110.7±14 118.2±14	Monolithic zirconia	Redon Hybrid Technology, 5-axis milling machine	3-D industrial scanner	50
Arezoobakhsh *et al.*, 2020[13]	10	3, AP	CI: PVS DI 1: Trios DI 2: CS 3600	91±40 60±15 55±13	184.33±72.66 100±24.33 115.6±22.33	Presintered zirconia blocks	5-axis milling machine	Silicone replica technique with stereomicroscopy at ×50	35
Kocaağaoğlu *et al.*, 2019[19]	10	3, AP	CI: PVS DI1: Cerec DI 2: Trios	98.8±16.43 63.78±4.05 65.14±18.05	NR	CoCrMoW alloys	Prototyping technology high precision high-energy laser	Stereomicroscopy	20
Moustapha *et al.*, 2019[20]	10	3, anterior	CI: PVS DI: Trios	30±10 20±5	104±25.3 115.6±29.6	Zirconia blanks	Five-axis CNC machine	Replica technique	80
Kim and Kim 2018[21]	10	4, posterior	CI: PVS DI: Cerec	73.62±11.76 65±12	154.20±18.83 143.71±23.25	Monolithic zirconia	5-axis dental milling machine	The replica technique	NR
Su and Sun 2016[22]	10	3, AP	CI: PVS DI: Trios	76±18 63±16	134±47 110±40	Presintered zirconia block	Milling machine (Upcera	A replica method	40 - MD 60 - ID
Shembesh *et al.*, 2017[23]	10	3, posterior	CI: PVS DI1: iTero DI2: Lava	81.4±6.8 62.4±5 26.6±4.7	NR	Zirconua	Hard sintering with firing temperature at 1450°C for about 12 h	Optical comparator (horizontal optical comparator)	35
Svanborg *et al.*, 2014[24]	10	3, posterior	CI: PVS DI: iTero	147±22.6 142±32.6	117±11.6 93±8.2	CoCr	CNC-milled	ATOS III triple-scan scanner with blue-light technology	30
Keul *et al.*, 2014[25]	12	4, posterior	CI: PE DI: iTero	141.08±193.17 127.23±66.87	165.9±137.8 153.8±59.46	Base metal alloy zirconia	3+1 axes milling unit	Reflected light microscope (Axioscope 2; Zeiss, Oberkochen, Germany) at ×50	30
Almeida e Silva *et al.* 2014[26]	12	4, posterior	CI: PE DI: Lava	65.33±37.27 63.96±36.75	65.94±41.9 58.46±35.91	Semi sintered zirconia	Five-axis milling machine LavaTM CNC 500	×50 with a microscope (Axioscope 2, Zeiss, Oberkochen, Germany)	30

AP: Anteroposterior; CI: Conventional impression; DI: Digital impression; PVS: Polyvinyl siloxane; PE: Polyether; NR: Not reported; CNC: Computer numerically controlled; CS: Carestream; ATOS: Advanced topometric optical sensor; CT: Computed tomography

Table 3: Characteristic of included randomized controlled trials

Author, year	Type of study	Number of patients	Number of units and region	Impression system	Marginal fit (µm)	Internal fit (µm)	Fabrication material	Manufacturing method	Testing procedure for fit evaluation	Cement space thickness
Morsy *et al.*, 2021[27]	RCT	12	3, AP	CI: PE DI: CS3500	40.02±19.50 30.91±15.15	41.86±18.94 30.86±13.57	Monolithic multilayer zirconia	Ceramill mind CAD software, version 2.2.5 (Amann Girrbach AG, Koblach, Austria)	Replica technique	50 µm
Benic *et al.*, 2019[28]	RCT	10	3, AP	CI: PE DI1: iTero DI2: Lava DI3: Cerec	117.7±129.4 91.41±95.2 106.4±103.7 108.3±93.8	127.5±86.1 116.5±66.8 140±102.5 131.8±77.1	Zirconia blocks (Lava Zirconia; 3M ESPE)	Centralized milling center lava milling center by Rainer Rominger	Replica technique	70 m
Ahrberg *et al.*, 2016[29]	RCT	8	3, AP	CI-PE DI-Lava	70.40±28.87 61.08±24.77	92.13±49.87 88.27±41.49	Presintered zirconia blanks	5-axis milling unit (Lava CNC 500, 3M ESPE, Seefeld, German	Replica technique	50 µm

RCT: Randomized controlled trials; AP: Anteroposterior; CI: Conventional impression; DI: Digital impression; PE: Polyether; CNC: Computer numerically controlled; CAD: Computer-aided design

Table 4: Quality assessment tool for *in vitro* studies tool

Criteria	AlmeidaE Silva *et al.* 2014[26]	Keul *et al.* 2014[25]	Svan borg *et al.* 2014[24]	Shem besh *et al.* 2017[23]	Su and Sun 2016[22]	Kim and Kim2018[21]	Mous tapha *et al.* 2019[20]	Koca ağaoğlu *et al.* 2019[19]	Arezo obaksh *et al.* 2020[13]	Uluc *et al.* 2022[18]	Ban diaky *et al.* 2023[17]
Clearly stated aims/objectives	2	2	2	2	2	2	2	2	2	2	2
Detailed explanation of sample size calculation	2	2	2	2	2	2	2	2	2	2	2
Sampling technique	2	2	2	2	2	2	2	2	2	2	2
Details of the comparison group	2	2	2	2	2	2	2	2	2	2	2
Detailed explanation of the methodology	2	2	2	2	2	2	2	2	2	2	2
Operator details	0	0	0	0	0	0	0	0	0	0	0
Randomization	NA	NA	2	NA	NA	NA	NA	2	2	NA	NA
Method of measurement of outcome	2	2	2	2	2	2	2	2	2	2	2
Outcome assessor details	0	0	0	0	0	0	0	0	0	0	0
Blinding	NA	NA	2	NA	NA	NA	NA	NA	NA	NA	NA
Statistical analysis	2	2	2	2	2	2	2	2	2	2	2
Presentation of results	2	2	2	2	2	2	2	2	2	2	2
Total score	16	16	20	16	16	16	16	18	18	16	16
Final score (%)	80	80	83.3	80	80	80	80	81.8	81.8	80	80

NA: Not applicable

the outcome variables were continuous. The results for each impression technique were represented separately. The inverse variance-weighted method was used to estimate overall SMD. Due to high heterogeneity, sub-group analysis was conducted to evaluate the marginal and internal fit associated with the different IOS used in the study. Funnel plots of effect size and standard error were used to assess publication bias for both marginal and internal fit.

RESULTS

A total of 236 studies were identified through electronic searches (PubMed: 126, Cochrane: 26, and Web of Science: 78) and hand searches (n = 6). After removing 108 duplicate studies, 128 remained for screening based on title and abstract, leading to the exclusion of 96 studies. Subsequently, 32 full-text articles were assessed for eligibility, with 18 being excluded due to lack of comparison with conventional impressions (n = 8), qualitative analysis only (n = 5), absence of internal fit discrepancy values (n = 3), and case report format (n = 2). Ultimately, 14 studies were included in the review, comprising 11 *in vitro* studies[13,17-26] and 3 RCTs.[27-29] [Figure 1].

A summary of the characteristics of the included studies is depicted in Tables 2 and 3. Ten studies employed the impression replica technique to evaluate discrepancies. In most of these studies, polyvinyl siloxane was used as the replica material; however, Moustapha *et al*.[20] utilized polyether for the replica technique, which may have contributed to methodological variability due to differences in material properties. Svanborg *et al*.[24] used the triple scan technique; likewise, a study by Bandiaky *et al*.[17] used a combination of impression replica along with micro computed tomography, Kocaağaoğlu *et al*.[19] used direct view technique and Shembesh *et al*.[23] used optical comparator. The observed heterogeneity may be partly attributed to variations in fit measurement techniques across studies, which can affect the accuracy and comparability of reported outcomes and, consequently, influence the pooled estimates.

Risk of bias assessment

The ROB results for RCTs are depicted in the Figure 2. All the RCTs manifested low risk in selection, detection, attrition, and reporting bias. There was an unclear risk of performance bias as there was no mention of blinding of participants or operators in all the three RCTs,[27-29] which limits the certainty of evidence. The ROB analysis for the *in vitro* studies using the QUIN tool had a final score above 70%, depicting a low ROB in these studies [Figure 3].

Assessment of marginal fit of *in vitro* studies

A statistically significant difference for marginal fit was found encompassing *in vitro* studies favoring the digital impressions over conventional impressions with SMD: −0.81; (95% CI: −1.06, −0.56; $P < 0.00001$). The meta-analysis depicting the marginal fit is shown in Figure 4. However,

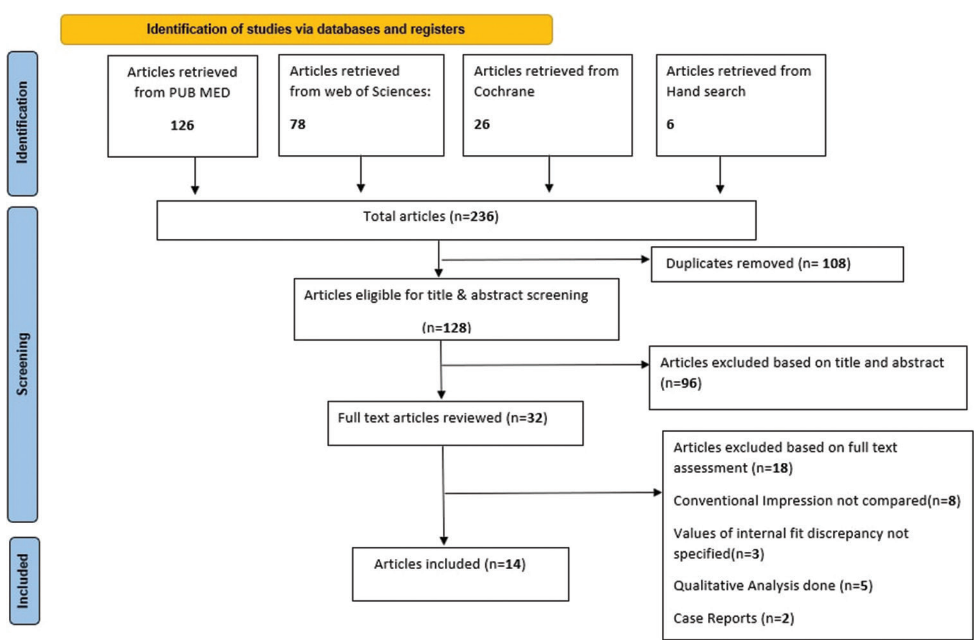


Figure 1: Preferred Reporting Items of Systematic Reviews and Meta-analyses flowchart for literature search.

the substantial heterogeneity (I^2 = 77%) suggests variability among studies, which may be due to the differences in study design, IOS type, or measurement techniques.

Figure 2: Risk of bias assessment of included studies using the cochrane collaboration tool.

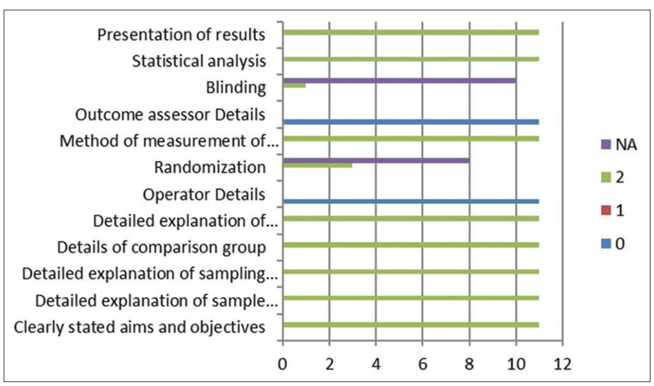


Figure 3: Quality Assessment of *in vitro* studies using QUIN tool.

Assessment of marginal fit of randomized controlled trial

An improved marginal fit was found favoring the digital impressions compared with conventional impressions (SMD: −0.25; (95% CI: −0.64, 0.14; P < 0.00001). The meta-analysis depicting the marginal fit is shown in Figure 5. However, the I^2 value 0% is suggestive of no heterogeneity among the studies.

Assessment of internal fit of *in vitro* studies

A statistically significant difference for the internal fit was found favoring digital impressions (SMD −0.52; 95% CI: −0.79, −0.24; P < 0.00001). I^2 = 52% denotes lesser heterogeneity, indicating lesser variability among studies. The meta-analysis for internal fit is depicted in Figure 6.

Assessment of internal fit of randomized controlled trial

A significant difference for the internal fit was found favoring digital impressions SMD −0.15; (95% CI: −0.55, 0.24; P < 0.00001). I^2 = 0% suggestive of no heterogeneity among the studies. The meta-analysis for internal fit is depicted in Figure 7.

A subgroup analysis by IOS type was performed by categorizing the studies based on the IOS used. Based on the subgroup analysis, the studies appear to include different IOS types such as Trios, Cerec, iTero, CS3600, and Lava. Total SMD for marginal fit: −0.78 (95% CI: −1.05–0.52) and for internal fit −0.50 (95% CI: −0.81 to −0.19) which indicates that digital impressions significantly outperform conventional impressions. Trios (3Shape) shows the strongest effect (−0.91 SMD), favoring

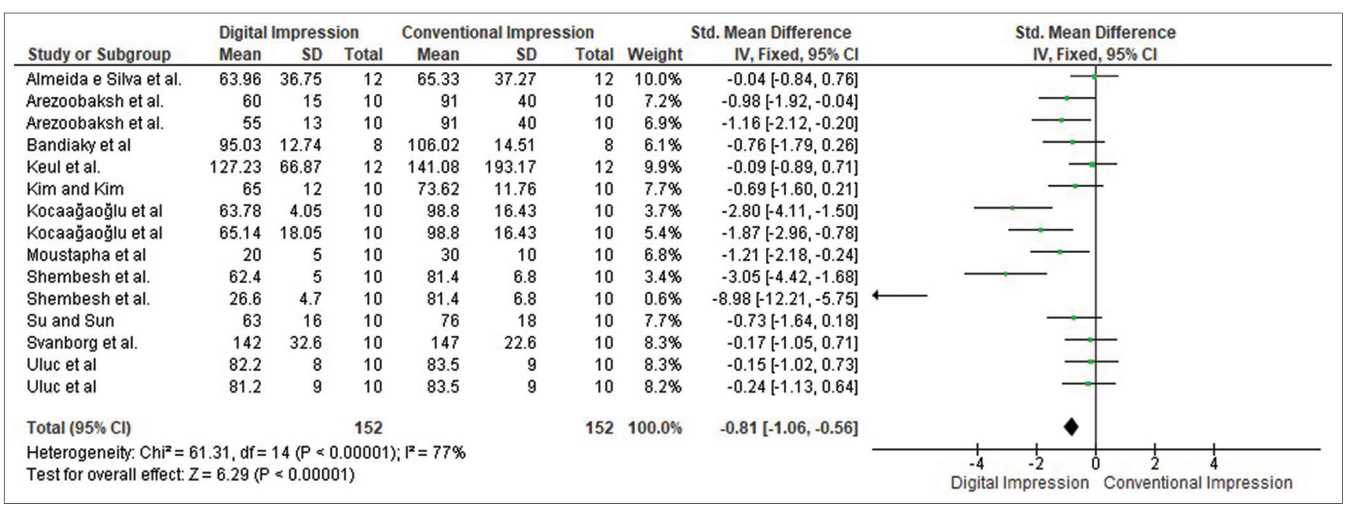
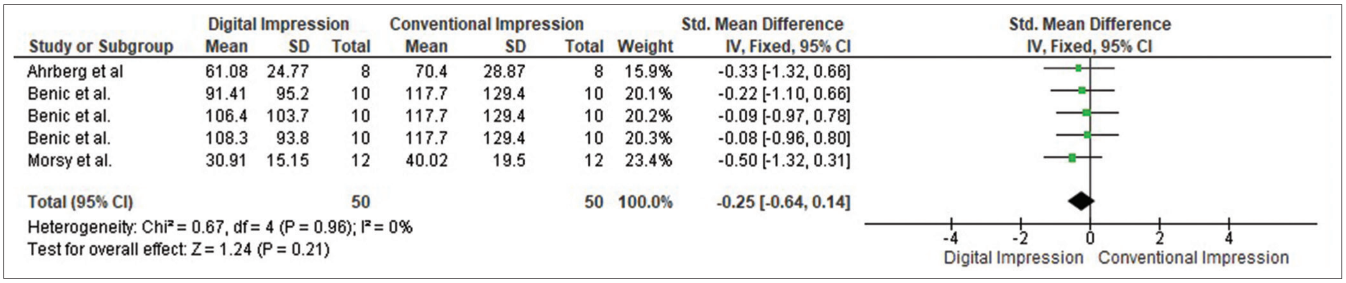


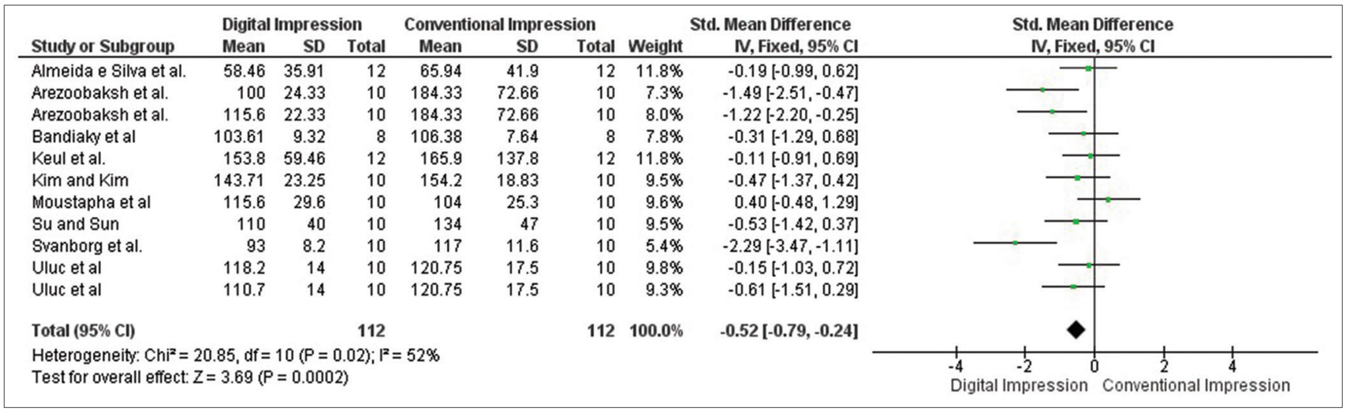
Figure 4: Forest plot of comparison of *in vitro* studies showing marginal fit as standardized mean difference.



Study or Subgroup	Digital Impression Mean	SD	Total	Conventional Impression Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Ahrberg et al	61.08	24.77	8	70.4	28.87	8	15.9%	-0.33 [-1.32, 0.66]
Benic et al.	91.41	95.2	10	117.7	129.4	10	20.1%	-0.22 [-1.10, 0.66]
Benic et al.	106.4	103.7	10	117.7	129.4	10	20.2%	-0.09 [-0.97, 0.78]
Benic et al.	108.3	93.8	10	117.7	129.4	10	20.3%	-0.08 [-0.96, 0.80]
Morsy et al.	30.91	15.15	12	40.02	19.5	12	23.4%	-0.50 [-1.32, 0.31]
Total (95% CI)			50			50	100.0%	-0.25 [-0.64, 0.14]

Heterogeneity: Chi² = 0.67, df = 4 (P = 0.96); I² = 0%
Test for overall effect: Z = 1.24 (P = 0.21)

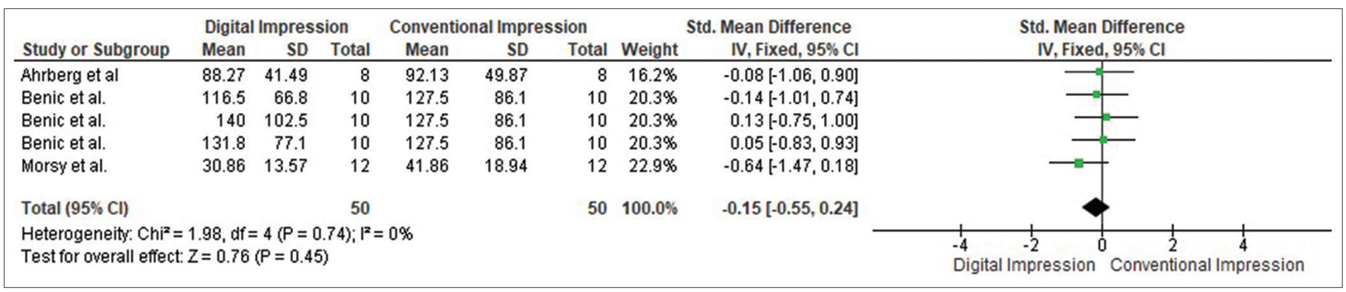
Figure 5: Forest plot of comparison of randomized controlled trial showing marginal fit as standardized mean difference.



Study or Subgroup	Digital Impression Mean	SD	Total	Conventional Impression Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Almeida e Silva et al.	58.46	35.91	12	65.94	41.9	12	11.8%	-0.19 [-0.99, 0.62]
Arezoobaksh et al.	100	24.33	10	184.33	72.66	10	7.3%	-1.49 [-2.51, -0.47]
Arezoobaksh et al.	115.6	22.33	10	184.33	72.66	10	8.0%	-1.22 [-2.20, -0.25]
Bandiaky et al	103.61	9.32	8	106.38	7.64	8	7.8%	-0.31 [-1.29, 0.68]
Keul et al.	153.8	59.46	12	165.9	137.8	12	11.8%	-0.11 [-0.91, 0.69]
Kim and Kim	143.71	23.25	10	154.2	18.83	10	9.5%	-0.47 [-1.37, 0.42]
Moustapha et al	115.6	29.6	10	104	25.3	10	9.6%	0.40 [-0.48, 1.29]
Su and Sun	110	40	10	134	47	10	9.5%	-0.53 [-1.42, 0.37]
Svanborg et al.	93	8.2	10	117	11.6	10	5.4%	-2.29 [-3.47, -1.11]
Uluc et al	118.2	14	10	120.75	17.5	10	9.8%	-0.15 [-1.03, 0.72]
Uluc et al	110.7	14	10	120.75	17.5	10	9.3%	-0.61 [-1.51, 0.29]
Total (95% CI)			112			112	100.0%	-0.52 [-0.79, -0.24]

Heterogeneity: Chi² = 20.85, df = 10 (P = 0.02); I² = 52%
Test for overall effect: Z = 3.69 (P = 0.0002)

Figure 6: Forest plot of comparison of *in vitro* studies showing internal fit as standardized mean difference.



Study or Subgroup	Digital Impression Mean	SD	Total	Conventional Impression Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Ahrberg et al	88.27	41.49	8	92.13	49.87	8	16.2%	-0.08 [-1.06, 0.90]
Benic et al.	116.5	66.8	10	127.5	86.1	10	20.3%	-0.14 [-1.01, 0.74]
Benic et al.	140	102.5	10	127.5	86.1	10	20.3%	0.13 [-0.75, 1.00]
Benic et al.	131.8	77.1	10	127.5	86.1	10	20.3%	0.05 [-0.83, 0.93]
Morsy et al.	30.86	13.57	12	41.86	18.94	12	22.9%	-0.64 [-1.47, 0.18]
Total (95% CI)			50			50	100.0%	-0.15 [-0.55, 0.24]

Heterogeneity: Chi² = 1.98, df = 4 (P = 0.74); I² = 0%
Test for overall effect: Z = 0.76 (P = 0.45)

Figure 7: Forest plot of comparison of randomized controlled trial showing internal fit as standardized mean difference.

digital impressions significantly with lowest heterogeneity (I^2 = 14%) suggesting more consistent results. The results of the sub-group analysis did not reveal significant differences in internal fit. Cerec and iTero also favor digital impressions, but with some variability. Lava scanners do not show a significant difference, suggesting inconsistent performance. Other scanners CS3600 also favor digital impressions with low variability [Figures 8 and 9].

The funnel plot for marginal fit shows the studies are clustered more on the left-hand side (negative SMD values), with fewer studies on the right. This asymmetry suggests potential publication bias or selective reporting, as studies favoring digital impressions (negative SMD) are more prevalent. While publication bias may slightly inflate effect estimates, the consistency and reproducibility of findings across multiple independent studies underscore the clinical advantage of digital workflows [Figure 10]. The funnel plot for internal fit shows no major asymmetry, indicating a reduced risk of publication bias. This strengthens the conclusion that findings on internal fit are more robust and less influenced by selective reporting [Figure 11]. Overall, these results suggest that digital impressions offer a predictable and efficient alternative to conventional techniques, with potential benefits including improved fit accuracy, reduced chairside adjustments, and enhanced workflow efficiency, thereby supporting their broader adoption in modern prosthodontic practice.

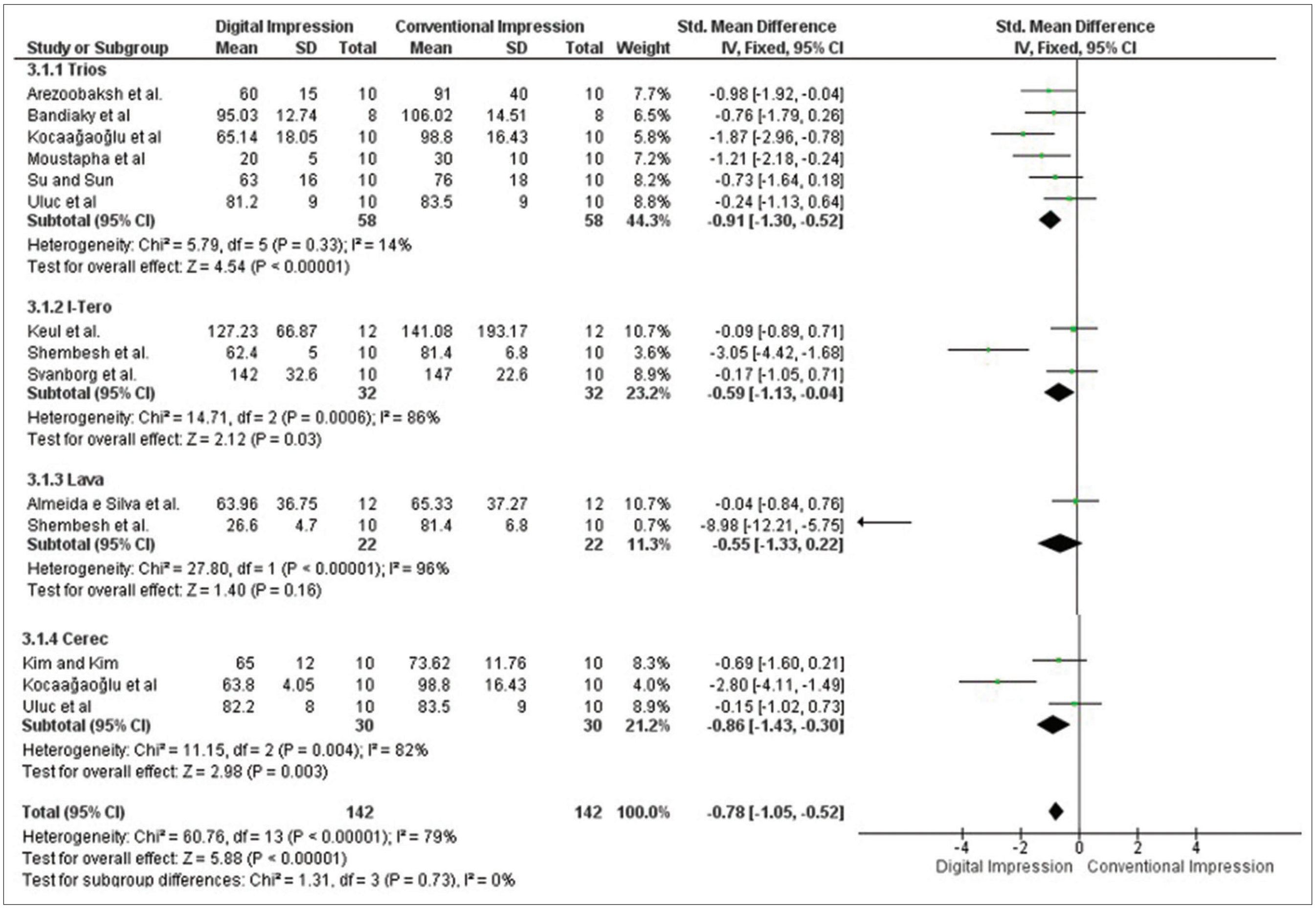


Figure 8: Subgroup analysis of comparison of *in vitro* studies showing marginal fit as standardized mean difference.

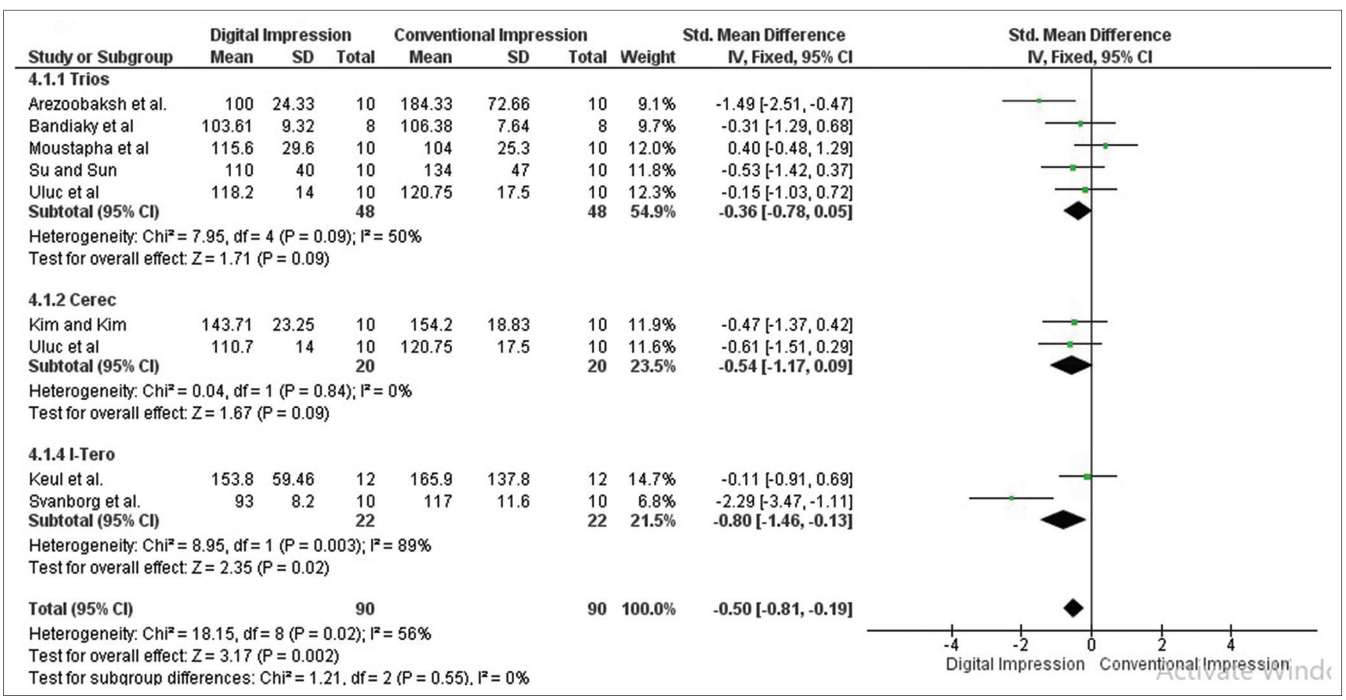


Figure 9: Subgroup analysis of comparison of *in vitro* studies showing internal fit as standardized mean difference.

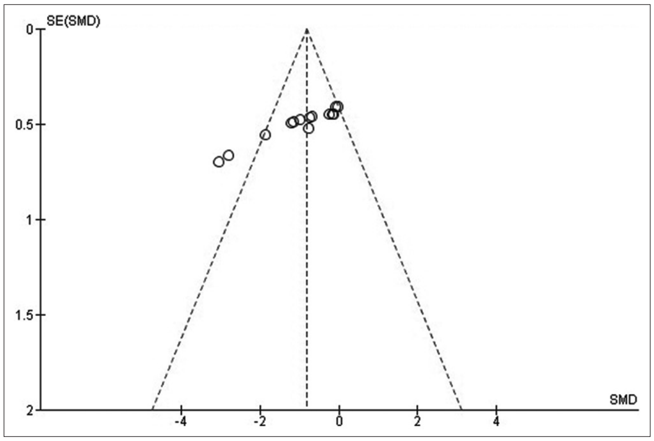


Figure 10: Funnel plot depicting publication bias for marginal fit.

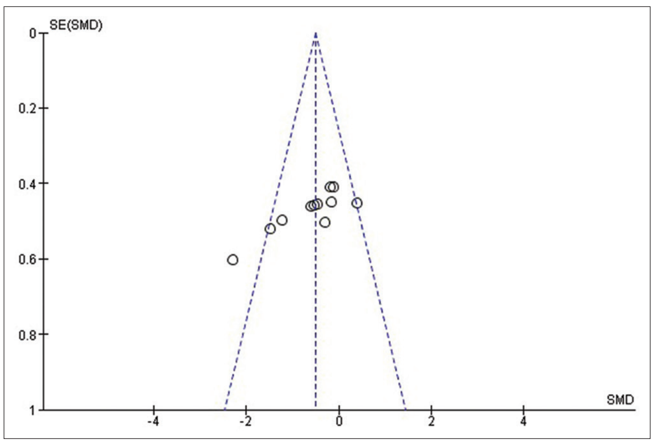


Figure 11: Funnel plot depicting publication bias for internal fit.

DISCUSSION

This systematic review unequivocally supports the superiority of digital over conventional impression techniques, clearly rejecting the null hypothesis. The meta-analysis results revealed a statistically significant difference in both marginal and internal fit when using digital impressions as compared to conventional impression. The results are contradictory to finding of Moustapha *et al*.[20] wherein he reported better internal fit with conventional impressions (104 µ) than with digital impressions (115.6 µ) Similarly, in the study by Benic *et al*.,[28] internal fit achieved through conventional impressions (127.5 µ) was better than that of Lava (140 µ) and Cerec (131.8 µ).

Although all the studies included in our review demonstrated an acceptable marginal fit (i.e., 120 µ or less) according to McLean and von Fraunhofer's[12] criteria in both the digital and conventional groups, however, our studies consistently showed acceptable internal discrepancies within the range of 100–200 µ.

No direct correlation could be established between the impression material used for the conventional impression or between the number of units in FDPs and the marginal or internal fit. Similarly, the studies included in the review did not establish a precise correlation between variables such as cement spacer, region of edentulousness, and the material of prostheses with the observed discrepancy.

Considering the substantial statistical heterogeneity, we opted for a subgroup analysis to compare the accuracy of various IOS used in the studies. Trios IOS demonstrated consistent results with lesser heterogeneity thus rejecting the second null hypothesis. Studies by Amornvit *et al*.[32] and Renne *et al*.[32,33] concluded that the Trios series depicted the best results consistent with our study's results. The observed heterogeneities in our review are likely attributed to the diverse generations of IOS used in the included studies and the inclusion of studies which scanned different regions of the mouth. Despite this variability, the overall pooled estimates consistently favored digital impressions, suggesting that the digital workflow offers comparable or superior fit accuracy to conventional methods. Notably, newer generation IOS, equipped with advanced software, tends to yield lower discrepancy values for marginal fit.

Such differences in the accuracy of scanners could be attributed to their different scanning strategies. There is a considerable possibility of errors while scanning with IOS, as it captures approximately 1200 images during the scanning process.[34,35] Errors may arise from the superimposition of these images during scanning and processing. These errors are more common in anterior teeth due to their steep inclines and smaller surface area. Additional errors can occur during computer processing, often due to filter algorithms and calibration issues.[36,37]

Previous studies reported that different IOSs varied in scanning accuracy.[5,38] No conclusion has been reached regarding the superiority of a certain IOS from the current subgroup analysis because few studies were included, and heterogeneity was high. However, the Trios scanner had the best performance in the digital group for marginal fit with 14% heterogeneity and SMD of −0.91, consistent with a previous review by Morsy *et al*.[16]

The accuracy of IOS is also contingent on various factors, including blood and moisture control, gingival retraction, and the position of the marginal finish line on the tooth. Notably, the operator's skill during scanning also plays a crucial role in determining accuracy.[39,40]

The limitations of this study were inclusion of only a few clinical studies, with the majority being *in vitro*, where frameworks were fabricated and tested under controlled laboratory conditions. This may not fully represent *in vivo* scenarios, slightly reducing clinical relevance. In future more *in vivo* studies with a long-term follow-up are needed to assess the accuracy of the fit of the prostheses. Although statistically significant differences were observed, the clinical relevance of these findings remains uncertain, as the magnitude of the effect may fall within clinically acceptable limits.

CONCLUSION

As the certainty of evidence is limited, the conclusions should be interpreted with caution.

1. The Digital Impression technique has demonstrated better marginal and internal fit than the conventional impression technique
2. The Trios IOS has depicted an enhanced marginal fit compared to the rest.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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