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Fit of three-unit zirconia frameworks using conventional versus digital impressions: A systematic review

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Abstract:

Known data on the marginal and internal fit of three-unit zirconia fixed partial dentures (FPDs) fabricated using digital and conventional impressions is of interest to dentist. Zirconia frameworks fabricated using digital impression techniques demonstrated superior marginal and internal fit compared to those fabricated using conventional impressions. Digital impression techniques provide a better fit for three-unit zirconia FPDs compared to conventional methods, potentially leading to improved clinical outcomes and patient satisfaction. Further clinical studies are recommended to validate these findings in a real-world setting.

Keywords: Zirconia, Fixed partial dentures, digital impressions

Background:

Zirconia has emerged as a reliable alternative to traditional metal-ceramic frameworks for the construction of tooth-supported fixed partial dentures (FPDs) involving three or more units **[1]**. Often referred to as a "smart ceramic," zirconia offers several mechanical advantages over other all-ceramic dental restorations, primarily due to its unique property of "transformation toughening" **[2]**. This phenomenon involves dimensional changes in zirconia that induce compressive stresses, thereby reducing crack propagation and enhancing the material's overall durability **[3].** The advantages of zirconia as a dental material are numerous. It acts as a thermal insulator, offers excellent biocompatibility, and exhibits high wear resistance and aesthetic appeal **[4].** Zirconia also boasts superior flexural strength, ranging from 900 to 1400 MPa, and fracture toughness of up to 10 MPa **[5].** These properties have contributed to the widespread adoption of zirconia in both anterior and posterior FPDs **[6]**. Traditional techniques for fabricating zirconia frameworks involve the use of elastomers such as polyether and polyvinylsiloxane to create impressions of prepared teeth **[7].** These impressions are then used to produce gypsum casts, which are subsequently scanned by laboratory scanners to generate a 3D model **[8].** The final restoration is designed using specialized CAD software and fabricated using 3D printing techniques **[9].** While these conventional methods have been effective, they are not without limitations. The process remains complex, requiring multiple steps, including impression making, cast fabrication, and scanning **[10].** In recent years, the advent of computer-aided design and computer-aided manufacturing (CAD/CAM) technology has revolutionized the fabrication of zirconia frameworks **[11]**. CAD/CAM systems consist of three main components: data acquisition devices, software for designing the restoration, and milling machines for manufacturing the final product **[12]**. Intraoral scanners, a key component of CAD/CAM systems, capture detailed information from the prepared area, eliminating the need for conventional impressions and reducing associated errors **[13].** The accuracy of CAD/CAM restorations is influenced by several factors, including the scanning process, software design, milling precision, and the material's shrinkage during the final sintering **[14]**. Holmes et al. introduced a classification system to describe the marginal gap, internal gap, and absolute marginal discrepancy of dental restorations **[15]**. These measurements are critical in assessing the fit of FPDs, as poor marginal adaptation can lead to cement exposure, plaque retention, cement dissolution, and subsequent endodontic complications **[16]**.

Clinically, a marginal gap of less than 120 μm is considered acceptable, though some researchers suggest that an ideal marginal gap should range between 50 μm and 75 μm **[17]**. The internal fit of a restoration is equally important, as an inadequate fit can reduce fracture resistance and compromise the retention of the prosthesis **[18]**. Studies have shown that an 80 μm cement layer on the occlusal surface enhances the mechanical stability of zirconia restorations **[19].** The accuracy of fit is closely linked to the accuracy of the impression **[20].** In a digital workflow, the accuracy is determined by the scanner's ability to reproduce the area of interest with high trueness and precision **[21]**. Digital workflows aim to address the limitations of conventional workflows, such as issues related to tray selection, material handling, and impression accuracy **[22].** Additionally, digital impressions offer greater comfort for patients, particularly those with a strong gag reflex **[23].** Despite the potential benefits of digital workflows, there is limited information on the performance of digital impression systems compared to conventional methods **[24].** Therefore, it is of interest to assess whether digital impressions provide a better marginal and internal fit for three-unit zirconia FPDs compared to conventional impressions.

Methodology:

Study design:

A systematic review and meta-analysis were conducted following the guidelines set by the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) 2020, the Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0), and the JBI Reviewer's Manual. The study protocol was registered with PROSPERO under the registration code CRD42023474343.

Focused review question:

Does digital impression produce better marginal and/or internal fit of three-unit zirconia FPDs compared to conventional impressions?

Eligibility criteria:

Inclusion criteria:

[1] **Population:** Studies including three-unit zirconia frameworks on anterior or posterior teeth, irrespective of the jaw type.
[2] **Intervention:** Studies assessing zirconia prostheses fabricated using digital impression techniques.
[3] **Comparison:** Studies assessing zirconia prostheses fabricated using conventional impression techniques.
[4] **Outcome:** Studies providing data on both marginal and internal fit in both groups.
[5] **Study Design:** In vitro studies published between January 1, 2010, and October 31, 2023, with available full-text articles.

Exclusion Criteria:

[1] Studies without full-text availability.
[2] Single-intervention studies without a comparative group.
[3] Observational studies, review reports, case series, and animal studies.
[4] Studies providing only abstracts.

Search strategy:

A comprehensive search was performed across multiple electronic databases, including PubMed/MEDLINE, Cochrane Central Register of Controlled Trials (CENTRAL), CINAHL, EMBASE, PsycINFO, Scopus, ERIC, and Science Direct. Keywords and MeSH terms related to zirconia frameworks, digital and conventional impressions and accuracy of fit were used in combination with Boolean operators.

The search strategy included a focus on the following aspects:

[1] **Population:** Zirconia frameworks in three-unit FPDs.
[2] **Intervention:** Digital impression techniques.
[3] **Comparison:** Conventional impression techniques.
[4] **Outcomes:** Marginal and internal fit accuracy.
[5] **Study Design:** In vitro studies.

Study selection:

Titles and abstracts were independently reviewed by two reviewers to identify potentially eligible studies. Full-text articles of relevant studies were retrieved and assessed for eligibility based on predefined criteria. Discrepancies between reviewers were resolved through discussion with a third reviewer.

Data extraction

Data were extracted independently by two reviewers using a standardized form that included study characteristics, participant details, intervention methods, outcome measures, and results. Data extraction focused on the following items:

[1] Study ID, author, and year of publication.
[2] Location and study design.
[3] Sample size and participant demographics.
[4] Digital and conventional impression techniques used.
[5] Methods for assessing marginal and internal fit.
[6] Study conclusions.

Risk of bias assessment:

The quality of the included studies was assessed using a risk of bias tool that evaluated parameters such as sample size justification, randomization, impression technique, and statistical analysis. Studies were categorized as low, medium, or high risk based on the total score of the assessed parameters.

Results:

Literature search:

The initial search yielded 137 titles, with 79 duplicates removed. After screening abstracts, 58 relevant studies were identified, of which 18 were selected for full-text review. Six studies met the inclusion criteria for the qualitative synthesis, and four were included in the quantitative meta-analysis **[25-30].** The PRISMA flow diagram (**Figure 1**) illustrates the study selection process.

Study characteristics:

The six included studies were conducted in diverse locations, including Boston, China, Lebanon, Iran, Bulgaria, and Bangkok **[25-30]**. All studies employed an in vitro design and evaluated the marginal and internal fit of zirconia frameworks using various digital impression techniques. Conventional impression methods typically involved polyvinyl siloxane or polyether materials. **Table 1** provides an overview of the characteristics of the included studies, including details on the digital and conventional impression techniques, zirconia fabrication methods, and outcomes assessed.

Quality assessment of included studies:

Among the included studies, only one study showed medium risk while remaining 5 studies showed low risk of bias. In study by Moustapha 2018 details of measuring procedures of experiment were not mentioned hence the total score of these studies was higher as compared to other studies. (**Table 2**)

Quantitative Synthesis

A total of 4 studies **[20,21,22,24]** fulfilled the inclusion criteria for quantitative analysis. Subsequently, two meta-analyses were performed to assess the marginal discrepancy and marginal gap comparing between digital impression technique and conventional impression technique group. The study by Shembesh 2016 used 2 types of digital impression techniques, so the 2 digital impression groups in each study were considered as separate studies for analysis.

Marginal discrepancy:

The meta-analysis of 3 studies (**Figure 2**) assessing the standardized mean difference for Marginal Discrepancy between digital impression technique and conventional impression technique carried out using random effect model showed a statistically significant difference favouring the digital impression technique as compared to conventional impression technique (SMD, -0.82, 95% CI = -1.28 - -0.36, p = 0.0005, I^2- 0%).

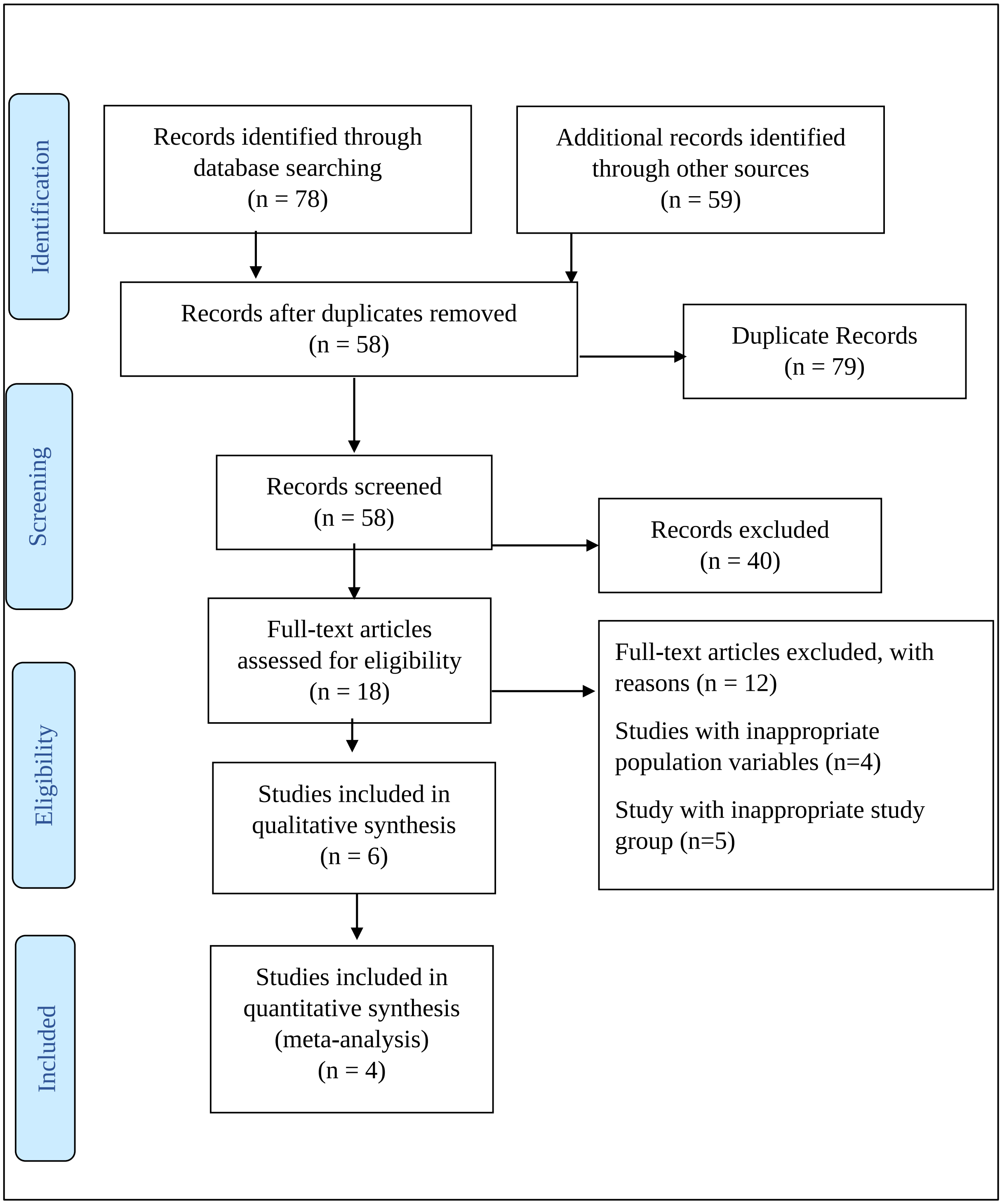

Figure 1: PRISMA Flow Diagram

Table 1: Characteristics of included studies

Study ID	Place of study	study design	Sample size	Teeth selected	Digital impression technique	Conventional impression technique	Zirconia fabrication	outcomes assessed	measures used for outcome assessment	Author conclusions
Shembesh 2016	Boston	*invitro*	40 FPD 4 groups 10 each group	FPD	1. iTero intraoral scanner 2. Lava True Definition intraoral scanner (3M ESPE).	poly vinyl siloxane (PVS) impressions of the prepared teeth were made with stock impression trays	The designed FDPs were transferred to the milling machine. Hard sintering was performed on the three-unit FDPs with firing temperature at 1450°C for about 12 hours, according to the manufacturers' specifications.	marginal gaps	mean SD, median IQR	Marginal gap within acceptable limit (120 µm). Lowest gap: Lava True Definition < stone cast scan < Cadent iTero < PVS impression scan. Significant differences.
Su 2016	China	*invitro*	20	maxillary left canine and second premolar FPDs	Trios intraoral digital scanner	2-step impression method was used to make 10 putty-wash impressions using a PVS impression material	N/A	marginal discrepancy, internal discrepancy	mean SD	Clinically acceptable marginal and internal fit for CAD/CAM zirconia FDPs. Intraoral digital impressions showed better fit than conventional impressions.
Moustapha 2018	Lebanon	*invitro*	20 10/10	maxillary central incisor and canine	An intraoral scanner Trios 3 (3Shape, Denmark) was used to digitalize.	made with a polyvinyl siloxane silicone (Honigum heavy automix and light; DMG, Hamburg, Germany) using custom acrylic trays	N/A	marginal, incisal, chamfer and axial discrepancy	mean SD	Better adaptation with intraoral scanner except at incisal tip. Conventional and scanned impressions had more underextended restorations.
Arezoobakhsh 2020	Iran	*invitro*	40 10/10/10/10	maxillary left first premolar, first molar	1. scans were made using the TRIOS intraoral scanner (TRIOS 2; 3Shape) 2. digital scans were made using the CS3600 intraoral scanner (CS3600; Carestream Dental)	made in stock trays with a 2-step putty/wash polyvinyl siloxane material (Panasil; Kettenbach) at room temperature	appropriate software (Engine Build 6136; exocad GmbH) was used. Subsequently, the copings were milled from presintered zirconia blocks (Upcera HT Zirconia; Shenzhen Upcera Co) and were sintered according to the manufacturer's guidelines.	marginal gap, mid-occlusal gap measurement	mean, standard error	Marginal gap within clinically acceptable range. Highest gap in DCL group. TRI and CSI groups had lower marginal and internal gaps than DCL and CIL.
Georgiev 2021	Bulgaria	*invitro*	30, 3 groups	N/A	intraoral	additive	N/A	marginal	mean SD	Marginal

		1. Conventional impression 2. Plaster model scanning 3. Intraoral scanning group			scanner TRIOS (Trios 3, 3Shape A / S, Denmark)	silicone impression material		discrepancy,		adaptation within clinically acceptable range. Highest in PCS group, lowest in ISG group.
Nagaviroj 2021	Bangkok	10	5/5	premolar	made with the intraoral scanner (CEREC Omnicam, Sirona dental, AC,Germany) . Each digital file (STL) was used to fabricate each zirconia FPD.	recorded using a double mix-double impression technique (putty-wash technique), using polyvinyl siloxane dual-viscosity impression materials	Designed using CAD software of Cerec software 16.1 (Sirona dental systems). The inCoris TZI Zirconia blocks 40/19 size 40x19x15 mm (Sirona, Germany) were milled in the milling machine	gap width between FPD and model at 10 measuring points	mean SD	No significant difference in marginal adaptation between digital and conventional impressions. Significant difference in internal gap widths, highest at occlusal surface of premolar.

Table 2: Risk of Bias assessment

Study ID	Randomisation	Impression technique	Sample preparation	Adequate statistical analysis	Measuring procedures of each experiment	Tests conducted by single blinded examiner	Total score	ROB
Shembesh 2016	1	0	0	0	0	1	2	Low
Su 2016	1	0	0	0	0	2	3	Low
Moustapha 2018	1	0	1	0	2	0	4	Medium
Arezoobakhsh 2020	1	0	0	0	1	1	3	Low
Georgiev 2021	1	1	0	0	0	0	2	Low
Nagaviroj 2021	1	1	0	0	0	0	2	Low

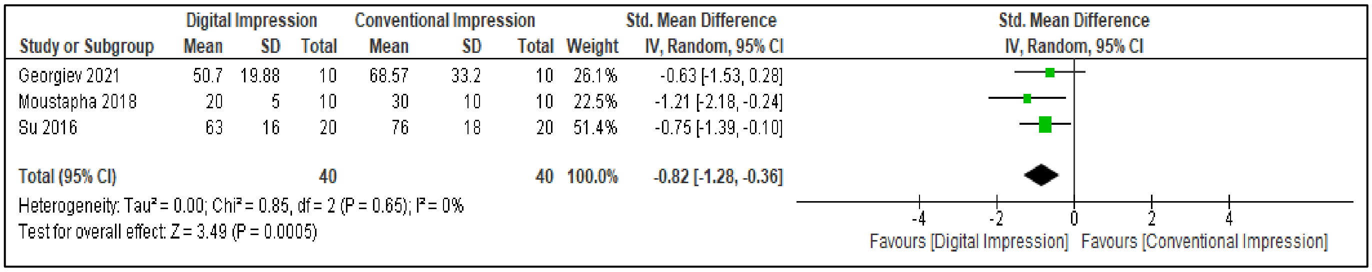

Figure 2: Forest plot comparing digital impression technique with conventional impression technique for marginal discrepancy

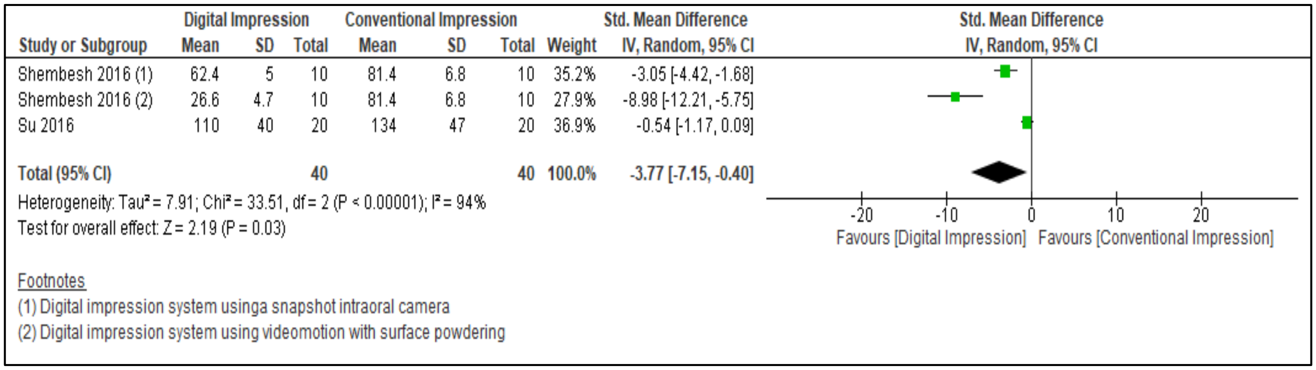

Figure 3: Forest plot comparing digital impression technique with conventional impression technique for marginal gap

Marginal gap:

The meta-analysis of 2 studies (**Figure 3**) assessing the standardized mean difference for Marginal Gap between digital impression technique and conventional impression technique carried out using random effect model showing a statistically significant difference between the groups favouring the digital impression technique as compared to conventional impression technique (SMD, -3.77, 95% CI = -7.15 - -0.40, p = 0.03, I^2- 94%).

Overall, the meta-analysis of the included studies revealed that digital impression techniques consistently resulted in better marginal and internal fit compared to conventional impressions. The differences were statistically significant, supporting the hypothesis that digital impressions provide a superior fit for three-unit zirconia FPDs.

Discussion:

This systematic review has provided a comprehensive comparison of digital and conventional workflows in the fabrication of three-unit zirconia fixed partial dentures (FPDs). The null hypothesis was rejected based on findings from all included studies, which revealed a statistically significant difference in the marginal and internal fits between the two impression techniques. Shembesh *et al.* **[25]** reported that three-unit zirconia FPDs fabricated using the Lava True Definition scanner exhibited the lowest average marginal gap at 26.6 µm. This enhanced fit could be attributed to the application of titanium dioxide, an opaque material that ensures consistent light dispersion, thereby improving scan accuracy. However, Loos *et al.* cautioned that spraying titanium oxide powder prior to surface scanning could potentially alter surface geometry, thereby compromising the accuracy of the internal fit **[31]**. The mean marginal gap increased progressively from master cast scan to Cadent iTero and finally to the traditional impression scan. Notably, several researchers have observed that cementation exacerbates marginal discrepancies in fixed restorations, which aligns with the methodology of measuring the marginal gaps of the three-unit zirconia FPDs in this study without cementation. Additionally, the use of green blanks, which offer the advantage of easier machining without water cooling or lubrication, presents a potential downside-namely, the chipping of thin margins. In the study by Wostmann *et al.*, the impact of impression techniques on marginal accuracy was scrutinized **[32]**, leading Su *et al.* to adopt a two-step technique for the conventional group in their study **[26].** They observed greater errors in the conventional group due to the inherent inaccuracies in the traditional impression-making process, which were likely exacerbated by material expansion and contraction. The superior overall fit observed in the digital group may thus be attributed to these inaccuracies in the conventional process. Interestingly, marginal and internal fit values were found to be higher in the incisor mesial and premolar distal aspects in the digital group. This observation could be due to the intraoral scanner's limited ability to capture three-dimensional data in areas adjacent to neighbouring teeth, which reduced the amount of light available for accurate scanning. Arezoobakhsh *et al.* demonstrated that the marginal gap was highest in the cast scan (DCL) group, followed by the conventional impression laboratory scanner (CIL) group, Trios intraoral scanner (TRI) group, and CS3600 intraoral scanner (CSI) group. The elevated marginal gap in the DCL group could be a consequence of errors during impression removal or cast deformation **[28].** Although intraoral scanning resulted in lower internal gaps, the occlusal gap was consistently larger than the axial gap across all groups, which aligns with findings by Vennerstrom *et al.* **[33]** and Rödiger *et al.* **[34].** This discrepancy may be due to limitations in scanner accuracy and resolution, which hindered the milling burs' access to occlusal areas, thereby increasing occlusal gaps. A precise fit is vital for a successful restoration; high gaps in axial and occlusal regions can lead to increased cement thickness and undesirable tensile stresses when resin cements are employed, particularly due to cement shrinkage. The authors concluded that different impression techniques significantly impacted the marginal and internal gaps on various abutment teeth. However, given the in vitro nature of this investigation, the effects of intraoral conditions on the internal and marginal fit of restorations could not be assessed, emphasizing the need for clinical trials with long-term follow-ups. In Moustapha et al.'s investigation, the direct digitization of the finish line resulted in evenly extended margins compared to other groups **[27]**. However, the analysis of cast models indicated slightly under extended restorations, which could be related to issues such as margin line selection, ditching, or cast contraction. In contrast, group S (scanned silicone impression) exhibited a mix of under extended and evenly extended sides. The one-step conventional impression group (group C) produced larger frameworks, likely due to larger dies in the single-step impression technique, which may have resulted from insufficient elastic recovery of the impression material. This finding is consistent with Silva *et al.*'s observation of a higher degree of axial adaptation on the non-pontic side **[35]**. Marginal and axial discrepancies were most pronounced in group C, followed by group S and group T (intraoral scanner group). Overbilling due to software design was the primary cause of the largest incisal gap discrepancies in group T. The only statistically significant difference in chamfer area discrepancy was observed in the central incisor tooth in groups S and T, with group S showing a larger discrepancy, likely because this region was in the highest position within the lab scanner, allowing more light penetration.

Georgiev *et al.* evaluated marginal adaptations and internal fit at four points on each abutment tooth, with points P1, P2, and P3 providing information about internal discrepancy and point P4 representing marginal discrepancy **[29]**. The conventional impression scanning (CIS) group exhibited the highest average values at P1 and P2, followed by the plaster cast scanning (PCS) group and the intraoral scanner (ISG) group. The average value at P3 was highest in the CIS group, followed by the ISG and PCS groups. At points P2 and P3, there was a statistically significant difference between the CIS group and the other two groups, but not between the PCS and ISG groups. Premolar teeth exhibited the lowest values across all points, with the ISG group showing the lowest marginal and internal discrepancies. The authors suggested that multiple factors, including impression technique, material type, margin design, model preparation (gypsum or virtual 3D), and cementing procedure, could influence the accuracy of prosthetic restorations.

Nagaviroj *et al.* used ten measuring points to calculate the gap widths between the FPD and the model. Points 1 and 10 indicated marginal gaps, while points 2 to 9 pertained to internal gaps **[30]**. Various levels of adaptation were observed at different measuring points, likely due to the quality of digital data- a crucial factor in ensuring the accuracy of CAD/CAM restorations. In this study, point 6 had the maximum internal gap width, possibly due to limitations in the milling technique's ability to generate grooves and inclined planes on occlusal surfaces. The diameter and form of milling tools, which were unable to replicate fine details, particularly in areas with sharp angles, also contributed to this issue. The authors concluded that there was no significant difference in the marginal adaptations of FPDs fabricated using conventional versus digital impression techniques. However, a significant difference was found in internal gap widths, with the largest values observed on the occlusal surface of premolars in the digital group.

The advantage of digital impression techniques over conventional methods in terms of marginal and internal fit accuracy is observed. These results align with previous studies that have highlighted the potential of digital workflows to reduce errors associated with conventional impressions and improve overall restoration quality. The clinical implications of these findings are significant, as better marginal and internal fit can reduce the risk of secondary caries, plaque accumulation, and restoration failure. However, further clinical studies are needed to validate these results in real-world settings and to explore the long-term outcomes of digitally fabricated zirconia FPDs.

Conclusion:

Digital impression techniques offer a better fit for three-unit zirconia FPDs compared to conventional impressions. This supports adoption of digital workflows in prosthodontics to enhance the accuracy and clinical outcomes of zirconia restorations.

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