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Journal of Dental Specialities

Journal homepage: https://www.jdsits.in/

Original Research Article

Comparative evaluation of marginal fit, prosthodontic and patient centered outcomes of milled zirconia crown using conventional and digital impression techniques – A split mouth, randomized clinical trial

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Abstract

Statement of problem: Advancements in restorative dentistry, especially all-ceramic restorations, have improved aesthetics, biocompatibility, and durability. The emergence of digital impression techniques has sparked debate over their clinical efficiency and accuracy compared to conventional methods in fabricating zirconia crowns.

Objectives: 1. To evaluate the marginal fit of zirconia crowns fabricated using conventional and digital impressions; 2. To assess prosthodontic outcomes between the two techniques; 3. To compare patient-centered outcomes across both groups.

Materials and Methods: Twenty-one patients requiring zirconia crowns for contralateral mandibular posterior teeth were selected and divided into two groups: Group A (conventional impression) and Group B (digital impression). Crowns were fabricated using CAD/CAM. Marginal fit was assessed using a stereomicroscope (40X magnification), prosthodontic outcomes via USPHS criteria, and patient satisfaction using a Visual Analog Scale (VAS). Data were analysed with SPSS v26 ($p < 0.05$).

Results: Digital impressions resulted in superior marginal fit, better occlusal contacts, and improved colour matching. Patient satisfaction was higher in the digital group. Both groups produced clinically acceptable crowns, but digital impressions showed fewer marginal discrepancies and better overall prosthodontic outcomes.

Conclusion: Digital impression techniques offer greater accuracy, efficiency, and patient comfort compared to conventional methods. Given their superior performance in key clinical parameters, they represent a preferred approach in contemporary prosthodontic practice.

Keywords: Zirconia crowns, CAD/CAM, Digital impression, Conventional impression, Marginal fit, Prosthodontic outcomes, Patient satisfaction.

Received: 11-05-2025; **Accepted:** 15-07-2025; **Available Online**: 29-09-2025

1. Introduction

Dentistry has experienced remarkable progress over recent decades, particularly within the realm of restorative procedures. Among the most transformative innovations is the introduction and increasing utilization of milled zirconia crowns.[1] These restorations offer several advantages over traditional metal-ceramic options, including superior aesthetics that more closely mimic natural teeth, enhanced biocompatibility that reduces the risk of adverse tissue reactions, and improved durability, which contributes to longer clinical service life.[2]

Traditionally, the fabrication of dental prosthetics depended on conventional impression techniques using elastomeric materials such as polyvinyl siloxane or polyether. While these methods have provided reliable results for many years, they are often technique-sensitive and time-consuming.[3] In contrast, the development of digital impression systems-employing intraoral scanners and CAD/CAM technology-has revolutionized the way impressions are captured and restorations are designed. These digital systems promise increased patient comfort, faster turnaround times, and streamlined workflows. However,

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https://doi.org/10.18231/j.jds.70016.1759125422

their clinical efficacy continues to be a subject of ongoing research and debate, particularly concerning the accuracy of digital scans in capturing fine marginal details and their long-term performance in comparison to traditional methods.[4]

One of the most critical factors influencing the success of any fixed prosthesis is its marginal fit-the-degree to which the restoration accurately adapts to the prepared tooth margins. Poor marginal adaptation can create micro-gaps that facilitate plaque accumulation and allow for microleakage, leading to complications such as secondary caries, pulp irritation, and periodontal inflammation. Therefore, achieving a precise and stable marginal seal remains a primary objective in both conventional and digital restorative techniques to ensure the longevity and biocompatibility of the final prosthetic outcome.[5,6]

2. Materials and Methods

The present clinical investigation was conducted within the Department of Prosthodontics and Crown & Bridge at I.T.S Centre for Dental Studies and Research, Ghaziabad. The study employed a split-mouth randomized clinical trial design involving a cohort of 21 patients, each presenting with the clinical requirement for full-coverage zirconia crowns on contralateral mandibular posterior teeth. Ethical approval with reference number ITSCDSR/IIEC/2022-25/PROSTHO/04. Informed consent was obtained from each subject before enrolling them in the study.

This methodological approach facilitated direct intraoral comparison by ensuring that each participant received one restoration fabricated using a conventional impression technique and the other via a digital impression system, thereby minimizing inter-individual variability.

To standardize clinical procedures and minimize confounding variables, uniform tooth preparation protocols were meticulously followed for both groups. These preparations included standardized occlusal, facial, lingual, and proximal reductions, incorporation of chamfer finish lines, and the rounding of all internal line angles to optimize marginal adaptation and ensure consistency across specimens.

This study aims to evaluate the marginal fit, prosthodontic accuracy, and patient-reported outcomes of zirconia crowns fabricated using conventional and digital impressions. A split- mouth, randomized clinical trial was conducted to test the null hypothesis that no significant differences exist between the two techniques.

In Group A (Conventional Impression Group), impressions were obtained using polyvinyl siloxane (PVS) material following a two-step putty-wash technique. High-precision Type IV dental stone was subsequently poured into the impression to generate the definitive working model, which served as the basis for the fabrication of zirconia crowns using conventional laboratory workflows.(**Figure 1,2**)

In Group B (Digital Impression Group), digital impressions were captured using an advanced intraoral scanning device, thereby obtaining the need for traditional impression materials and physical models. The acquired digital data were utilized in a fully digital workflow incorporating computer-aided design and computer-aided manufacturing (CAD/CAM) for the fabrication of monolithic zirconia crowns via a computer-controlled milling system. followed by final cementation.(**Figure 3-6**)

Marginal fit evaluation was performed using a stereomicroscope at 40X magnification, enabling high-resolution assessment of the marginal discrepancies between the crown and tooth interface. Clinical performance of the prostheses was further assessed using the United States Public Health Service (USPHS) evaluation criteria. This included systematic evaluation of key parameters such as marginal integrity, anatomical form, occlusal contacts, and color stability. In addition, patient-centered outcomes were recorded using the Visual Analogue Scale (VAS), which quantitatively measured subjective parameters including perceived comfort, overall satisfaction, and ease of procedure.

Statistical analysis was conducted, with significance set at $p < 0.05$.

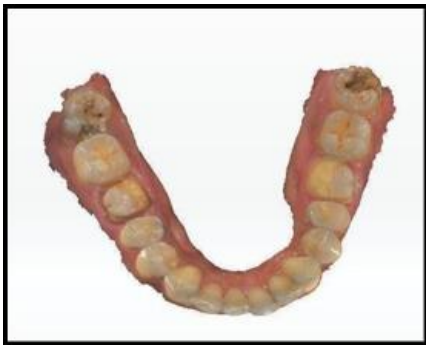

Figure 1: Tooth preparation wrt 36,46

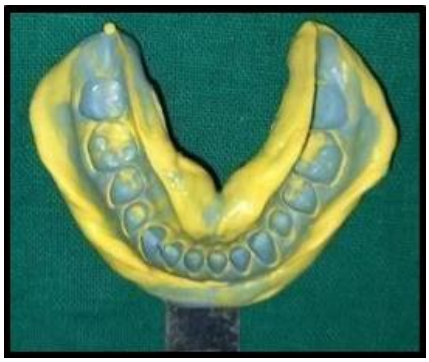

Figure 2: Conventional impression (Group A)

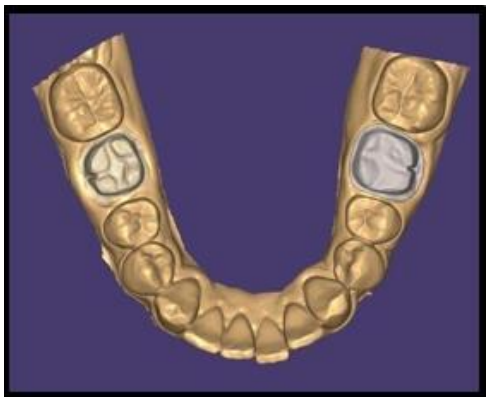

Figure 3: Digital impression of prepared arch (Group B)

Figure 4: Marginal fit (Group A)

Figure 5: Marginal fit (Group B)

Figure 6: Final Cementation wrt 36 and 46

3. Results

The comparative analysis between conventional and digital impression techniques revealed statistically significant differences in several key areas, including marginal adaptation, prosthodontic accuracy, and patient-reported satisfaction. Crowns fabricated using digital impression techniques consistently demonstrated superior clinical performance across multiple parameters.

In terms of marginal adaptation, crowns derived from digital impressions exhibited a significantly better marginal fit compared to those fabricated conventionally. **Table 3** At baseline, 81.0% of crowns made using digital impressions were rated as having excellent marginal adaptation according to USPHS criteria, whereas only 52.4% of conventional crowns achieved the same rating. Over a three-month observation period, the marginal integrity of conventional crowns further deteriorated, while digitally fabricated crowns maintained consistent marginal accuracy.(**Table 1**)

This outcome aligns with existing literature suggesting that digital impressions mitigate dimensional inaccuracies commonly associated with elastomeric materials, model casting errors, and technician variability.

Regarding anatomical form and occlusal contact, 76.2% of digitally fabricated crowns retained excellent anatomical form compared to 71.4% in the conventional group-a modest yet clinically relevant difference in preserving tooth morphology. More notably, 90.5% of digital restorations exhibited optimal occlusal contact, significantly reducing the need for post- cementation adjustments.(**Table 2**)

This underscores the precision of digital design and milling processes in replicating occlusal anatomy. Colour stability also favored digital techniques, with 85.7% of digitally produced crowns retaining their original shade after three months, compared to only 33.3% in the conventional group. This improvement is likely due to the use of advanced digital shade- matching tools and reduced human error in the CAD/CAM workflow.

Patient-reported outcomes further reinforced the advantages of digital impressions. Participants rated their experience with digital impressions significantly higher on the Visual Analogue Scale (VAS), citing increased comfort, reduced gag reflex, and shorter procedure times as key benefits. The absence of elastomeric materials and the less invasive nature of digital scanning contributed to an overall improved patient experience, making digital impression techniques not only more clinically effective but also more patient-friendly.(**Table 4**)

Table 1: Comparison of USPHS criteria immediately after crown placement among two groups

Criteria		Conventional			Digital			p- value
		Alpha	Bravo	Charlie	Alpha	Bravo	Charlie	
Patient satisfaction	n	14	5	2	18	3	0	0.288
	%	66.70%	23.80%	9.50%	85.70%	14.30%	0.00%	
Marginal fit	n	11	8	2	17	4	0	0.099
	%	52.40%	38.10%	9.50%	81.00%	19.00%	0.00%	
Anatomic form	n	18	2	1	18	3	0	0.549
	%	85.70%	9.50%	4.80%	85.70%	14.30%	0.00%	
Proximal contact	n	18	3	0	19	2	0	1.000
	%	85.70%	14.30%	0.00%	90.50%	9.50%	0.00%	
Occlusal contact	n	10	11	0	19	2	0	0.006*
	%	47.60%	52.40%	0.00%	90.50%	9.50%	0.00%	
Color match	n	8	11	2	18	3	0	0.005*
	%	38.10%	52.40%	9.50%	85.70%	14.30%	0.00%	
Occlusal wear	n	21	0	0	21	0	0	–
	%	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%	

* Indicates a significant difference at p≤0.05

Table 2: Comparison of USPHS criteria 3 months after crown placement among two groups

Criteria		Conventional			Digital			p-value
		Alpha	Bravo	Charlie	Alpha	Bravo	Charlie	
Patient satisfaction	**n**	9	10	2	16	4	1	0.088
	%	42.90%	47.60%	9.50%	76.20%	19.00%	4.80%	
Marginal fit	**n**	10	8	3	15	5	1	0.260
	%	47.60%	38.10%	14.30%	71.40%	23.80%	4.80%	
Anatomi c form	**n**	15	5	1	16	4	1	0.931
	%	71.40%	23.80%	4.80%	76.20%	19.00%	4.80%	
Proxim al contact	**n**	14	5	2	18	3	0	0.223
	%	66.70%	23.80%	9.50%	85.70%	14.30%	0.00%	
Occlusal contact	**n**	18	3	0	18	3	0	1.000
	%	85.70%	14.30%	0.00%	85.70%	14.30%	0.00%	
Color match	**n**	7	11	3	17	4	0	0.005*
	%	33.30%	52.40%	14.30%	81.00%	19.00%	0.00%	
Occlusal wear	**n**	18	3	0	19	2	0	1.000
	%	85.70%	14.30%	0.00%	90.50%	9.50%	0.00%	

* Indicates a significant difference at p≤0.05

Table 3: Comparison of marginal fit among the two groups

Region	Group	Mean	SD	Difference	p-value
Buccal	Conventional	27.48	3.30	6.58	<0.001*
	Digital	20.90	4.93		
Lingual	Conventional	45.48	5.84	14.67	<0.001*
	Digital	30.81	4.26		
Total	Conventional	72.95	7.09	21.24	<0.001*
	Digital	51.71	6.61		

* Indicates a significant difference at p≤0.05

Table 4: Comparison of Patient-centered outcomes using VAS score between the two groups

VAS score	Conventional		Digital		p-value
	Mean	SD	Mean	SD	
Overall discomfort of an impression	5.24	0.44	2.38	0.50	<0.001*
The overall time of impression	2.86	0.36	2.52	0.51	0.021*
Smell	3.48	0.51	1.62	0.50	<0.001*
Taste	3.10	0.44	1.10	0.30	<0.001*

Queasiness	3.90	0.30	1.29	0.46	<0.001*
Discomfort during mouth was opened	2.62	0.67	1.10	0.30	<0.001*
Discomfort in TMJ	1.90	0.30	1.00	0.00	<0.001*
Breathing difficulty	1.43	0.60	1.00	0.00	0.002*
Teeth and periodontal sensitivity	1.33	0.48	1.00	0.00	0.004*
Total evaluation score	25.86	1.59	13.00	1.84	<0.001*

* Indicates a significant difference at $p \leq 0.05$

4. Discussion

The integration of digital technologies into dental practice, particularly computer-aided design and computer-aided manufacturing (CAD-CAM) systems, has significantly enhanced the precision, efficiency, and cost-effectiveness of crown fabrication. Although the traditional lost wax technique remains widely used, it is associated with several limitations, including increased time requirements, multiple procedural steps, higher costs, and greater potential for error. In contrast, CAD-CAM technology enables the milling of crowns from pre-sintered porcelain or zirconia blocks, thereby minimizing internal defects, improving marginal fit, and reducing procedural variability.[7-10]

Zirconia crowns, when compared to all-metal and porcelain-fused-to-metal (PFM) restorations, exhibit superior mechanical properties, biocompatibility, and aesthetic outcomes, while also being MRI-compatible. IPS E-max CAD is preferred for anterior restorations due to its high translucency, whereas monolithic zirconia is favored for posterior restorations due to its greater flexural strength and cost-effectiveness.[11,12] Accurate marginal adaptation is critical to the long- term success of dental restorations, as poor fit may result in cement dissolution, microleakage, and increased plaque accumulation. Digital fabrication techniques enhance marginal accuracy and reduce these risks. Furthermore, zirconia crowns can be fabricated using either conventional or digital impressions.[13] While polyvinyl siloxane remains the preferred material for conventional impressions, it is susceptible to dimensional changes. Additionally, gypsum models used in traditional workflows may introduce errors due to expansion and abrasion.[14]

Digital impressions, obtained via intraoral scanners, eliminate several intermediate steps, thereby improving accuracy, enhancing patient comfort, and reducing turnaround time. These scans also facilitate improved communication, treatment planning, and patient education. Although factors such as saliva and bleeding may impact scan quality, they are generally manageable in clinical practice.[15-17]

The accuracy of marginal fit-particularly vertical marginal discrepancy-is a pivotal factor in the clinical success of restorations. This study measured marginal gaps using stereomicroscopy before cementation to exclude the influence of luting agents, with glass ionomer cement (GIC) used for final placement. Although no universal standard exists, a marginal gap below 100–120 µm is generally considered clinically acceptable. The results indicated that zirconia crowns fabricated via CAD-CAM exhibited a significantly lower marginal gap (51.71 ± 6.61 µm) compared to those produced using conventional impressions (72.95 ± 7.09 µm).

Patient satisfaction, an important evaluative parameter, was assessed using a visual analogue scale (VAS). Despite high-quality clinical outcomes, individual perceptions of care can vary. Satisfaction is closely linked to the extent to which care meets or exceeds expectations and directly influences clinical success and patient retention. The study found that digital impressions resulted in significantly less discomfort for patients and were perceived as easier to manage by clinicians. The digital group recorded a higher mean comfort score (25.86 ± 1.59 µm) than the conventional group (13.00 ± 1.84 µm, $p \leq 0.05$), consistent with prior studies by Lee et al.[12]

A three-month clinical evaluation using the USPHS criteria demonstrated that digital crowns outperformed conventional crowns across multiple domains. Patient satisfaction remained consistently higher in the digital group, both immediately post-placement and after three months.[18-20] Marginal adaptation was superior and more stable in digitally fabricated crowns. Although both groups initially exhibited comparable anatomic form and proximal contact, digital crowns maintained slightly better anatomical integrity and contact over time. Occlusal contact was significantly better in the digital group upon placement and remained stable. Colour match and stability were also superior in the digital group, with significantly less degradation observed over three months. While occlusal wear was minimal in both groups, digital crowns showed marginally better wear resistance. Collectively, these findings suggest that digital techniques offer enhanced clinical outcomes, precision, and patient-centered benefits compared to conventional methods.[21]

5. Conclusion

Within the limitations of this split-mouth randomized clinical trial, the findings demonstrate that digital impression techniques significantly outperform conventional polyvinyl siloxane- based methods in the fabrication of monolithic zirconia crowns. Crowns derived from digital impressions exhibited superior marginal adaptation, reduced occlusal discrepancies, and enhanced colour stability over time. These improvements can be attributed to the elimination of material-induced distortions, increased precision in data acquisition, and the inherent accuracy of CAD/CAM workflows.

Furthermore, digital impressions were associated with significantly higher levels of patient- reported satisfaction, primarily due to improved procedural comfort, reduced chairside time, and the non-invasive nature of the scanning process. Collectively, these outcomes suggest that digital impression systems not only enhance prosthodontic accuracy and clinical efficiency but also contribute to a more favorable patient experience.

The integration of digital workflows in fixed prosthodontics represents a clinically advantageous shift toward more precise, efficient, and patient-friendly treatment protocols. Continued research involving larger cohorts, extended follow-up periods, and multi-center validation is recommended to substantiate these findings and explore long-term clinical outcomes.

6. Clinical Implications

The CAD/CAM-based digital workflow offers measurable benefits over conventional methods, including enhanced marginal adaptation, improved prosthodontic outcomes, and greater patient satisfaction. The superior fit of digitally fabricated crowns reduces the risk of microleakage and associated complications such as secondary caries and periodontal inflammation. Moreover, the accuracy of occlusal contacts and long-term color stability underscore the clinical reliability of digital systems. From a workflow perspective, digital impressions streamline clinical procedures, reduce chairside time, and increase efficiency for both clinicians and dental laboratory technicians.

7. Source of Funding

None.

8. Conflict of Interest

None.

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Cite this article: Singla N, Datta P, Rani G, Tripathi S, Chaudhary N, Pal SR. Comparative evaluation of marginal fit, prosthodontic and patient centered outcomes of milled zirconia crown using conventional and digital impression techniques – A split mouth, randomized clinical trial. *J Dent Spec*. 2025;13(2):192-197.