PILOT STUDY

Pioneering 3D-printed dental crowns for adult patients: a pilot quasi-experimental study in Karachi, Pakistan

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Abstract

Objective: To compare patient-reported clinical outcomes between patients receiving three-dimensional-printed dental crowns versus conventional ones.

Method: The pilot, quasi-experimental, single-blind study was conducted at Karachi Medical and Dental College, Karachi, from April to November 2024, and comprised patients with a clinical indication for dental crown placement. Based on the attending dentist's clinical judgment, the participants were assigned to three-dimensional-printed crown group A or conventional crown group B. Data was collected using semi-structured interviews. Outcomes were assessed 15 days after the procedure, and intergroup comparison was done. Data was analysed using Stata 15.

Results: Of the 24 participants, 12(50%) each were in the two groups, and both the groups had 6(50%) males and as many females. The mean age in group A was 29.8±8.4 years compared to 47.7±15.5 years in group B (p=0.002). Patients in group A reported more favourable outcomes, and higher satisfaction compared to those in group B (p<0.05). No significant difference was observed in occlusal function (p=0.478).

Conclusion: The three-dimensional-printed dental crowns were found to be more effective than conventional crowns.

Key Words: 3D-printed crowns, Digital dentistry, Conventional crown, Pilot study.

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Introduction

Dental crowns are widely used in restorative dentistry to replace missing teeth and restore the function, aesthetics and structural integrity of the damaged teeth. Traditionally, these crowns are fabricated using materials, such as porcelain-fused-to-metal (PFM) or all-ceramic compounds, which have been the gold standard for several decades due to their durability and effectiveness .[1] However, the conventional fabrication process for these crowns is time-consuming and costly, requiring multiple appointments, detailed impressions and extensive laboratory work, resulting in high costs and inconvenience for patients.[2]

In recent years, the advent of three-dimensional (3D) printing technologies has presented a promising solution for the dental restoration process. Through additive manufacturing, 3D printing enables same-day fabrication, reducing the need for multiple appointments and minimising material wastage. This technology also provides improved customisation, enhances clinical efficiency, and reduces dependency on external dental labs, while aiming at maintaining similar or even superior clinical outcomes compared to the traditional crowns.[3] Additionally, 3D printing techniques are more cost-effective for patients because of low material cost.[4]

In contemplating the adoption of digital dentistry, numerous studies have explored clinical performance, accuracy, strength and patient satisfaction associated with 3D-printed crowns compared to conventional crowns. Studies have reported that 3D-printed crowns have shown superior mechanical properties, inferior physical properties, and potentially compromised longevity compared to the traditional crowns.[5,6] Also, 3D printing allows for the fabrication of metal-free crowns, which can offer improved aesthetic outcomes compared to the traditional metal-based crowns.[7] Patients with 3D-printed prostheses have reported higher overall satisfaction.[8]

The 3D Printing Country Index highlights global disparities in 3D printing adoption. High-income countries (HICs), like the United States, Germany and South Korea, have widely adopted 3D printing technology because of strong infrastructure, resources and skilled professionals. Regions like Europe and Asia have shown varying adoption levels, with some countries advancing faster than the others. In contrast, low- and middle-income countries (LMICs), including Pakistan, face challenges, such as limited resources, insufficient digital infrastructure, and a shortage of trained personnel,

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hindering widespread adoption.[9]

In Pakistan, the lack of locally relevant evidence-based research further hinders the adoption of 3D-printed dental crowns.[10,11] To address these gaps, the Aga Khan Development Network Digital Health Resource Centre (AKDN dHRC) has initiated efforts to utilise 3D printing technology to fabricate dental crowns, implants and dentures, and generate evidence-based insights for local adoption.

The current study was planned to assess patient-reported clinical outcomes, fit and comfort, occlusal function, patient satisfaction, appearance satisfaction and potential complications, among patients receiving 3D-printed dental crowns compared to those receiving conventional crowns in an LMIC setting.

Patients and Methods

The pilot, quasi-experimental, single-blind study was conducted at Karachi Medical and Dental College (KMDC), Karachi, from April to November 2024, after approval from the ethics review committee of Aga Khan University (AKU), Karachi, and formal permission from KMDC. The sample, raised using non-probability purposive sampling technique, comprised adult patients presenting at the outpatient department (OPD) with a clinical indication for dental crown placement either for functional restoration, like decay, caries and fractures, or aesthetic enhancement. Both vital and root-canal-treated teeth were considered eligible. Patients were excluded if they had complex dental conditions requiring treatment beyond crown placement, suffered from severe comorbidities, like uncontrolled diabetes, cardiovascular or renal disorders, had advanced periodontal disease, or declined to participate. The sample size aligned with the recommended sample size for pilot studies.[12] Based on the attending dentist's clinical judgment, the participants were assigned to 3D-printed crown group A or conventional crown group B.

After taking informed consent from the patients, baseline demographic and clinical data, including age, gender, medical history, and type of crown, was recorded.

Control group B received conventional porcelain crowns fabricated through standard manual techniques by certified dental laboratories. Intervention group A received crowns produced using 3D printing with permanent crown resin via additive manufacturing technology. Depending on clinical requirements, the crown units varied depending on clinical requirements, including single-, double- or triple-unit restorations, and the procedure lasted between 30 minutes and two hours. All the patients received standardised oral hygiene counselling post-treatment. The research team was committed to managing any complications related to the 3D-printed crowns for up to six months post-placement.

The outcome assessor was kept blinded to the grouping to minimise potential bias. Follow-up assessments were conducted via telephonic interviews 15 days post-intervention. Patient-reported outcomes, including crown fit and comfort, occlusal function, crown appearance, overall satisfaction, and the presence of any complications, such as pain, fractures or ulcers, ever noted.

Data was collected using a self-designed questionnaire. To establish content validity, a panel of five experts reviewed the questionnaire. Minor modifications were made based on expert feedback to improve comprehension, and the Scale-level Content Validity Index (S-CVI) scores were 1.00 for outcome items. Additionally, for the outcome-related items (fit and comfort, appearance, overall satisfaction, occlusal function), the scale showed good reliability with Cronbach's alpha (α) value 0.70, indicating acceptable internal consistency.

Crown fit and comfort assessed marginal fit and was rated on a 5-point Likert scale, ranging from 1 = very dissatisfied to 5 = very satisfied. The occlusal function was evaluated by patient-reported pain or discomfort while chewing (Yes/No). The crown appearance was assessed on a 5-point Likert scale based on satisfaction with colour and aesthetics, with responses ranging from 1 = very dissatisfied to 5 = very satisfied. Overall satisfaction was measured on a 5-point Likert scale, ranging from 1 = very dissatisfied to 5 = very satisfied. Finally, complications was recorded as a binary variable (Yes/No).

Data was analysed using Stata 15. Continuous variables were presented as mean ± standard deviation (SD) or median with interquartile range (IQR), while categorical variables were presented as frequencies and percentages. Data normality was assessed using the Shapiro-Wilk test. Independent t-tests were used for normally distributed continuous variables, and Fisher's exact test for categorical variables. Patient-reported outcomes were analysed using t-tests for normal distributions and the Wilcoxon rank-sum (Mann-Whitney) test for non-normal distributions. Occlusal function was assessed using Fisher's exact test. $P<0.05$ was considered significant.

Results

Of the 24 participants, 12(50%) each were in the two groups, and both the groups had 6(50%) males and as

Table-1: Demographic characteristics of the participants.

	Total n=24	3- D printed Crown n=12	Conventional Crown n=12	P value
Age (Mean±SD)	38.75 ±15.20	29.83±8.41	47.67±15.45	0.002
Gender n (%)				1
Male	12(50)	6(50)	6(50)	
Female	12(50)	6(50)	6(50)	
Crown Unit n (%)				1
Single Unit Crown	17(71)	8(67)	9(75)	
Double Unit Crown	2(8)	1(8)	1(8)	
Triple Unit Crown	5(21)	3(25)	2(17)	
Employment Status n (%)				0.276
Employed	8(33.3)	3(25)	5(41.6)	
Retired	2(8.3)	0(0.0)	2(16.7)	
Unemployed	14(58.3)	9(75)	5(41.7)	
Marital Status n (%)				0.155
Single	6(25)	5(42)	1(8)	
Married	18(75)	7(58)	11(92)	
Medical History n (%)				1
Yes	3(12.5)	1(8)	2(17)	
No	21(87.5)	11(92)	10(83)	

SD: Standard deviation.

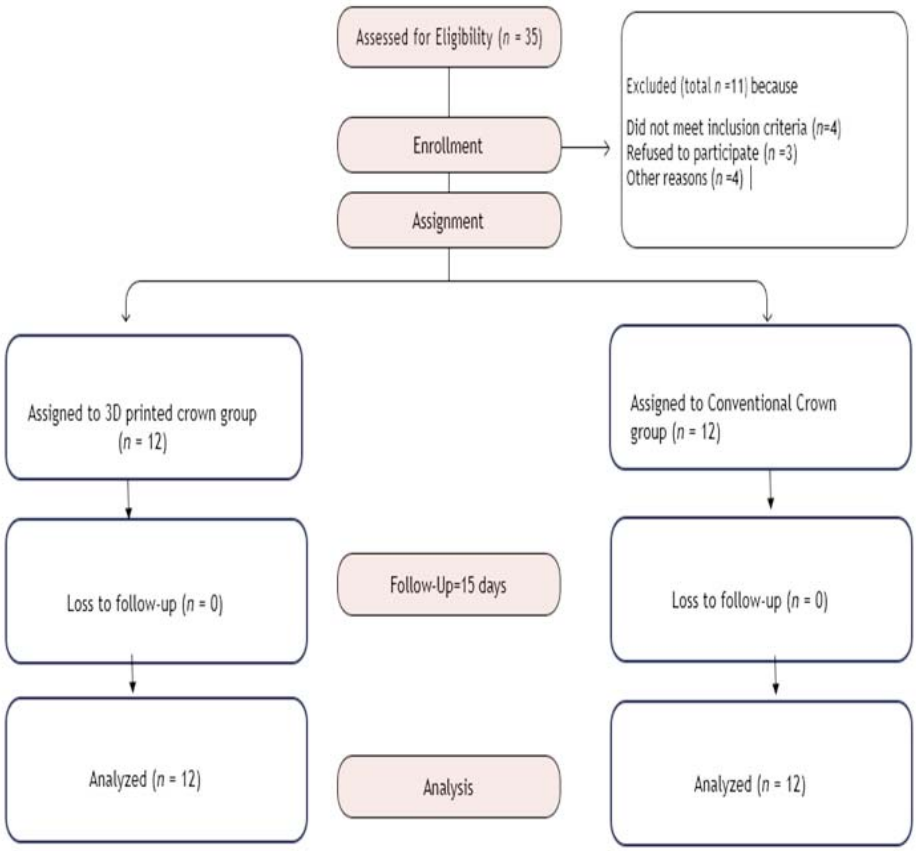

Figure-1: Study flowchart.

Table-2: Comparison of patient-reported outcomes.

	3-D printed Crown n=12	Conventional Crown n=12	P Value
Fit and Comfort Satisfaction Median (IQR)	5(4-5)	4 (4-4)	0.039
Appearance Satisfaction Mean (SD)	4.5(0.9)	3.4(0.9)	0.007
Overall Satisfaction Mean (SD)	4.3(0.7)	3.7(0.6)	0.033
Occlusal Function n (%)			0.478
No	10 (83.3)	12(100)	
Yes	2(16.7)	0(0.00)	

Values are reported as mean (standard deviation [SD\) for normally distributed variables, as median with interquartile range (IQR) for non-normal variables, and as frequency (n) and percentage (%) for categorical variables.

many females (Figure). The mean age in group A was 29.8±8.4 years compared to 47.7±15.5 years in group B (p=0.002).

There were no significant differences between the groups in terms of crown unit distribution, employment status, marital status and medical history (p>0.05) (Table 1).

Patients in group A reported more favourable outcomes, and higher satisfaction compared to those in group B (p<0.05). No significant difference was observed in occlusal function (p=0.478) (Table 2).

Discussion

The pilot, quasi-experimental study aimed at evaluating differences in fit, comfort, occlusal function, patient satisfaction, complications, and appearance of 3D-printed and conventional crowns. The findings highlighted no statistically significant differences in occlusal function, though significant differences were observed in crown fit, appearance and overall satisfaction between the groups.

Patients with 3D-printed crowns reported slightly higher satisfaction, suggesting improved comfort and fit. The higher satisfaction might be due to the advancement in 3D printing, particularly through Computer Aided System (CAD)/Computer Aided Manufacturing (CAM) systems that have substantially improved the precision and adaptability of dental prostheses.[13] Techniques like stereolithography (SLA), renowned for their high precision and rapid production, allow 3D-printed crowns to be manufactured with exact specifications, closely matching individual dental anatomy and improving comfort.[14,15] In contrast, the conventional crowns often involve manual fabrication processes that can lead to slight discrepancies in fit and decreased mechanical strength.[16]

Patients with 3D-printed crowns reported significantly higher appearance mean satisfaction scores compared to those with the conventional crowns in the current study. This finding aligns with previous literature, which suggests that 3D printing technology's ability to produce highly customised metal-free crowns improved aesthetics [8,17] However, in the current study, dissatisfaction due to colour fading over time was reported by some patients. This colour instability may be linked to the material's microstructure and lower polymerisation rates, which make it more susceptible to discolouration.[18] Enhancements in resin composition, improved polymerisation methods, and the application of surface treatments or protective coatings may help mitigate this issue.[19] Conversely, dissatisfaction in the current study with conventional crowns due to porcelain chipping was also reported. This complication could be a result of fabrication errors and may potentially be reduced by optimising firing processes and selecting more durable materials.[20]

The current study found no significant difference in occlusal function between 3D-printed and traditional crowns. However, another research reported that resin composite 3D-printed crowns may exhibit more occlusal dysfunction than the conventional crowns.[13] While 3D-printed dental crowns offer a better fit, continuous monitoring and occlusal adjustments may be necessary to maintain their functional integrity over time. Moreover, none of the participants reported a crown fracture in the current study. However, literature reported more 3D-printed crown fractures than conventional crown fractures.[21]

Patients with 3D-printed crowns reported higher overall satisfaction than those with the conventional crowns, likely due to lighter weight and improved fit, consistent with findings by Kharat S et al.[8] In the current study, differences in mean age between the groups may have contributed to differences in findings, as younger participants in the 3D-printed group could perceive greater satisfaction, suggesting age as a potential moderating factor. In contrast, de Souza FA et al. reported no significant difference, possibly reflecting variations in patient preferences, crown design and materials.[21] Overall, 3D-printed crowns appear to offer advantages in fit, aesthetics and comfort, likely due to enhanced customisation and precision.

A key strength of the current study lies in its comparative evaluation of 3D-printed dental crowns with the conventional crowns, providing valuable insights into the

clinical application of digital technology in dentistry. The study demonstrates the practical benefits of 3D printing, particularly in enhancing crown fit and comfort as well as overall patient satisfaction. Its comprehensive approach to assessing multiple patient-centred outcomes offers a holistic view of the performance and clinical implications of 3D-printed and conventional crowns, making these findings highly relevant to clinical practice. The study addresses a significant research gap by providing locally relevant evidence in an LMIC context, making it a valuable contribution towards understanding the feasibility of 3D printing in dentistry in these regions.

However, the current study has several limitations. The quasi-experimental design with non-randomised allocation may have introduced selection bias, limiting generalisability of the findings. Differences in mean participant age could have influenced outcomes, and the short follow-up period precludes assessment of long-term crown durability. Additionally, patient behaviours (e.g., betel nut chewing) and intraoral factors (e.g., periodontal health) were not controlled, which may affect crown performance. Addressing these limitations in future research would enhance the robustness of the findings.

Despite the limitations, the study contributes valuable insights to the growing body of literature on 3D-printed dental prosthetics, highlighting practical considerations for dental professionals in adopting digital technology, providing a foundation for informed decision-making in clinical practice

Conclusion

The 3D-printed dental crown offered significant advantages over the traditional crowns in terms of aesthetics, fit, comfort and patient satisfaction. While further research is needed to address long-term durability and material challenges, the potential benefits of 3D printing in enhancing access to high-quality dental care are undeniable.

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Conflict of Interest: None.

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SS, SSF, NA, FJ, SS, OA, HIA & AM: Concept, design, data acquisition, analysis, interpretation, drafting, revision and final approval.