RESEARCH PAPER

Evaluation And Comparison of Flexural Strength of Two Different Posterior Provisional Crowns Fabricated Using CAD-CAM and 3D Printing: An in-vitro study

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ABSTRACT

Background: Provisional restorations play an important role in fixed prosthodontics in maintaining function, esthetics and protecting prepared teeth until permanent restorations are applied. Digital dentistry is becoming more and more common, and computer-aided design/computer-aided manufacturing (CAD-CAM) milling and three-dimensional (3D) printing are now modern ways to make things. But there is limited comparative research on their flexural strength. The study aimed to assess and compare the flexural strength of posterior provisional crowns made utilizing CAD-CAM milling and 3D-printing technologies.

Materials and Methods: Thirty standardized acrylic dies were produced from a master cobalt chromium die and were randomly divided into 2 groups (n = 15). Group A was composed of temporary crowns milled from polymethyl methacrylate (PMMA) via CAD-CAM, and Group B was composed of crowns made of 3D-printed light-polymerized urethane dimethacrylate resin. The specimens were cemented with eugenol-free temporary luting cement and loaded in compression using a universal testing machine (crosshead speed: 1 mm/min) till fracture. Flexural strength was determined in Newton (N). The data were analyzed statistically using Shapiro Wilk test and independent samples t-test. The level of significance was established at $p < 0.05$.

Results: The mean flexural strength of CAD-CAM milled provisional crowns (1633.33 ± 391.09 N) was greater than 3D-printed provisional crowns (1452.00 ± 406.08 N). However, the difference between groups was not statistically significant ($t = 1.246$, $p = 0.223$). The values of flexural strength in both groups were higher than the typical posterior masticatory forces, showing good mechanical performance.

Conclusion: Flexural strength of CAD-CAM milled and 3D printed temporary crowns was clinically acceptable. CAD-CAM crowns had a greater mean fracture resistance, but the difference was not statistically significant, justifying the clinical use of both digital fabrication processes for posterior provisional restorations....

Keywords: CAD-CAM; 3D printing; temporary crowns; flexural strength; fracture strength; polymethyl methacrylate; digital dentistry.

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INTRODUCTION

Provisional restorations are an essential component of fixed prosthodontic treatment, serving as an intermediate restoration between tooth preparation and placement of the definitive prosthesis. They protect prepared teeth from thermal, chemical, and bacterial insults while maintaining pulpal vitality, occlusal stability, periodontal health, esthetics, and function. Additionally, they prevent tooth migration and allow evaluation of occlusion, phonetics, and esthetics before definitive rehabilitation. As these restorations may remain in function for extended periods, they must possess adequate mechanical properties to resist fracture and deformation under functional loading. Burns et al. emphasized that the success of fixed prosthodontic treatment largely depends on the structural integrity and clinical performance of provisional restorations throughout the treatment period.[1]

Among the mechanical properties of provisional restorative materials, flexural strength is particularly important because restorations are continuously exposed to compressive, tensile, and shear stresses during mastication. These multidirectional forces generate bending moments, and failure occurs when tensile stresses exceed the material's inherent strength. Osman and Owen demonstrated that fracture resistance testing closely simulates clinical loading conditions and provides a clinically relevant assessment of the flexural behavior of provisional restorative materials.[2] Similarly, Gegauff and Pryor highlighted that fracture toughness is a critical determinant of the longevity of provisional restorations, particularly in posterior regions where occlusal forces are considerably higher.[3]

Conventionally, provisional restorations are fabricated using autopolymerizing polymethyl methacrylate (PMMA), polyethyl methacrylate, or bis-acryl composite resins because of their ease of manipulation and cost-effectiveness. However, these materials are associated with limitations such as polymerization shrinkage, porosity, residual monomer release, dimensional instability, and reduced fracture resistance, which may compromise their clinical longevity. Haselton et al. reported that both material composition and resistance to functional loading significantly influence the clinical performance of provisional restorations.[4]

Advances in digital dentistry have introduced computer-aided design/computer-aided manufacturing (CAD-CAM) and three-dimensional (3D) printing as reliable methods for fabricating provisional restorations. CAD-CAM provisional crowns are milled from industrially polymerized PMMA blocks, resulting in improved polymer conversion, reduced porosity, superior dimensional accuracy, and enhanced mechanical properties. Stawarczyk et al. demonstrated that CAD-CAM milled provisional crowns exhibit significantly greater load-bearing capacity owing to their homogeneous microstructure.[5] Likewise, Rayyan et al. reported superior fit, marginal adaptation, and mechanical performance of CAD-CAM fabricated interim restorations compared with conventionally fabricated restorations.[6]

Three-dimensional printing has emerged as an attractive additive manufacturing technique because of its reduced material wastage, shorter fabrication time, lower production cost, and ability to fabricate complex anatomical structures. Nevertheless, the layer-by-layer manufacturing process may influence mechanical properties through variations in printing orientation, layer thickness, degree of polymerization, and interlayer bonding. Tahayeri et al. concluded that although 3D-printed provisional materials exhibit adequate mechanical properties for clinical application, they generally possess lower elastic modulus and different fracture behavior than conventionally processed materials, warranting further investigation.[7]

Recent studies have demonstrated encouraging results for digitally fabricated provisional restorations. Htay et al. reported that digitally fabricated implant-supported provisional crowns maintained fracture resistance above normal masticatory forces even after thermomechanical aging.[8] Yılmaz and Yeşil observed that CAD-CAM provisional restorations demonstrated superior fracture strength and marginal accuracy compared with 3D-printed and conventionally fabricated restorations.[9] Similarly, Titihazan et al. reported higher fracture resistance for CAD-CAM provisional materials while maintaining satisfactory esthetic performance.[10] However, Abtahi et al. and Digholkar et al. emphasized that the mechanical performance of provisional restorations remains highly dependent on both the fabrication technique and the material used.[11,12]

Posterior provisional crowns are subjected to greater occlusal forces than anterior restorations, making adequate flexural strength essential for preventing fracture during clinical service. Although CAD-CAM milling and 3D printing are increasingly used in contemporary prosthodontics, comparative evidence regarding the flexural strength of posterior provisional crowns fabricated using these techniques remains limited. Therefore, the present in vitro study was undertaken to evaluate and compare the flexural strength of CAD-CAM milled and 3D-printed posterior provisional crowns under simulated clinical loading conditions. The findings may assist clinicians in selecting the most appropriate digital fabrication technique for posterior provisional restorations.

METHODOLOGY

A digitally designed mandibular first molar was created with typical preparation parameters comprising a 1.0-mm circumferential shoulder finish line, 1.5-mm occlusal reduction and a 6-degree axial taper. The prepared tooth design was machined from a cobalt-chromium (Co-Cr) alloy to create a standardized metal master die. A bespoke tray was digitally developed and built with 3D-printing technology for imprint manufacturing. Impressions of the master die were made using polyvinyl siloxane impression material (putty and light-body consistency) and poured with self-cure clear acrylic resin to prepare thirty identical acrylic dies.

The acrylic dies were randomly divided into 2 groups (n = 15). A Medit T500 desktop dental laboratory scanner (Medit Corp., Seoul, South Korea) was utilized to scan the metal master die in Group A and an exocad DentalCAD 3.0 (Galway version) standard tessellation language (STL) file was generated. Fifteen provisional crowns were milled by CAD-CAM from industrially polymerized heat cured polymethyl methacrylate (PMMA) blanks by use of a CORiTEC 350i milling unit (imes-icore GmbH, Eiterfeld, Germany). In Group B, the identical STL file was utilized to create fifteen temporary crowns with a 3D printer (Ackuretta SOL-130, Ackuretta Technologies, Taiwan) and a light-polymerized urethane dimethacrylate resin .

All fabricated crowns were bonded onto their respective acrylic dies using a eugenol-free temporary luting cement under specified conditions. Each specimen was tested for fracture using a universal testing machine after cementation. A vertical compressive force was applied to the central fossa of each crown with a stainless-steel spherical indenter (5 mm diameter) at a crosshead speed of 1 mm/min till fracture. The maximum fracture force was determined in Newtons (N) and was regarded as the flexural strength of the provisional crown.

The data gathered were input into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were obtained for each group (mean, standard deviation, etc.). Data normality was tested using the Shapiro–Wilk test. As the data were normally distributed, the independent-samples t-test was employed to evaluate the mean flexural strength between the CAD-CAM milled and the 3D-printed provisional crowns. Statistical significance was defined as a P value of <.05.

RESULTS

Fifteen CAD-CAM milled PMMA crowns and 15 three-dimensional (3D)-printed resin crowns were examined, a total of 30 posterior provisional crowns. The flexural strength values of all the specimens were measured in Newton (N) and compared between the two production procedures.

The flexural strength tests showed a mean flexural strength of 1633.33 ± 391.09 N for the CAD-CAM milled provisional crowns and 1452.00 ± 406.08 N for the 3D-printed provisional crowns. The mean flexural strength of the CAD-CAM milled crowns was greater than that of the 3D-printed crowns. However, the variability within each group was similar, as demonstrated by the standard deviations (391.09 N and 406.08 N, respectively).

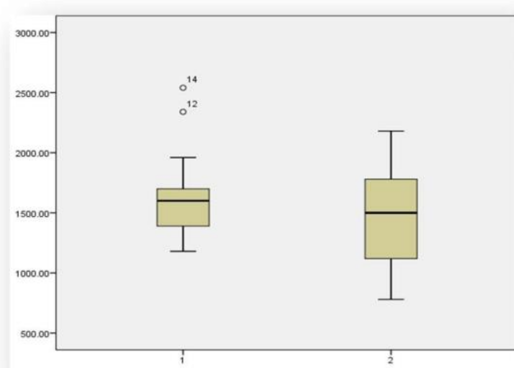
The mean flexural strength of two groups was compared statistically by independent-samples t-test and the difference was not statistically significant (t=1.246, p=0.223) (Table 1). The null hypothesis was accepted because the p-value was higher than the predetermined level of significance ($p < 0.05$), implying that no statistically significant difference in flexural strength existed between the CAD-CAM milled and 3D-printed provisional crowns under the experimental conditions. The boxplot of the flexural strength values of both groups is presented in Figure 1. The median flexural strength of the CAD-CAM milled provisional crowns was somewhat greater than that of the 3D-printed crowns. The interquartile ranges of the two groups overlapped significantly, indicating similar distributions of measures.

Table 1. Comparison of flexural strength between the study groups

Group	n	Mean ± SD(N)	t-value	p-value
CAD-CAM milled provisional crowns	15	1633.33 ± 391.09	1.246	0.223
3D-printed provisional crowns	15	1452.00 ± 406.08		

Independent-samples t-test; statistically significant at $p < 0.05$.

Figure 1: Boxplot Showing Distribution of Flexural Strength in CAD-CAM Milled and 3D Printed Provisional Crowns



DISCUSSION

This in vitro study compared and evaluated the flexural strength of posterior provisional crowns created with CAD-CAM milling and 3D-printing methods. CAD-CAM milled provisional crowns demonstrated higher mean flexural strength (1633.33 ± 391.09 N) than 3D-printed provisional crowns (1452.00 ± 406.08 N) as per the results. However, the difference between the two groups was not statistically significant (p = 0.223), which suggests that both fabrication procedures give clinically adequate mechanical performance for posterior provisional restorations.

Flexural strength is a crucial mechanical feature, because provisional crowns are continuously subjected to compressive, tensile and shear stresses during mastication. Osman and Owen revealed that flexural loading closely mimics the clinical stresses that cause fracture of provisional restorations. Therefore, fracture resistance testing provides a clinically relevant way to evaluate the mechanical performance of provisional restorations.[2] Kelly and Zhang et al. further stressed that fracture testing of anatomically shaped crowns better mimics the clinical behavior than typical bar-shaped specimens.[13,14] The increased flexural strength of the CAD-CAM group can be explained by the usage of industrially polymerized PMMA blocks. These materials are characterized by a dense homogeneous structure, low porosity, high degree of polymerization and hence superior mechanical qualities. According to Stawarczyk et al. and Abdullah et al. CAD-CAM milled provisional restorations had higher load bearing capacity and fracture resistance owing to their homogeneous microstructure and fewer internal flaws.[5,15]
Conversely, 3D printing is an additive manufacturing process whereby restorations are built up in a layer-by-layer fashion, utilizing light-polymerized resin. This method has advantages including fast production, less material waste and better freedom of design. However, the layer-by-layer approach might result in interlayer interfaces that alter the mechanical properties. Tahayeri et al. and Alharbi et al. found that the printing orientation, layer thickness, resin composition, and post-curing processes can alter the flexural strength and fracture behavior of 3D-printed provisional restorations.[7,16] The current study findings are in agreement with earlier studies . Digholkar et al demonstrated that CAD-CAM provisional materials have higher flexural strength than rapid prototyping materials because to better polymerization and structural uniformity.[11] In this way, CAD-CAM provisional restorations exhibit greater fracture strength than additive manufacturing techniques, despite the fact that both procedures provide clinically acceptable restorations.[17] Titihazan et al. also reported greater fracture resistance of CAD-CAM provisional materials than chairside materials.[10] Good results have recently been shown for digitally produced temporary restorations. Htay et al. demonstrated that fracture resistance of digitally generated provisional crowns was beyond typical masticatory stresses even after thermomechanical aging.[8] Pantea et al showed that mechanical properties of modern 3D printed interim materials are similar to traditional materials but CAD-CAM restorations usually have a mechanical advantage due to better structural homogeneity.[18] Furthermore, Park et al. emphasized the importance of optimizing printing conditions to improve the flexural strength of 3D-printed resins. The flexural strength values observed in the present study for both groups were higher than the normal posterior chewing forces reported in the literature, indicating that both CAD-CAM milled and 3D-printed provisional crowns have sufficient strength for clinical use during the provisional phase of treatment.[19] Thus, the statistical insignificance in the difference shows that any fabrication approach can be successfully used for posterior provisional restorations.

Clinically, CAD-CAM milled restorations can be favored in cases when higher mechanical durability is needed, such as long-span provisional restorations, parafunctional patients or lengthy durations of provisionalization . On the contrary, 3D printing has the advantages of less production time, less material waste, cheaper manufacturing cost, and easier incorporation into digital workflow. Thus, the choice of fabrication technology should be based not only on mechanical performance but also on clinical needs, treatment time, laboratory facilities, and cost factors.

CONCLUSION

Both CAD-CAM milled and 3D-printed provisional crowns demonstrated clinically acceptable flexural strength. Although CAD-CAM crowns exhibited higher mean fracture resistance, the difference was not statistically significant, supporting both techniques for posterior provisional restorations.

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