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Evaluation And Comparison Of Flexural Strength Of CAD/CAM Milled And Conventional Provisional Pmma Materials: An Invitro Study

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Abstract:
Background: *Provisional restorative materials must possess adequate mechanical properties to withstand functional stresses during temporization. With the advent of CAD/CAM technology, pre-polymerized PMMA materials have been introduced, offering improved strength and reliability compared with conventional resins. However, limited evidence exists regarding differences in flexural strength among commercially available CAD/CAM-milled PMMA materials.*
Materials and Methods: *A total of 60 specimens were fabricated and divided into three groups (n=20). Group A consisted of conventional self-polymerizing provisional PMMA (DPI). Group B and Group C consisted of CAD/CAM-milled provisional PMMA specimens fabricated from DELTA and UPCERA blocks, respectively. All specimens were prepared according to standardized dimensions. Flexural strength was evaluated using a three-point bending test in a universal testing machine. The data obtained were statistically analyzed using one-way ANOVA and post hoc tests.*
Results: *The mean flexural strength values were 26.88 ± 7.00 MPa for Group A, 91.69 ± 11.42 MPa for Group B (DELTA), and 113.83 ± 15.01 MPa for Group C (UPCERA). CAD/CAM-milled PMMA materials showed significantly higher flexural strength compared to conventional PMMA ($P<0.05$). Among the CAD/CAM materials, UPCERA demonstrated higher flexural strength than DELTA.*
Conclusion: *CAD/CAM-milled provisional PMMA materials exhibited superior flexural strength compared to conventional self-polymerizing provisional PMMA. Among the CAD/CAM materials, UPCERA showed the highest flexural strength, indicating better mechanical performance for provisional restorations.*
Key Words: *Polymethyl methacrylate; CAD/CAM; Flexural strength; Provisional restorations; Long- term temporization*

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I. Introduction

Provisional restorations play a vital role in fixed prosthodontics [[1]]. They serve as temporary restorations that protect the pulp of the prepared tooth, maintain esthetics, and allow evaluation of occlusal schemes and phonetics [[1]][[2]]. In addition, they help maintain inter-abutment alignment, periodontal health, and functional loading until the definitive prosthesis is delivered [[1]][[3]]. Provisional restorations are broadly classified as short-term or long-term based on their duration of use [[4]]. Short-term provisionals are typically used for a few days to weeks, whereas long-term provisional restorations are indicated when extended treatment periods are anticipated, such as during orthodontic therapy, full-mouth rehabilitation, delayed laboratory procedures, or patient unavailability [[4]]. Under such conditions, the mechanical properties of provisional materials become critical to ensure clinical success [[6]].

Conventionally, polymethyl methacrylate (PMMA) resins have been widely used for fabricating provisional restorations by both conventional techniques and computer-aided design/computer-aided manufacturing (CAD/CAM) methods [[6]]. CAD/CAM milling is a subtractive manufacturing process that produces restorations from pre-polymerized PMMA blocks, offering high reliability, superior dimensional accuracy, and improved mechanical properties [[8]][Error! Reference source not found.]. These advantages are attributed to industrial polymerization under high temperature and pressure, which results in a higher degree of conversion and reduced residual monomer compared with conventional methods [Error! Reference source not found.].

Flexural strength is a key mechanical property that reflects a material's ability to resist tensile and compressive stresses simultaneously, making it particularly important in areas subjected to occlusal loading [[9]]. Previous studies have compared the flexural strength of conventional, three-dimensional (3D)-printed, and CAD/CAM-milled provisional PMMA materials [[11]][[12]]. These studies have demonstrated that CAD/CAM-milled PMMA exhibits superior surface hardness, homogeneity, and flexural strength, making it suitable for long-span fixed dental prostheses and extended temporization [[11]][[12]][**Error! Reference source not found.**]. However, limited information is available regarding the comparison of flexural strength among different commercially available CAD/CAM-milled provisional PMMA materials. Therefore, the purpose of this in vitro study was to evaluate and compare the flexural strength of conventional self-polymerizing provisional PMMA material with two commercially available CAD/CAM-milled provisional PMMA materials.

II. Material And Methods

A total of 60 specimens were fabricated and divided into three groups, with 20 specimens in each group. Group A specimens were fabricated using conventional self-cure provisional PMMA material (DPI), whereas Groups B and C specimens were milled from two different commercially available pre-polymerized PMMA blanks (DELTA and UPCERA respectively)

A wax pattern with standardized dimensions of 25 mm (length) × 2 mm (breadth) × 2 mm (height) was prepared in accordance with ADA-ANSI specification No.27. A putty index was then made from this wax pattern, into which self-cure acrylic resin was poured to fabricate the Group A specimens. One of these specimens was selected as a reference sample and scanned to generate STL files for digital design. These STL files were subsequently used for milling the PMMA specimens in Groups B and C.

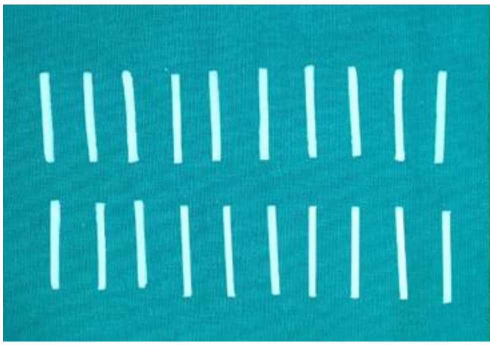


Fig. 1: Conventional group

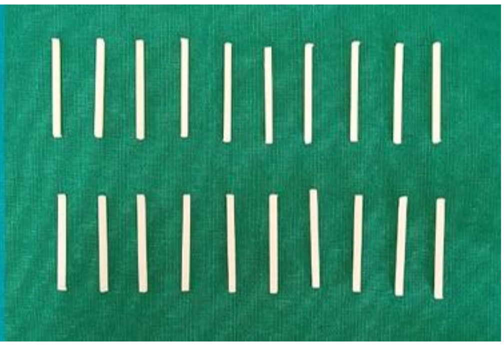


Fig. 2: Delta group

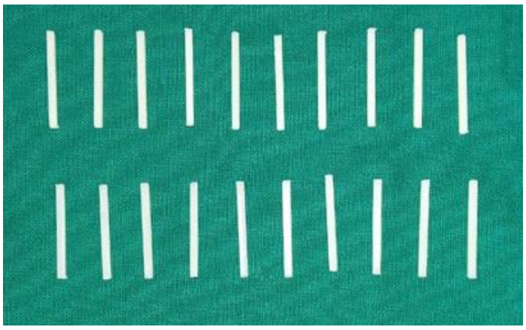


Fig. 3: Upcera group

Each specimen was subjected to a three-point bending test using a universal testing machine at a crosshead speed of 2 mm/min to evaluate flexural strength. Distance between supports is 20mm. The load was applied to the center of the specimen and continued till the specimen fractured. The fracture load was recorded (in kilonewtons) the results obtained were analyzed statistically. The flexural strength values were calculated using the following formula:

$$F.S = \frac{3FL}{2bd^2}$$

where F represents the fracture load, L is the span length, b is the width of the specimen, and d is the thickness of the specimen. The flexural strength values obtained were in KN/mm2, which were converted into Mega-Pascal (MPa) by multiplying it with 1000.

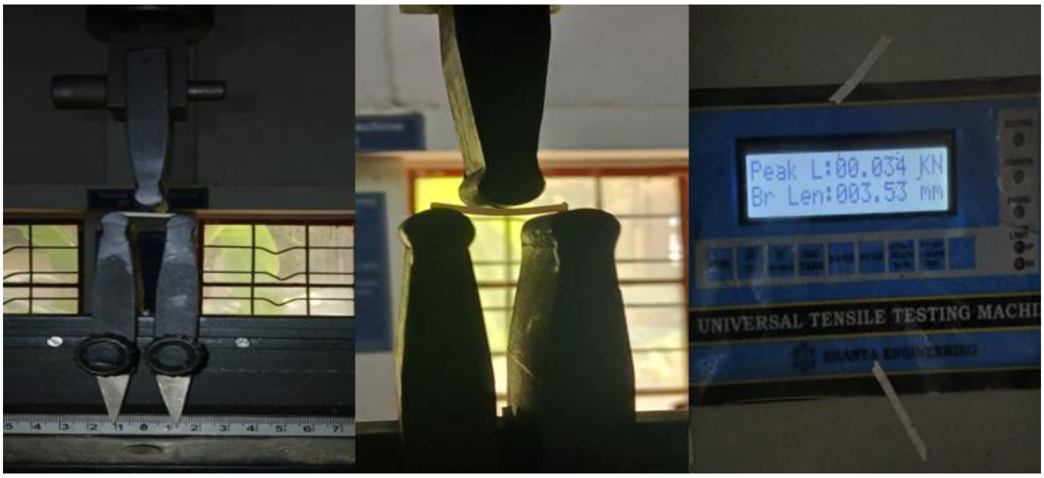


Fig. 4: Sample testing in Universal testing machine

III. Results

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software (version 26.0, IBM Corp., Armonk, NY, USA). Descriptive statistics, including mean, standard deviation, minimum, maximum, and 95% confidence intervals, were calculated for flexural strength (MPa) in each group. The assumption of normality was considered, and homogeneity of variances was assessed using Levene's test. Since the data satisfied the assumption of equal variances ($p > 0.05$), intergroup comparison of mean flexural strength among the three groups was performed using one-way analysis of variance (ANOVA). Following a statistically significant ANOVA result, post hoc multiple comparisons were carried out using Tukey's Honestly Significant Difference (HSD) test to identify pairwise differences between the groups. A p-value of less than 0.05 was considered statistically significant.

Table 1: Descriptive Statistics of flexural Strength (MPa) Among Conventional, Delta, and Upcera Groups

Group	N	Mean (MPa)	Std. Deviation	Std. Error	Minimum (MPa)	Maximum (MPa)
Conventional (Group A)	20	26.88	6.87	2.17	15.2	37.1
Delta (Group B)	20	91.69	10.78	3.41	77.8	111.2
Upcera (Group C)	20	113.83	14.71	4.65	87.4	137.2
Total	60	77.47	39.20	7.16	15.2	137.2

Interpretation: The mean flexural strength was lowest in the Conventional group (26.88 ± 6.87 MPa), followed by the Delta group (91.69 ± 10.78 MPa), and highest in the Upcera group (113.83 ± 14.71 MPa). The observed range of flexural strength values was 15.2–37.1 MPa for the Conventional group, 77.8–111.2 MPa for the Delta group, and 87.4–137.2MPa for the Upcera group

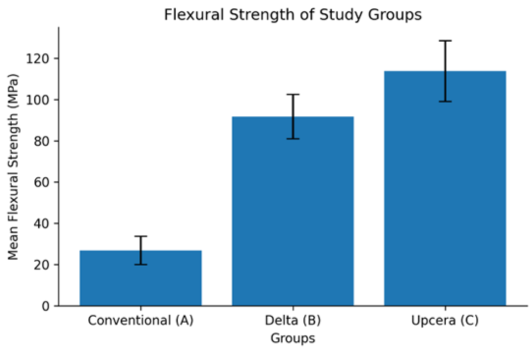


Table 2: One-Way Analysis of Variance (ANOVA) for Comparison of Mean flexural Strength (MPa) Among Conventional, Delta, and Upcera Groups

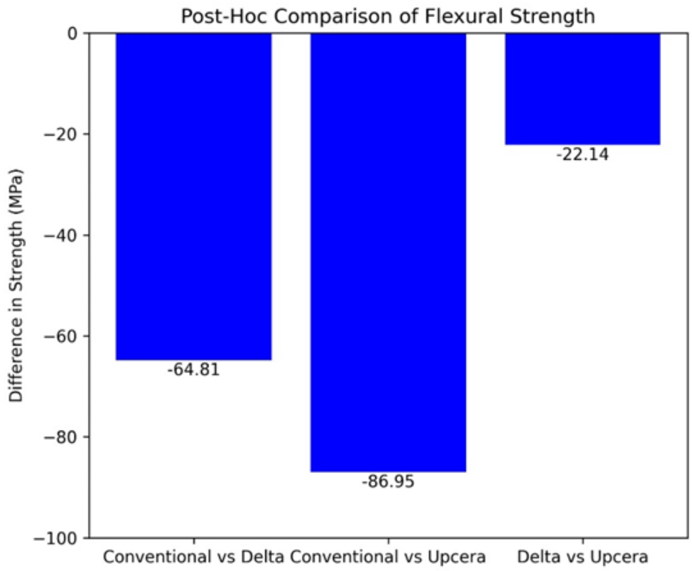
Source of Variation	Sum of Squares	Degrees of Freedom (df)	Mean Square	F Value	Significance (p value)
Between Groups	40465.52	2	20232.76	179.40	<0.001
Within Groups	3045.36	27	112.79		

Interpretation: One-way ANOVA revealed a statistically highly significant difference in mean flexural strength among the three groups ($p < 0.001$). This indicates that the observed differences in flexural strength were primarily due to differences between the materials rather than random variation.

Table 3: Post Hoc Multiple Comparisons Using Tukey's Honestly Significant Difference (HSD) Test for flexural Strength (MPa)

(I) Group	(J) Group	Mean Difference (I–J) (MPa)	Standard Error	Significance (p value)
Conventional (A)	Delta (B)	-64.81	4.75	<0.001
Conventional (A)	Upcera (C)	-86.95	4.75	<0.001
Delta (B)	Upcera (C)	-22.14	4.75	<0.001

Interpretation: Tukey's HSD post hoc test revealed that all pairwise comparisons showed statistically highly significant differences ($p < 0.001$), with Upcera demonstrating the highest flexural strength, followed by Delta, and Conventional showing the lowest.



Overall Interpretation:

The findings of the present study clearly demonstrate that flexural strength varies significantly among the three materials tested. Upcera exhibited the highest flexural strength, followed by Delta, while the Conventional material showed the lowest values. The differences were statistically highly significant across all comparisons, indicating superior mechanical performance of Upcera compared to both Delta and Conventional groups.

IV. Discussion

The present in vitro study evaluated and compared the flexural strength of conventional self-polymerizing PMMA and two commercially available CAD/CAM-milled PMMA materials. Based on the results, the CAD/CAM-milled groups exhibited significantly higher flexural strength than the conventional PMMA group, with the UPCERA CAD/CAM material demonstrating the highest values among all groups.

The superior performance of CAD/CAM-milled PMMA materials can be attributed to their industrial polymerization under controlled conditions of high temperature and pressure, resulting in a higher degree of monomer conversion and reduced residual monomer content [[8]][Error! Reference source not found.]. This leads to improved structural homogeneity, reduced internal porosities, and enhanced mechanical properties [[6]][Error! Reference source not found.]. In contrast, conventional self-polymerizing PMMA is more susceptible to polymerization shrinkage, air entrapment, and incomplete polymerization, which can compromise its flexural strength [[6]][[6]].

The finding that the UPCERA CAD/CAM material exhibited higher flexural strength than the DELTA CAD/CAM material suggests that not all CAD/CAM PMMA materials perform equally, despite being manufactured using similar subtractive techniques [[13]]. This difference may be attributed to variations in raw material composition, degree of cross-linking, polymer chain density, and manufacturing protocols among different commercial brands. Differences in filler content, polymerization cycles, and block fabrication processes may also influence the final mechanical properties [Error! Reference source not found.].

The superior flexural strength of UPCERA CAD/CAM PMMA compared to Delta PMMA may be attributed to its higher degree of polymer cross-linking, lower residual monomer content, higher filler content and reduced water sorption, resulting in enhanced resistance to crack propagation under load.

These findings are consistent with previous studies that have reported superior mechanical properties of CAD/CAM-milled PMMA compared with conventional provisional materials [[11]][**Error! Reference source not found.**]. Pre-polymerized PMMA blocks have been shown to exhibit enhanced flexural strength, surface hardness, and resistance to fracture, making them suitable for long-span fixed dental prostheses and extended temporization [[8]][**Error! Reference source not found.**].

Flexural strength is a critical parameter for provisional restorations, especially in posterior regions subjected to higher occlusal forces [[9]]. Materials with higher flexural strength are less prone to fracture under functional loading, thereby improving the durability and clinical longevity of provisional restorations [[9]].

Despite these findings, certain limitations of this study should be acknowledged. As an in vitro investigation, it does not fully replicate intraoral conditions, where factors such as thermal fluctuations, moisture, pH changes, and cyclic loading may affect material performance. Additionally, only flexural strength was evaluated, whereas other clinically relevant properties such as fracture toughness, wear resistance, and color stability were not assessed.

Future studies should incorporate thermocycling and fatigue loading to simulate oral conditions more closely. Further research comparing a wider range of commercially available CAD/CAM materials would provide a more comprehensive understanding of provisional material performance.

Within the limitations of this study, CAD/CAM-milled PMMA materials demonstrated superior flexural strength compared to conventional self-polymerizing PMMA. Among the CAD/CAM materials tested, UPCERA exhibited higher flexural strength than DELTA, indicating that material selection plays a significant role in the mechanical performance of provisional restorations.

V. Conclusion

Based on the findings of the study, it can be concluded that:

Among the three groups, the CAD/CAM-milled PMMA materials demonstrated higher mean flexural strength compared to the conventional self-polymerizing PMMA group. Among the CAD/CAM groups, the UPCERA specimens showed the highest mean flexural strength (113.83 MPa), followed by DELTA (91.69 MPa), whereas the conventional PMMA group exhibited the lowest values (26.88 MPa).

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