



A Comparative Study To Evaluate The Hardness and Flexural Strength of Commercially Available Five Types of Provisional Restorative Material- In Vitro Study

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Abstract

Objective: This in vitro study aims to evaluate and compare the hardness and flexural strength of five commercially available provisional restorative materials. The purpose is to provide dental professionals with critical data to inform material selection for temporary restorations, ensuring optimal patient care and prosthetic outcomes.

Materials and Methods: Five types of provisional restorative materials were selected for this study: polymethyl methacrylate (PMMA), bis-acryl composite, and three other commonly used materials in clinical practice. Specimens for each material were prepared according to standardized dimensions and protocols. Hardness was measured using a Vickers hardness tester, while flexural strength was assessed using a three-point bending test. Both tests were conducted under controlled

laboratory conditions to ensure consistency and accuracy of results

Results: The results indicated significant differences in the hardness and flexural strength among the five provisional materials. PMMA exhibited the highest hardness value, while one of the newer hybrid materials showed superior flexural strength. Bis-acryl composites demonstrated a balance between hardness and flexural strength, making them a versatile option for various clinical situations. The other materials showed varying degrees of performance, with some excelling in hardness but lacking in flexural strength, and vice versa.

Conclusion: The findings of this study underscore the importance of material selection in provisional restorations. PMMA, with its high hardness, is ideal for situations where wear resistance is critical. The hybrid material with superior flexural strength is recommended for cases requiring greater structural integrity. Bis-acryl composites offer a balanced approach, suitable for a wide range of temporary restorations. This comparative analysis provides valuable insights into the mechanical properties of provisional materials, aiding clinicians in making informed decisions to enhance patient outcomes.

Keywords: Provisional restorative materials, hardness, flexural strength, PMMA, bis-acryl composite, in vitro study, dental materials.

Introduction

A provisional restoration is an interim dental prosthesis that maintains aesthetics, provides masticating surfaces, and protects soft and hard tissues before the final prosthesis is delivered. It must meet various mechanical, biological, and aesthetical factors¹ Temporary restorations, such as crowns and fixed partial dentures made from acrylic resin, can last from a few weeks to half a year. The longer a material is exposed to the oral environment, the greater the likelihood of material wear

and discoloration. To lessen plaque adherence, reduce gingival inflammation, and prevent discoloration, the restoration's surface should be smooth.¹ Color stability of provisional materials is a concern when worn for extended periods in the aesthetic zone. Common materials include polyurethane dimethacrylate (PMMA), polyethyl methacrylate (PEMA), composite resin (bis-acryl composite), and polymethyl methacrylate (PMMA). PMMA is the most popular material for provisional fixed partial dentures due to its durability, color stability, ease of manipulation, and polishability. Bis-acryl composite resins, although more expensive, exhibit a mild exothermic reaction upon setting, good marginal fit, and moderate color retention and strength.^{2,4,5} The flexural strength of a provisional restoration is crucial to resist fracture, especially when the patient is subjected to use the restoration for an extended period or when long-span prosthesis is planned. Commercial accessibility of various surface processing processes and the wide choice of temporary prosthetic materials on the market make it difficult to provide advice on the best polishing technique.^{5,8}

Therefore, this study makes an attempt to compare and evaluate the hardness of four different materials used for fabrication of interim restoration.

Material and Method

Instruments and materials used in this study are,

1. Standard brass mould,
2. Addition silicon impression material(Flexceed)
3. Modelling wax, (Deepti)
4. Type II- Dental plaster (Dentsply India Private Limited)
5. Clamp and flask, (Eurolife India)
6. Heat cure polymethyl methacrylate (Acralyn - H)
7. Self cure polymethyl methacrylate, (DPI-RR Cold Cure)

8. Dual cure composite resin (3M ESPE)
9. Separating medium,
10. Milling machine
11. Polymethyl methacrylate CAD CAM, Composite CAD CAM,
12. Universal testing machine,
13. Fischer scope HM 2000,
14. Digital Vernier caliper

The five different types of commercially available provisional restorative materials were used listed as following,

Group A: Self cure polymethyl methacrylate.

Group B: Heat cure polymethyl methacrylate.

Group C: Dual cure Protemp.

Group D: Polymethyl methacrylate CAD CAM.

Group E: Composite CAD CAM.

Specimen Preparation

Preparation of the specimen was started by fabricating a putty index made from a standardized brass model measuring 10 mm x 10 mm x 2 mm (Fig 1 & 2). Ten specimens for flexural strength and ten specimens for microhardness of each group A, B, and C were fabricated using a putty index (Fig 7) made from a standardized brass model measuring 10 mm x 10 mm x 2 mm.

Ten specimens for flexural strength and ten specimens for microhardness of Groups D & E each were designed for the same dimensions i.e. 10 mm x 10 mm x 2 mm using the open-source CAD software. After the sample preparation for each group, they were set and finished according to their manufacturer's instructions.

All specimens were checked by a Vernier caliper for accurate dimensions (Fig 21). All the specimens were immersed in distilled water for 24 hours before testing.

GROUP A (Heat cure polymethyl methacrylate):

Wax patterns were created using a putty index fabricated from a brass model, then invested in an investment flask.

Heat polymerizing samples were fabricated using a compression moulding technique and a short curing cycle. Modeling wax was melted, poured into the index, and then invested in a dental flask. The wax pattern flushed with the plaster surface, creating two equal mold spaces for fiber reinforcement. (Fig 10).

The mould was dewaxed, cleaned, and flushed with boiling water. Acrylic dough was packed into flasks, bench cured for 60 minutes, followed by a heat-polymerized resin curing cycle. Samples were retrieved, finished, and polished. (fig 3,11)

GROUP B (Self-cure polymethyl methacrylate)

The process involved mixing auto polymerised resin monomer and polymer, packing it into a putty index, smoothing it with a cellophane sheet, and finishing the sample before polishing it. (Fig 13).

GROUP C (Dual cure composite resin)

Group C used a dual cure composite resin in a putty index, smoothed with a cellophane sheet, and cured using LED light for 30 seconds. After 5 minutes, the pattern was removed, finished, and polished. (fig 14)

Group D & E: (Polymethyl methacrylate CAD CAM & Composite CAD CAM)

The technique involves designing samples with set dimensions of 10mm x 10mm x 2mm using open-source CAD software, saving them as STL files and exporting them to 3D printing software. The samples are then milled in polymethyl methacrylate CAD CAM and Composite CAD CAM. After finishing, the samples are tested for flexural strength using a Universal Testing Machine with an accuracy of $\pm 1\%$ Model number Unitest 10 by ACME engineers, having an accuracy of $\pm 1\%$, and specifications cross head speed 1mm/minute with distance between supports 8 mm and dimension of 10m×10mm×2mm (Fig 17).

To calculate the Flexural Strength (F.S) following

Formula was used:

$F.S = 3PL / 2bd^2$ Where,

P= Fracture Load

L= Span Between Supports

d = Thickness

b=Width

To calculate the microhardness of the samples Vickers's Microhardness Tester was used with serial number 363798 of Brand Reichert Austria Make with Indenter Diamond and angulation 136 degrees with a load of 50 g (Fig 18 & 20).

Result

The present in vitro study was undertaken to compare the flexural strength and micro hardness of five different five types of provisional restorative material.

The samples were prepared by fabricating a putty index from a standardized size brass mould. For Group A,B and C having 10 samples each the sample was prepared through the putty index. For Group D and E the sample was prepared by designing the samples through CAD software prior to milling process.

The samples were categorized in five groups based on different materials:

Group A : Heat cure polymethyl methacrylate

Group B: Self-cure polymethyl methacrylate

Group C: Dual cure composite resin

Group D: Polymethyl methacrylate CAD CAM

Group E: Composite CAD CAM

For Group A ,the samples were made by first creating the wax patterns using putty index , then these pattern were invested in investment flask, then using the compression moulding technique and the short cycle the material was cured and finishing was done.

For Group B, the auto or cure polymethyl methacrylate monomer and polymer were mixed in the manufacturer

ratio and instructions and then placed in putty index ,after setting of the material the samples were finished and polished.

For Group C , a Dual core composite resin was placed in the mould of putty index ,then after initial set it was removed from index and cured with the light cure device for the final set for 30 seconds.

For Group D and E , the samples were designs in the CAD software before milling process , and then after designing the samples , they were milled in the PMM CAD CAM for Group D and Composite CAD CAM for Group E respectively.

The prepared samples were tested for flexural strength and micro hardness using the universal testing machine and Vickners' micro hardness tester.

All the values obtained from the study were tabulated and subjected to the statistical analysis using ANOVA test, Post- hoc Tukey's test and t-test using IBM SPSS-20 software, at the significance level of 0.05 (P<0.05=Significant).

Comparison of flexural strength between all groups:

Table 1: Comparison of flexural strength

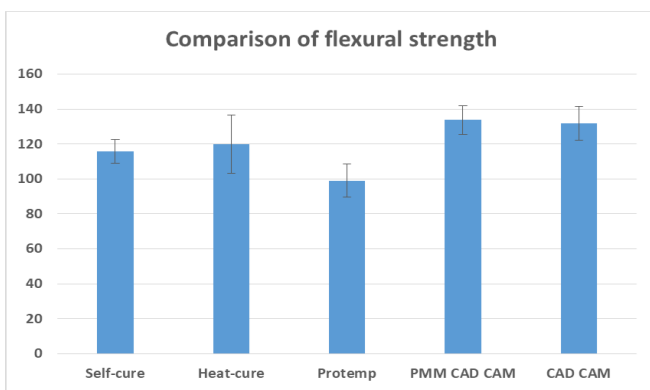
Group	N	Mean	SD	F value	p-value
Self-cure	10	115.8	6.7	17.170	<0.001*
Heat-cure	10	119.9	16.7		
Protemp	10	99.0	9.4		
PMM CAD CAM	10	133.7	8.3		
CAD CAM	10	131.9	9.6		

One-way ANOVA test; * indicates a significant difference at p≤0.05

In Group A, the mean value of the flexural strength analyzed was 119.9 with SD of 16.7 , for group B, the

Mean value for the flexural strength was 115.8 with SD 6.7, for group C., Mean value flexural strength analyzed was 99 with SD of 9.4; which was least among all five group , for group D, the Mean value for the flexural strength was 133.7 with SD 8.3 which was highest among all and for Group E the mean value for Flexural length was 121.9 with standard deviation of 9.6 that was second highest among all five groups.(Graph 1 Table 4). The difference in the flexural strength values of the five groups was statistically significant.

Graph 1: Comparison of flexural strength



Comparison of flexural strength between all groups

Comparison between GROUP A and GROUP B:

As the mean value obtained by measuring flexural strength of group A of heat cure polymethyl methacrylate was 119.9 with SD of 16.7 and that of sample prepared by self cure polymethylmethacrylate was 115.8 with SD 6.7 .(Table 5 and Graph 2). The mean difference between group A and group B was -4.07 which showed mean increase of the flexural strength in group A (Table 5 & Graph 2).

Comparison between GROUP B and GROUP C

As the mean value obtained by measuring flexural strength of group B of self cure polymethyl methacrylate was 115.8 with SD 6.7and that Group C of sample prepared by Dual core composite resin i.e Protemp was 99 with SD of 9.4.(Table 5 and Graph 2). The mean difference between group B and group C was 16.8

which showed mean increase of the flexural strength in group B (Table 5 & Graph 2).

Comparison between GROUP B and GROUP D

As the mean value obtained by measuring flexural strength of group B of self-cure polymethyl methacrylate was 115.8 with SD 6.7and that Group D of sample prepared by Polymethyl methacrylate CAD CAM was 133.7 with SD of 8.3.(Table 5 and Graph 2). The mean difference between group B and group D was -17.88 which showed mean increase of the flexural strength in group D (Table 5 & Graph 2).

Comparison between GROUP B and GROUP E

As the mean value obtained by measuring flexural strength of group B of self-cure polymethyl methacrylate was 115.8 with SD 6.7and that Group E of sample prepared by composite CAD CAM was 131.9 with SD of 9.6.(Table 5 and Graph 2). The mean difference between group B and group E was -16.08 which showed mean increase of the flexural strength in group E (Table 5 & Graph 2).

Comparison between GROUP A and GROUP C

As the mean value obtained by measuring flexural strength of group A of heat cure polymethyl methacrylate was 119.9 with SD of 16.7 and 7and that Group C of sample prepared by Dual core composite resin i.e Protemp was 99 with SD of 9.4. (Table 5 and Graph 2). The mean difference between group A and group C was 20.87 which showed mean increase of the flexural strength in group A (Table 5 & Graph 2)

Comparison between GROUP A and GROUP D

As the mean value obtained by measuring flexural strength of group A of heat cure polymethyl methacrylate was 119.9 with SD of 16.7 and that Group D of sample prepared by Polymethyl methacrylate CAD CAM was 133.7 with SD of 8.3. (Table 5 and Graph 2). The mean difference between group A and group D was -4.20

which showed mean increase of the flexural strength in group D (Table 5 & Graph 2).

Comparison between GROUP A and GROUP E

As the mean value obtained by measuring flexural strength of group A of heat cure polymethyl methacrylate was 119.9 with SD of 16.7 that Group E of sample prepared by composite CAD CAM was 131.9 with SD of 9.6.(Table 5 and Graph 2). The mean difference between group A and group E was -12.01 which showed mean increase of the flexural strength in group E (Table 5 & Graph 2).

Comparison between GROUP C and GROUP D

As the mean value obtained by measuring flexural strength that Group C of sample prepared by Dual core composite resin i.e Protemp was 99 with SD of 9.4 and that of sample that Group D prepared by Polymethyl methacrylate CAD CAM was 133.7 with SD of 8.3. The mean difference between group C and group D was - 34.68 which showed mean increase of the flexural strength in group D (Table 5 & Graph 2).

Comparison between GROUP C and GROUP E

As the mean value obtained by measuring flexural strength of that Group C of sample prepared by Dual core composite resin i.e Protemp was 99 with SD of 9.4 and Group E of sample prepared by composite CAD CAM was 131.9 with SD of 9.6. (Table 5 and Graph 2). The mean difference between group C and group E was - 32.88 which showed mean increase of the flexural strength in group E (Table 5 & Graph 2).

Comparison between GROUP D and GROUP E

As the mean value obtained by measuring flexural strength of that Group D prepared by Polymethyl methacrylate CAD CAM was 133.7 with SD of 8.3 and Group E of sample prepared by composite CAD CAM was 131.9 with SD of 9.6. (Table 5 and Graph 2). The mean difference between group A and group B was 1.80

which showed mean increase of the flexural strength in group D (Table 5 & Graph 2)

Table 2: Pairwise comparison of flexural strength

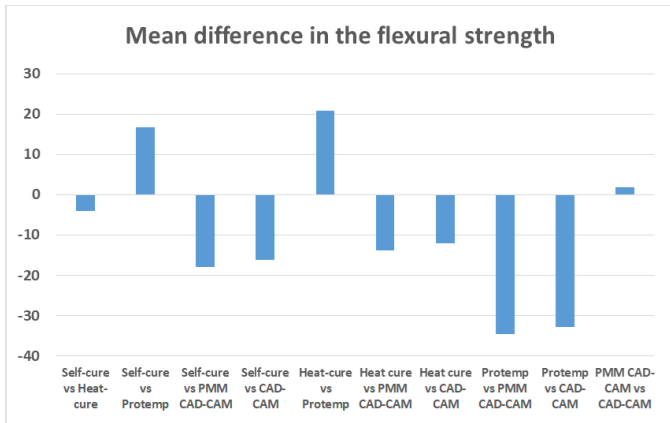
Group	Mean difference	p-value
Self-cure vs Heat-cure	-4.07	0.913
Self-cure vs Protemp	16.80	0.009*
Self-cure vs PMM CAD-CAM	-17.88	0.005*
Self-cure vs CAD-CAM	-16.08	0.013*
Heat-cure vs Protemp	20.87	0.001*
Heat cure vs PMM CAD-CAM	-13.81	0.045*
Heat cure vs CAD-CAM	-12.01	0.107
Protemp vs PMM CAD-CAM	-34.68	<0.001*
Protemp vs CAD-CAM	-32.88	<0.001*
PMM CAD-CAM vs CAD-CAM	1.80	0.996

Post hoc Tukey test; * indicates a significant difference at $p \leq 0.05$

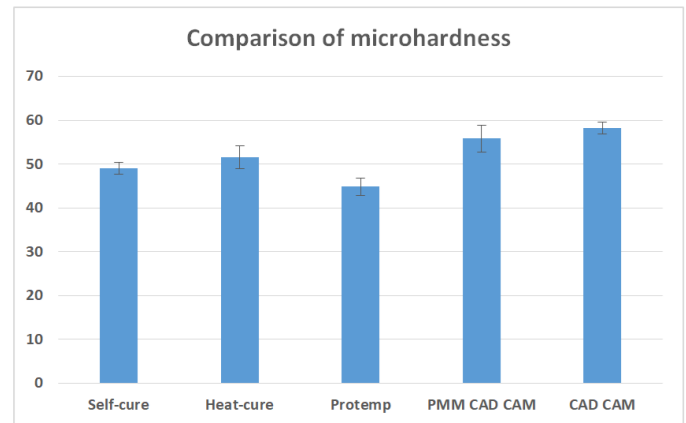
Inter group comparison (Tukey’s Post Hoc test)

The pairwise comparison of flexural strength values among the five groups. PMM CAD CAM material showed a significantly greater flexural strength as compared to the self-cure, heat-cure, and protemp material and similar flexural strength to that of the CAD CAM material. CAD CAM material showed a significantly greater flexural strength as compared to the self-cure, and protemp material and similar flexural strength to that of the heat-cure material. Protemp material showed a significantly lower flexural strength as compared to the self-cure, heat-cure, PMM CAD CAM and CAD CAM material.

Graph 2: Mean difference of flexural strength



Graph 3: Comparison of micro hardness



Comparison of Micro Hardness

Table 3: Comparison of microhardness

Group	N	Mean	SD	F value	p-value
Heat-cure	10	51.6	2.6		
Self-cure	10	49.0	1.4		
Prot Kemp	10	44.8	2.0		
PMM CAD CAM	10	55.8	3.1		
CAD CAM	10	58.2	1.4		

One-way ANOVA test; * indicates a significant difference at $p \leq 0.05$

In Group A, the mean value of the micro hardness analyzed was 51.6 with SD of 2.6, for group B, the Mean value for the micro hardness was 49.0 with SD 1.4, for group C, Mean value microhardness analyzed was 44. with SD of 2.0; which was least among all five group , for group D, the Mean value for the micro hardness was 55.8 with SD 3.1 which was second highest among all five and for Group E the mean value for micro hardness was 58.2 with standard deviation of 1.4 that was highest among all five groups.(Graph 3 , Table 6). The difference in the flexural strength values of the five groups was statistically significant.

Comparison of micro hardness between all groups:

Comparison between GROUP A and GROUP B:

As the mean value obtained by measuring micro hardness of group A of heat cure polymethyl methacrylate was 51.6 with SD of 2.6 and that of sample prepared by self-cure polymethylmethacrylate was 49.0 with SD 1.4. (Table 7 and Graph 4). The mean difference between group A and group B was -2.60 which showed mean increase of the micro hardness in group A (Table 7 & Graph 4).

Comparison between GROUP B and GROUP C

As the mean value obtained by measuring micro hardness of group B of self-cure polymethyl methacrylate was 49.0 with SD 1.4 and that Group C of sample prepared by Dual core composite resin i.e. Prot Kemp was 44. with SD of 2.0. (Table 7 and Graph 4). The mean difference between group B and group C was 4.20 which showed mean increase of the micro hardness in group B (Table 7 & Graph 4)

Comparison between GROUP B and GROUP D

As the mean value obtained by measuring micro hardness of group B of self-cure polymethyl methacrylate was 49.0 with SD 1.4 and that Group D of sample prepared by Polymethyl methacrylate CAD CAM was 55.8 with SD of 3.1.(Table 7 and Graph 4). The mean difference between group B and group D was -6.80 which showed

mean increase of the micro hardness in group D (Table 7 & Graph 4).

Comparison between GROUP B and GROUP E

As the mean value obtained by measuring micro hardness of group B of self cure polymethyl methacrylate was 49.0 with SD 1.4 and that Group E of sample prepared by composite CAD CAM was 58.2 with SD of 1.4. (Table 7 and Graph 4). The mean difference between group B and group E was -9.20 which showed mean increase of the micro hardness in group E (Table 7 & Graph 4).

Comparison between GROUP A and GROUP C:

As the mean value obtained by measuring micro hardness of group A of heat cure polymethyl methacrylate was 51.6 with SD of 2.6 and that Group C of sample prepared by Dual core composite resin i.e Protemp was 44. with SD of 2.0. (Table 7 and Graph 4). The mean difference between group A and group C was 6.80 which showed mean increase of the micro hardness in group A (Table 7 & Graph 4).

Comparison between GROUP A and GROUP D

As the mean value obtained by micro hardness of group A of heat cure polymethyl methacrylate was 51.6 with SD of 2.6 and that Group D of sample prepared by Polymethyl methacrylate CAD CAM was 55.8 with SD of 3.1. (Table 7 and Graph 4). The mean difference between group A and group D was -4.20 which showed mean increase of the micro hardness in group D (Table 7 & Graph 4).

Comparison between GROUP A and GROUP E: As the mean value obtained by micro hardness of group A of heat cure polymethyl methacrylate was 51.6 with SD of 2.6 and that Group E of sample prepared by composite CAD CAM was 58.2 with SD of 1.4. (Table 7 and Graph 4). The mean difference between group A and group E was -6.60 which showed mean increase of the micro hardness in group E (Table 7 & Graph 4).

Comparison between GROUP C and GROUP D

As the mean value obtained by measuring micro hardness that Group C of sample prepared by Dual core composite resin i.e Protemp was 44. with SD of 2.0 and that Group D of sample prepared by Polymethyl methacrylate CAD CAM was 55.8 with SD of 3.1. (Table 7 and Graph 4). The mean difference between group C and group D was -11 which showed mean increase of the microhardness in group D (Table 7 & Graph 4).

Comparison between GROUP C and GROUP E: As the mean value obtained by measuring micro hardness that Group C of sample prepared by Dual core composite resin i.e Protemp was 44. with SD of 2.0 and that Group E of sample prepared by composite CAD CAM was 58.2 with SD of 1.4 (Table 7 and Graph 4). The mean difference between group C and group E was -13.40 which showed mean increase of the micro hardness in group E (Table 7 & Graph 4).

Comparison between GROUP D and GROUP E:

As the mean value obtained by measuring micro hardness of Group D of sample prepared by Polymethyl methacrylate CAD CAM was 55.8 with SD of 3.1 and that Group E of sample prepared by composite CAD CAM was 58.2 with SD of 1.4 (Table 7 and Graph 4). The mean difference between group D and group E was -2.40 which showed mean increase of the microhardness in group E (Table 7 & Graph 4).

Table 4: Pairwise comparison of microhardness

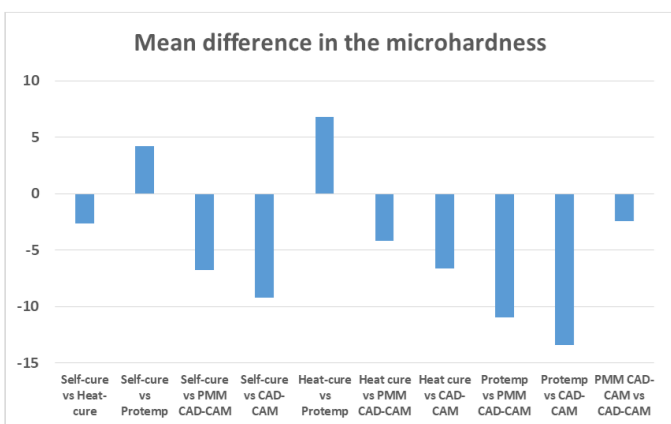
Group	Mean difference	P-value
Self-cure vs Heat-cure	-2.60	0.083
Self-cure vs Protemp	4.20	0.001*
Self-cure vs PMM CAD-CAM	-6.80	<0.001*
Self-cure vs CAD-CAM	-9.20	<0.001*
Heat-cure vs Protemp	6.80	<0.001*
Heat cure vs PMM CAD-CAM	-4.20	0.001*
Heat cure vs CAD-CAM	-6.60	<0.001*
Protemp vs PMM CAD-CAM	-11.00	<0.001*
Protemp vs CAD-CAM	-13.40	<0.001*
PMM CAD-CAM vs CAD-CAM	-2.40	0.128

Post hoc Tukey test; * indicates a significant difference at $p \leq 0.05$

Inter group comparison (Tukey’s Post Hoc test)

The pairwise comparison of microhardness values among the five groups. PMM CAD CAM material showed a significantly greater microhardness as compared to the self-cure, heat-cure, and protemp material and similar microhardness to that of the CAD CAM material. CAD CAM material showed a significantly greater microhardness as compared to the self-cure, heat-cure, and protemp material. Protemp material showed a significantly lower microhardness as compared to the self-cure, heat-cure, PMM CAD CAM, and CAD CAM material.

Graph 4: Mean difference of micro hardness



Discussion

This study compared the flexural strength and hardness of five commercially available provisional restorative materials: Heat-cure PMMA, Self-cure PMMA, Protemp, PMMA milled CAD CAM, and Composite milled CAD CAM. The materials were grouped as follows: Group A (Heat-cure PMMA), Group B (Self-cure PMMA), Group C (Protemp), Group D (PMMA milled CAD CAM), and Group E (Composite milled CAD CAM). Standardized specimens were fabricated using various techniques appropriate for each material.

Flexural Strength: The PMMA CAD CAM group exhibited the highest flexural strength, followed by the Composite CAD CAM group, with the least strength seen in the Protemp group. The differences among the groups were statistically significant. Microhardness: The Composite CAD CAM group had the highest microhardness, followed by the PMMA CAD CAM group, with Protemp again showing the lowest values. These differences were also statistically significant.

Flexural Strength: ** PMMA CAD CAM > Composite CAD CAM > Heat Cure PMMA > Self Cure PMMA > Protemp

Microhardness: Composite CAD CAM > PMMA CAD CAM > Heat Cure PMMA > Self Cure PMMA > Protemp

Provisional restorations are essential for protecting and recovering the aesthetics of abutment teeth before final restorations. Their duration can range from a few days to several weeks, depending on the case complexity and periodontal conditions. The ideal interim material should exhibit good marginal adaptation, adequate retention, durability, non-irritating properties, dimensional stability, and esthetic acceptability, while also being cost-effective. Mechanical properties such as flexural strength and hardness are crucial for the longevity and performance of

interim restorations. The study highlights the superiority of CAD/CAM-fabricated materials over conventionally processed materials, suggesting they are more suitable for prolonged use due to their higher strength, fracture resistance, and surface hardness.

Despite these findings, it is essential to note that in-vitro results may not always correlate perfectly with clinical performance. Therefore, ongoing research and clinical evaluations are necessary to validate these materials for long-term use in diverse clinical scenarios.

Conclusion

In the field of in situ restoration materials, there is still a necessity for advancement in terms of developing materials with superior properties to the contemporary used materials, as well as conducting long-term studies of the biocompatibility and wear of multiple materials in vivo. The aspect of surface finishing is of particular interest in the industry, as it is proved to affect the mechanical properties of the restoration. The application of CAD/CAM in dentistry provides state-of-art dental care. Hence, it is vital for the CAD/CAM framework in dentistry to be developed for further benefit of the patients,

With the limitation of the in-vitro study it is observed from the conducted study that there is a significant difference in wear resistance, surface hardness and fracture resistance among the groups

1. The highest flexural strength was seen in the PMM CAD CAM group followed by the CAD CAM group. The least flexural strength was seen in the Protemp group.
2. The difference in the flexural strength values of the five groups was statistically significant.
3. The highest microhardness value was seen in the CAD CAM group followed by the PMM CAD CAM

group. The least microhardness value was seen in the Protemp group.

4. The difference in the microhardness values of the five groups was statistically significant.

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Legend figures:

Figure 1: Standardized brass model



Figure 2: Material for making putty index



Figure 3: Material for Group A heat cure PMMA



Figure 4: Material for Group B self cure PMMA



Figure 5: Material for making Group C Protemp



Figure 6: Material for Group D, PMMA CAD-CAM

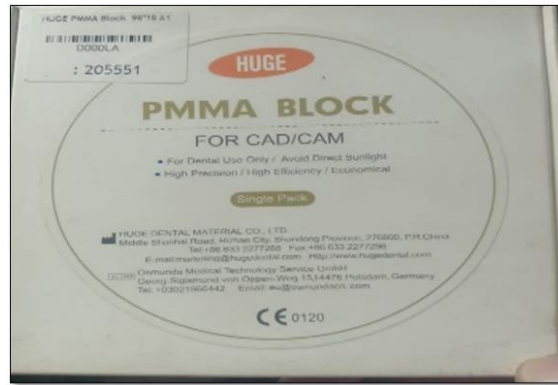


Figure 7: Material for Group E, Composite CAD CAM



Figure 8: Putty Index

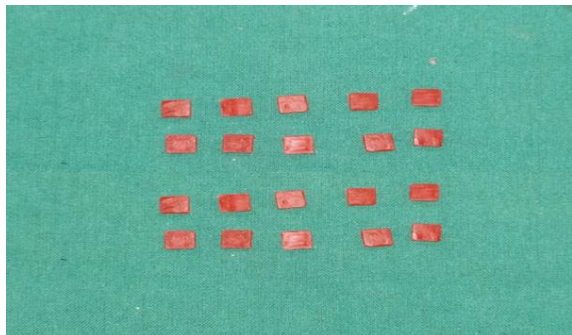


Figure 9: Wax pattern made from putty index

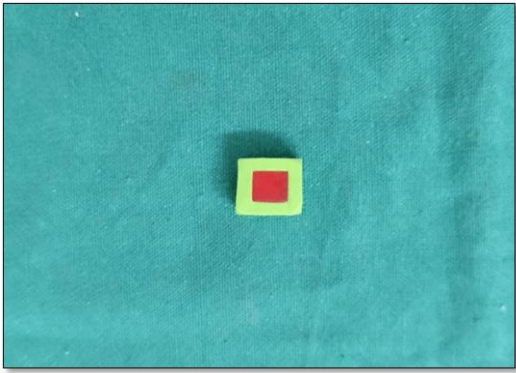


Figure 10: Wax pattern for heat cure PMMA

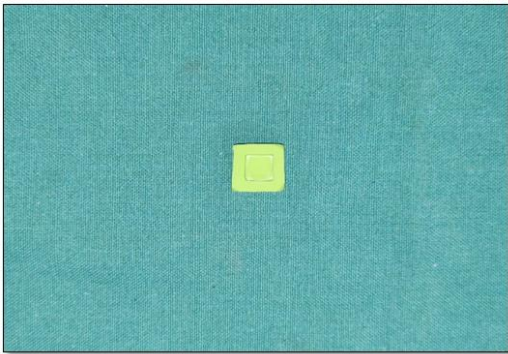


Figure 11: Wax pattern invested in flask

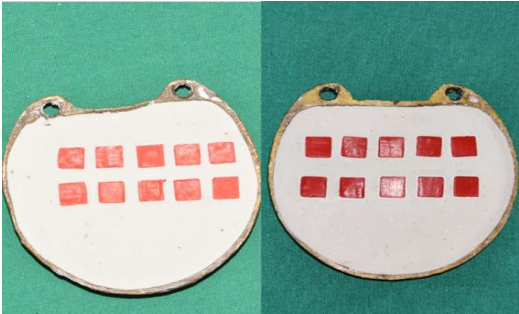


Figure 12: Sample for group A

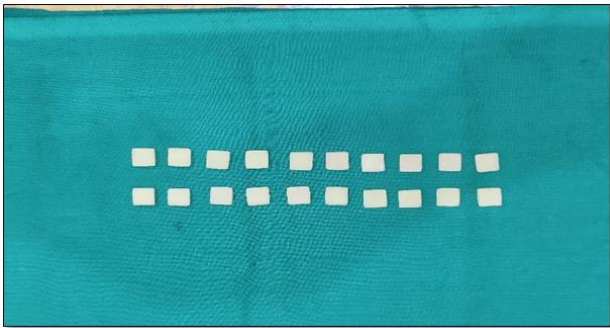


Figure 13: Sample for group B

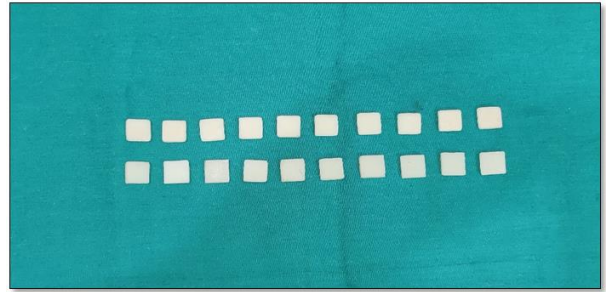


Figure 14: Sample for group C

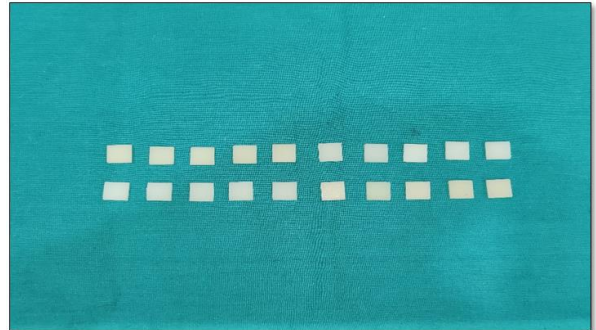


Figure 15: Sample for group D

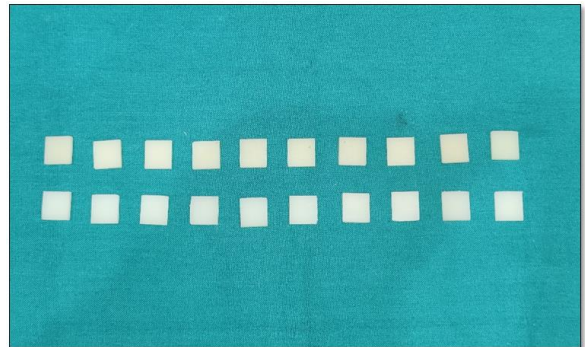


Figure 16: Sample for group E

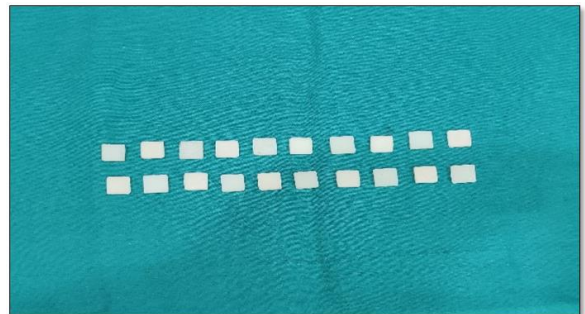


Figure 17: Universal testing machine



Figure 20: Milling machine for group D & E



Figure 18: Vickers' Microhardness Tester



Figure 21: Armamentarium for measuring length (Digital Vernier Caliper)



Figure 19: Placement of sample to test for microhardness

