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Original Research

A comparative analysis of compressive strength and surface roughness of three different provisional restorative materials - An in vitro study

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ABSTRACT:
Objective: Provisional dental crown and bridge materials (PCB) are intermediate solutions prior to long term restorations. They are aimed to rehabilitate the normal function and health of the dentition and its surrounding tissues. The purpose of this study was to compare and evaluate mechanical properties of different provisional restorative materials.**Aim:** The aim of the study was to evaluate and compare different provisional materials for compressive strength and surface roughness.**Materials and methods:** 30 bar shaped specimens of 8mm×4mm×4mm were made of provisional resins. The samples were equally distributed in groups of 10 each. Group A samples were fabricated by milling specimens with CAD/CAM milling machine from PMMA blank. Group B samples were made using Bis acryl composite resin and Group C samples were made Conventional autopolymerizing resin. All the samples were then tested for surface roughness and compressive strength.**Results:** A one-way ANOVA with Tukey HSD pair-wise comparisons was employed to analyze the data. Mean surface roughness for Group A was 1.129±0.664 µm, for Group B was 1.660±0.557 µm and for Group C was 1.214±0.338µm. There was statistically insignificant difference amongst the groups for surface roughness. Mean compressive strength for Group A was 106.528±4.309 N/sqmm, for Group B was 62.066±6.823 N/sqmm and for Group C was 75.605±8.352 N/sqmm respectively. There was statistically significant difference amongst the groups for compressive strength.**Conclusion:** The results of this study indicate that mechanical properties of the CAD/CAM pmma are superior than the other two counterparts- Bisacryl composite resin and conventional pmma.
Key Words:CAD/CAM, Compressive strength, Surface Roughness.

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INTRODUCTION

Over the decades, conventional self-cured and pressure-cured acrylic resins have been frequently used in the direct, indirect or indirect–direct fabrication of interim dental prostheses due to their affordability, favorable working characteristics, polish ability, and easy manipulation and repair. However, improved conventional interim prosthetic materials, such as bis-glycidyl methacrylate and bis-acryl-based materials provide better aesthetics, better mechanical properties, and lower polymerization shrinkage than acrylic resins. More recent technologies, such as

additive manufacturing (3D printing) and subtractive technology (milling), represent indirect modern CAD/CAM (computer-aided design/computer-aided manufacturing) methods for obtaining interim dental prostheses.

Although all these CAD/CAM technologies have different weaknesses and strengths it offers various advantages when compared to traditional manufacturing, including reduced production time (speed), less material waste, lower costs, easy mass customization, the independence of the milling instruments, the combination of materials, higher quality, and innovation/transformation. These aspects relating to the particularities of interim dental prosthetic materials represent subjects of interest in present-day medical scientific research and, at the same time, require continuous evaluation.[3]

MATERIAL AND METHODS

This invitro study was carried out in Department Of Prosthodontics and Crown & Bridge and Oral Implantology Rajasthan Dental College & Hospital, Jaipur, Rajasthan, to evaluate surface roughnessand compressive strength of different provisional materials namely CAD/CAM Upcera, Bis Acryl composite Resin Vericom and conventional Polymethyl methacrylate DPI.

Methodology:

FABRICATIONOFMASTERMODEL

To fabricate the test specimens master die was prepared with CAD/CAM polymer. Thedimensions of the master model was 8mm × 4mm × 4mmaccording to ASTM standards. (Figure 1)

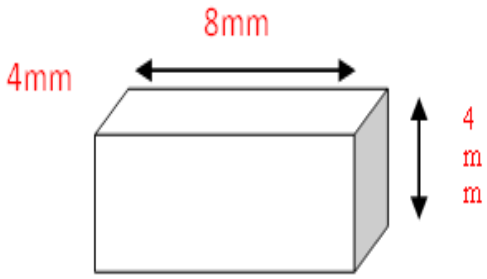


Figure 1: Line diagram of test specimen

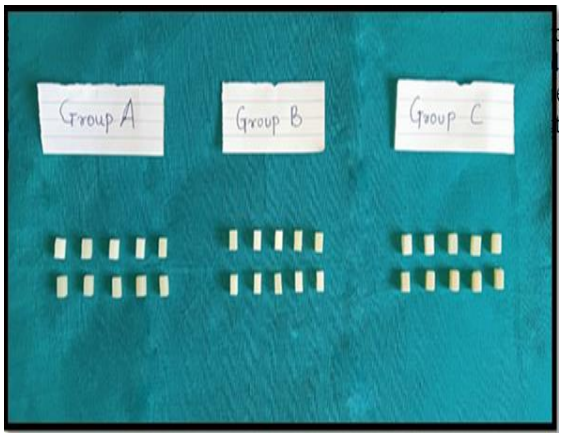
Test specimens of Group A were prepared from CAD/CAM Polymethyl methacrylate blocks. Test dimensions were kept at 8mm × 4mm × 4mm. An .STL file was developed by using ExoCad software of given dimensions and milling was done by using HYPERDENT CLASSIC CAM software. Test bars received by means of milling were polished under running water with a 400-grit and 1000-grit silicon carbide abrasive paper for 10s by a single operator. Ten such test specimens were prepared.

All specimens were numbered and catalogued for later identification. All specimens were polished using rubber polisher. Specimens were analysed using a stereomicroscope. A 50 × stereomicroscope was used in order to ensure the absence of cracks or defects. The specimens were then used for measurement of compressive strength and surface roughness.

Specimens of Group B were fabricated from dual cure Bisacryl composite resin. To create specimens of composite resins, soft thermoplastic sheet of 1.5mm was used. The sheet was cut into a circular shape for its adaptation on the Biostar pressure moulding device with a curved scissor and then placed on heater platform. Master dies were put onto the other platform of Biostar device. The sheet was heated by setting the code and recommended heating time according to the manufacturer's instructions. The pressure chamber was closed and opened after cooling phase had finished. The sheet was then removed.

The composite resin was mixed according to manufacturer's instruction and inserted into the thermoplastic mould in increments of 2mm. It was then allowed to polymerise and later light cured according to manufacturer's instructions. After polymerisation of 1st layer, next layer was added. A glass slab was placed on the open end of the mould to provide smooth surface. The specimens were removed from the mould after polymerization.

Each specimen was polished under running tap water with a 400-grit and 1000-grit silicon carbide abrasive paper for 10 s by a single operator. A 50 X stereomicroscope was used in order to ensure the absence of cracks or defects. All specimens were numbered and catalogued for later identification. The specimens were then used for measurement of compressive strength and surface roughness.

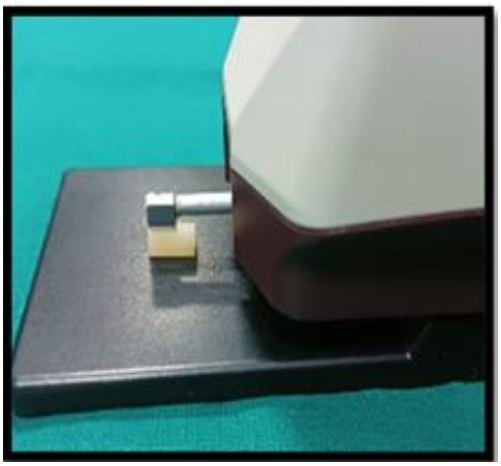


Group C test specimens were fabricated from autopolymerising PMMA. To create specimens of autopolymerising resins, soft thermoplastic resin moulds were used which were fabricated for Group B specimens. The autopolymerising resins was mixed according to manufacturer's instruction and inserted into the soft thermoplastic sheet moulds. The specimen was removed from the matrix after polymerization, according to the manufacturers' instructions in the laboratory at room temperature of 23°C.

Each specimen was polished under running water with a 400-grit and 1000-grit silicon carbide abrasive paper for 10 s by a single operator. A 50 X stereomicroscope is used in order to ensure the absence of cracks or defects. All specimens were numbered and catalogued for later identification. The specimens were then used for measurement of compressive strength and surface roughness.

- **Evaluation of Surface Roughness of Test Specimens**

Surface roughness of test specimens of all groups was evaluated using surface profilometer. The test specimens were placed on a flat surface and were kept at the same height of that of surface profilometer. The tip of the surface profilometer was allowed to run over the complete length of the specimen. The Ra value was recorded and then tabulated for each sample.



- **Evaluation of Compressive Strength of Test Specimens**

Test specimens of all groups were evaluated for compressive strength using Universal Testing Machine. Dimensions of all specimens were recorded and their mean values were inserted. A plastic guide was used to align the specimens on the flat platform of Universal Testing Machine. Another flat metal plate attached to the machines loading cell was kept in such a way that it just touched the specimen without applying any amount of force on it. Then a load of 10kN load cell was applied. Specimens were then loaded on at a crosshead speed of 1.3mm/min. The graph of Force at 10% strain was recorded as compressive strength of specimen.

Statistical analysis

The observations for Surface roughness and Compressive strength were tabulated and subjected to statistical analysis by one way analysis of variance (ANOVA) post Hoc Tukey HSD was used for multiple comparison between the three groups. The level of significance was set at $P \leq 0.05$.

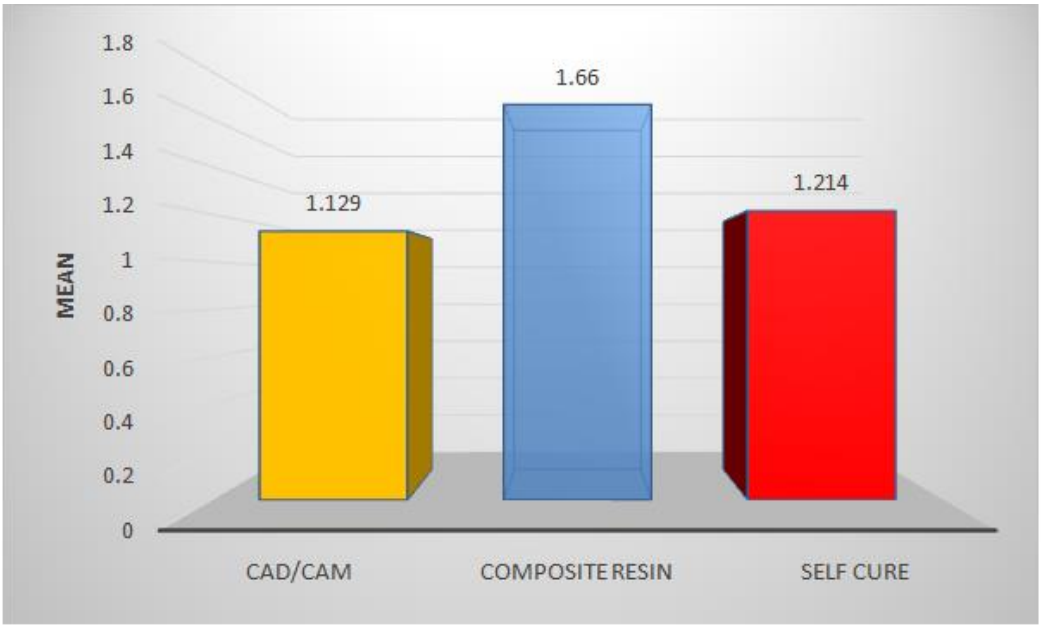
RESULT

Test specimens of each group were evaluated for surface roughness by surface profilometer. Compressive strength of test specimens of all groups was evaluated by Universal Testing Machine. The test values were recorded at 10% strain for each specimen. The observations for surface roughness and compressive strength were tabulated and subjected to one way ANOVA followed by post Hoc Tukey HSD test for multiple comparisons. The level of significance was set at $P \leq 0.05$.

SpecimenNo.	Surface Roughness (Ra value)		
	Group A(µm)	Group B(µm)	Group C (µm)
1	1.130	1.546	0.772
2	0.961	2.622	1.136
3	2.811	2.235	1.730
4	0.879	1.310	1.002
5	0.536	2.221	1.176
6	1.079	1.515	0.905
7	0.880	1.675	1.333
8	0.468	1.003	0.888
9	0.992	1.621	1.623
10	1.557	0.860	1.582
Mean ± Standard deviation	1.129±0.664µm	1.660±0.557µm	1.214±0.338µm

Descriptive statistics and one way ANOVA for surface roughness of all groups. On subjecting the mean values of surface roughness of Group A, Group B and Group C to one way analysis of variance the value of p was found to be 0.07 indicating that there is statistically insignificant difference in surface roughness of all groups. (P>0.05)

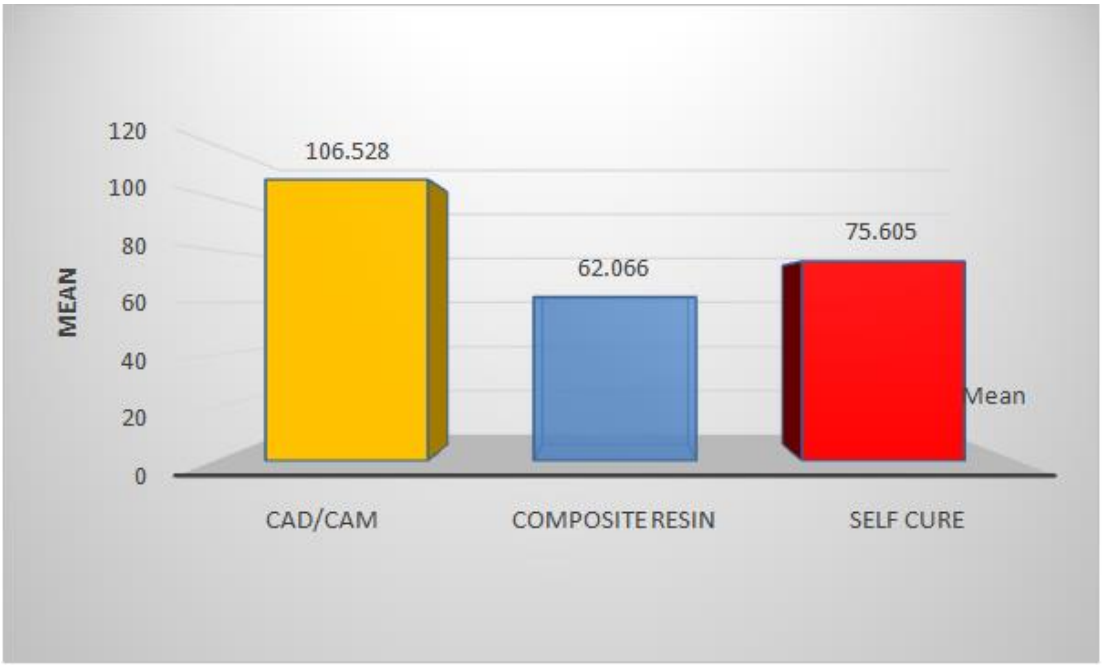
Post Hoc Tukey HSD analysis for surface roughness of all groups for pairwise comparisons between Group A, Group B and Group C. On subjecting the mean values of surface roughness to Tukey HSD analysis the value of p was 0.08 for Group A Vs Group B, 0.93 for Group A vs Group C, 0.08 for Group B vsGroup A, 0.17 for Group B vs Group C, 0.93 for Group C vs Group A and 0.17 for Group C vs Group B. This indicates that the values were not significant. (P>0.05)



SpecimenNo	Compressive Strength (at 10% strain)		
	Group A (N/sqmm)	Group B (N/sqmm)	Group C (N/sqmm)
1	107.034	60.546	63.976
2	110.697	55.303	82.228
3	106.918	70.401	70.474
4	107.518	55.817	64.221
5	99.691	62.267	68.226
6	110.392	59.885	83.508
7	106.639	71.884	76.321
8	112.823	66.009	79.422
9	102.809	51.211	80.282
10	100.761	67.343	87.396
Mean ± Standard deviation	106.528±4.309 N/sqmm	62.066±6.823 N/sqmm	75.605±8.352 N/sqmm

Descriptive statistics and one way ANOVA for Compressive strength of all groups. On subjecting the mean values of compressive strength of Group A, Group B and Group C to one way analysis of variance the value of p was found to be 0.001 indicating that there is statistically significant difference in compressive strength of all groups. (P<0.05)

Post Hoc Tukey HSD analysis for compressive strength of all groups for pairwise comparisons between Group A, Group B and Group C. On subjecting the mean values of compressive strength to Tukey HSD analysis the value of p was 0.00 for Group A Vs Group B, 0.00 for Group A vs Group C, 0.00 for Group B vs Group A, 0.00 for Group B vs Group C, 0.00 for Group C vs Group A and 0.00 for Group C vs Group B. This indicates that the values were significant. (P<0.05)



DISCUSSION

A good provisional restoration is meant to withstand masticatory forces without fracturing or deformation, ensuring adequate protection to the prepared tooth and maintaining stability during the interim period. This can be possible if the material has high compressive strength to resist fracture prematurely and to prevent the need for repetitive replacements and maintain patient comfort at the same time.

Currently, available provisional materials can be divided into four groups namely – Polymethyl Methacrylate (PMMA), polyethyl methacrylates, bis-acryl composite resins and visible light cure resin.

Several studies on the flexural strength, surface hardness, polymerisation shrinkage, colour stability of provisional restorations have been done but there is very little data on compressive strength and surface roughness of the materials, hence the purpose of the study.

Because compressive strength and surface roughness being one of the critical factors for determining the success of interim restoration three different types of provisional materials were selected on the basis of mode of polymerisation.

Group A being CAD/CAM pmma resin, Group B being Bisacryl composite resin and Group C being conventional pmma resin which had been used for making of temporary crown and bridges. These groups were subjected to undergo testing for compressive strength and surface roughness to find out which group amongst them has better compressive strength and surface finish respectively.

Compressive strength is defined as a mechanical property to measure materials ability to withstand compressive forces without permanent deformation or fracture. It is a critical parameter to assess the load bearing capacity and structural integrity of materials under compression.it is expressed in terms of N/sqmm or MPa.

For this study the specimens were placed on a flat platform and another flat metal plate attached to the machines loading cell was kept in such a way that it touched the specimen without applying any amount of force. Each sample was then applied a load of 10kN at a cross head speed of 1.3mm / min. In this particular study 8mm×4mm×4mm specimens were prepared which were according to ASTM standards forbrittle materials. The specimens were tested by Universal testing machine by Dak system Inc. The force the specimen could withstand at 10% strain was recorded for each specimen and compared. This method was similar to the method used by Z Vally, LM Sykes, ME Aspeling, J van de Merwe and R Ballyram in their study on In vitro comparison of the compressive strengths of seven different provisional crown materials in 2013. 9

The results obtained revealed that the Group A (CAD/CAM PMMA) has the highest compressive strength of 106.528N/sqmm followed by Group C (Self Cure PMMA) with compressive strength of 75.605N/sqmm and Group B (Dual Cure Composite resin) with compressive strength of 62.066N/sqmm.

As for the compressive strength values found for each material CAD/CAM pmma had the highest which is comparable to the study done by Adil Othman Abdullah, Effrosyni A Tsitrou and Sarah Pollington. 11

Surface Roughness measures the deviations in height of surface profile from its ideal form.The most common parameter used to quantify surface roughness is the Ra (average roughness). Surface roughness can be measured by various techniques which includes contact profilometry, optical profilometry, atomic force microscopy and scanning electron microscopy.For this study surface

profilometer was used for recording the Ra value. The Ra value was then tabulated and statistical analysis was done. This method was similar to that method used by Rashin Giti, Shima Dabiri, Mohammad Motamedifar and Reza Derafshi in the study on surface roughness, plaque accumulation, and cytotoxicity of provisional restorative materials fabricated by different methods. 10

Results revealed that Group A (CAD/CAM) has least surface roughness of 1.129 µm, followed by Group C (Self Cure) of 1.214 µm and then Group B (Composite Resin) of 1.66 µm.

In the study by Rashin Giti et al on-Surface roughness, plaque accumulation, and cytotoxicity of provisional restorative materials fabricated by different methods, it was found that conventionally cured PMMA had significantly higher surface roughness than the digitally fabricated groups which were similar to the results of our study. Presumably, the high surface roughness of the conventional group is due to the air bubbles incorporated through hand mixing of liquid and powder during filling of external mold.16

Provisional restorations should have adequate strength to withstand a variety of compressive, tensile and shear stresses as well as should be able to repel bacterial colonisation.PMMA are relatively inexpensive, with good colour stability, excellent polishability and good marginal adaptation.22

However, in certain clinical cases where there is increased parafunction, abnormal jaw relationships,23 cases of raised vertical dimension, long span bridges, forces acting on provisional restoration are far more than normal. Also, where provisional materials are used for extended periods of time like full mouth rehabilitation its strength assumes paramount importance.26

The limitations of the study-

- Sample size was small. (n=10)
- Study was done in vitro so clinical scenarios could not be recreated like bacterial presence and long-term results.
- Standardized sample sizes are used which usually not depict those used in clinical scenarios.
- Individual patient factors like tooth morphology and occlusal stability were ignored.
- Potential for bias i.e. researcher bias.

CLINICAL CONSIDERATION

- All of the provisional materials (CAD/CAM PMMA, Bis acryl Composite resin, Autopolymerizing resin) used in the study had their values of compressive strength and surface roughness within clinically acceptable limits. 27
- The compressive strength of provisional crowns plays a crucial role in their clinical performance. Higher strength ensures that the crowns remain intact for longer duration as it allows them to withstand masticatory forces.
- Controlling surface roughness is essential for longevity, hygiene and patient satisfaction. Surface roughness can lead to premature wear. It may also lead to discomfort and irritation to soft tissues. Rough surfaces tend to accumulate stains and plaque.28,29
- Among the provisional materials used, CAD/CAM PMMA was better in compressive strength and had least surface roughness. It can be recommended for their use in anterior and posterior regions for long term provisionals, implant crowns and to restore normal functionality.

SCOPE FOR FUTURE RESEARCH

- Materials with different chemistry and polymerization techniques can be considered.
- Additive reinforcements can be added to improve its strength.
- The study can be conducted in stimulated oral conditions.
- Antimicrobial properties can be added thus reducing bacterial and plaque accumulation.
- Samples can be prepared to depict the tooth morphology.

CONCLUSION

With in the limitations of this study, the following conclusions could be derived as .

- CAD/CAM PMMA has the highest compressive strength followed by autopolymerizing pmma and Bis acryl composite resin respectively. The difference between them was statistically significant.
- Surface roughness of Bis acryl composite resin and auto polymerizing resin was statistically similar to CAD/CAM PMMA.
- All of the above materials were evaluated and were found to be clinically suitable for use as provisional materials.
- The results of this study indicate that mechanical properties of the CAD/CAM pmma are superior than the other two counterparts- Bisacryl composite resin and conventional pmma.
- The CAD/CAM provisional should be preferred for long span provisionals, implant crowns, full mouth rehabilitation, for space maintainer in orthodontics.
- Keeping in mind, the disadvantages like exothermic reaction, polymerization shrinkage and dispersion of monomer from the mixture these crowns made from CAD/CAM pmma could acts as a perfect alternative to the traditional methods.
- Future investigation needs to be done to compare the quality of these materials and how they respond to the oral environment.

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