Original Article

DOI: 10.7860/JCDR/2022/51527.15830

Dentistry Section

Comparative Evaluation of Flexural Strength and Surface Roughness of Three Different Commercially Available Provisional Restorative Materials: An In-vitro Study

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ABSTRACT

Introduction: Provisional restorative materials require good mechanical properties for long term restorations. Provisional restorative materials are continuously being updated and improved upon for these mechanical, biological and esthetic properties.

Aim: To determine and compare the surface roughness and the strength of three different commercially available provisional restorative materials at different periods.

Materials and Methods: This in-vitro study involved 120 samples of a stainless steel mould fabricated and equally divided. The study was carried out for one year in the Department of Prosthodontics and Crown & Bridge, School of Dental Sciences, Sharda University between June 2020 to June 2021. Materials compared were Dental Products of India (DPI) heat cure acrylic, Protemp 4 and Revotek LC. Each group was further categorised into four groups to measure the flexural strength (after 24 hours, storage in artificial saliva for seven days and 30 days) and surface roughness. A Universal Testing Machine determined the flexural strength and Perthometer for surface roughness. Statistical analysis was done using a one-way Analysis of Variance (ANOVA) test followed by a post-hoc test.

Results: In the three types of materials studied, flexural strength after 24 hours, 7 days, and 30 days was statistically significantly higher (p-value=0.001) in DPI than Protemp 4 and Revotek LC whereas, DPI exhibited a decrease in surface roughness when compared to Protemp 4 and Revotek LC (p-value=0.002).

Conclusion: Within the limitations of the study it was found that DPI demonstrated a higher flexural strength at 24 hours than Protemp 4 and Revotek LC. After storage in saliva for 7 days and 30 days, there was a decrease in the flexural strength of three commercially available provisional materials. The mean surface roughness of Revotek LC was more than DPI and Protemp 4.

Keywords: Bisphenol glycidyl methacrylate, Perthometer, Polymethyl methacrylate, Urethane dimethacrylate, Universal testing machine

INTRODUCTION

Prosthodontic management of partially edentulous individuals usually requires continual planning of provisional restorations which helps the clinician analyse the success of the final restoration in its mechanical, aesthetic, and functional aspects [1]. Biologically, provisional restorations help in pulp protection, prevent tooth fracture, help in the maintenance of periodontal health, oral hygiene, and occlusal compatibility. Mechanically they help in retention, strength, and inter abutment alignment. In addition to this, provisional restorations must also be aesthetically stable in colour and translucent [2].

Since the 1930s, provisional restorative materials have changed greatly from acrylics and prepared crowns (first generation) to modern bisacryl materials and heat cure Polymethyl Methacrylate (PMMA) blocks that are being used for Computer Aided Design/ Computer Aided Manufacturing (CAD/CAM) restorations [1,2]. The history of provisional restorations dates back to the 1930s. In 1937 Walter introduced PMMA heat cure resin. Auto polymerising acrylic resin was introduced in 1947 and prefabricated aluminum and celluloid crowns in 1959. Polycarbonate resin was introduced in 1973 by Charles et al., Weiner in 1983 described a technique that uses silicon putty impression material for fabrication of provisional restorations. Visible light-cured microfilled composite resin was also used by some researchers and finally provisional restorations were introduced in implant dentistry in 1987 [3].

Interim restorative substances can be categorised into four following constitutions: (a) PMMA; (b) Polyethyl or Butyl methacrylate; (c) Microfilled bisphenol A Glycidyl Methacrylate (Bis-GMA) composite resin; and (d) Urethane Dimethacrylate (UDMA) (light-polymerising resins) [4,5]. PMMA resins are comparatively economical, have good colour stability, good marginal accuracy, and superior ability to be polished. However, the main drawback of this type of resin is high polymerisation shrinkage, an exothermic reaction, low strength and wear resistance as well as pulpal irritation due to surplus free monomer [1].

Latest bis-acryl materials have resolved the disadvantages related to traditional acrylic. In the 1960s Bowen developed Bis-GMA, the backbone for most composite resins used to date. It also paved the way for bis-acryl self-cured composites. Although available in a wide variety of shades, including bleach, bis-acrylate comes in a convenient syringe applicator having a low exothermic reaction, decreased shrinkage and less odour. A drawback is ease in breakage when placed under areas of stress, but they are easy to repair [2].

The UDMA is available in an adaptable putty consistency and is light-cured. It offers a good marginal fit in addition to a polished surface, exhibiting low shrinkage and no exothermic reaction. It can be fixed with flowable and hybrid composites, provides good transverse strength, and is relatively abrasion resistant. A disadvantage is its availability in a single shade. UDMA is well suited for immediate load implant prostheses [5].

Clinicians have many choices while fabricating provisional restorations that are being updated and improved upon for their aesthetic, biological and mechanical properties. Out of these properties, flexural strength and surface roughness are important for the success of any provisional restoration. Flexural strength might have an impact on the integrity of the restoration during use making it of accurate significance in long span restorations as well as in patients with parafunctional habits [5].

The surface roughness of restorative materials is important for the periodontal health of the teeth. Rough surfaces on provisional restorations develop conditions for the multiplication of microorganisms, especially those responsible for caries and periodontal disease [1].

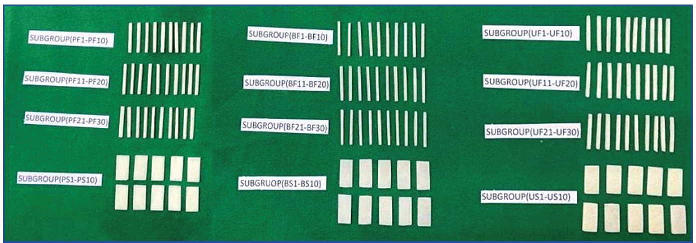
There still exists a lacuna of information in the literature, even though research on the impact strength of various provisional restorative materials has been performed. Hence, this study was done to assess the flexural strength and surface roughness of three commonly used provisional restorative materials (DPI heat cure tooth moulding acrylic resin, Bis-GMA, and UDMA) in simulated intraoral conditions (Wet mouth Artificial saliva, ICPA Health Products Ltd., Mumbai). A paucity of research in the literature regarding UDMA and the comparison of its result with different existing provisional restorative materials makes this study novel.

MATERIALS AND METHODS

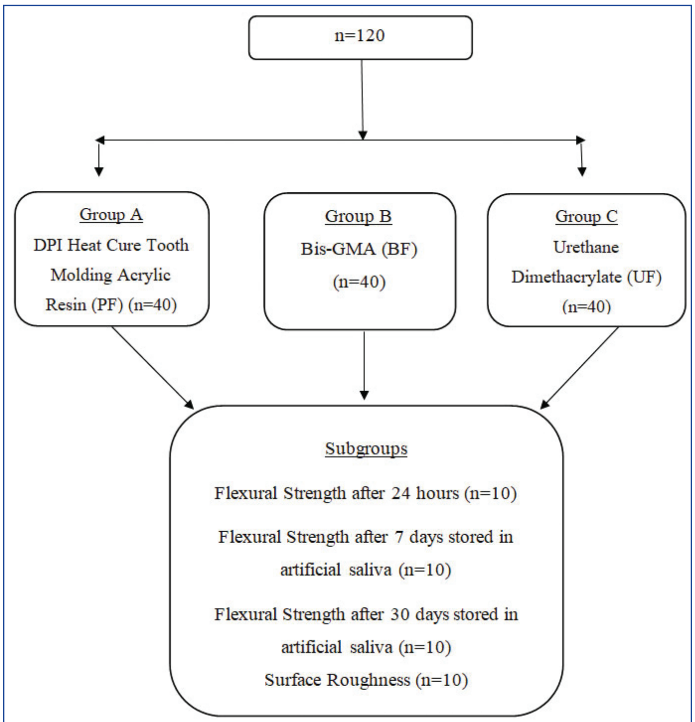
This in-vitro study was conducted in the Department of Prosthodontics and Crown & Bridge, School of Dental Sciences, Sharda University, Uttar Pradesh, India between June 2020 to June 2021. Before the commencement of the laboratory study, the study design was approved by the Institutional Ethical Review committee (Ref. No. SU/SMS&R/76-A/2018/120).

Procedure

A total of 120 samples were made and equally divided into three groups. Further, each group was subdivided into four subgroups [Table/Fig-1,2].



[Table/Fig-1]: Test samples of Group A, Group B and Group C.



[Table/Fig-2]: Flowchart for methodology.

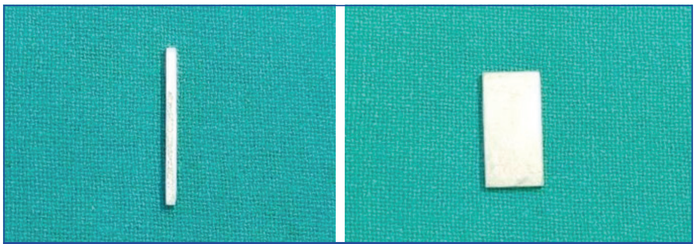
The study was divided into two parts: Part I- Preparation of test samples and part II- Evaluation of test samples.

Preparation of test samples includes: a) Preparation of acrylic resin (DPI tooth moulding resin: polymer and monomer, Dental product of India: The Bombay Burmah Trading Corporation Ltd.,) test samples (represented as PF1, PF2, PF3, PF4). b) Preparation of Protemp 4 (Bis GMA) (3M Deutschland GmbH Batch no 41453- Neuss-Germany) test sample (represented as BF1, BF2, BF3, BF4). c) Preparation of Revoteck LC (Urethane Dimethacrylate) (GC Dental Products Corp. Tokyo Japan) test samples (represented as UF1, UF2, UF3, UF4). Evaluation of test samples includes: a) Evaluation of test samples for flexural strength and b) Evaluation of test samples for surface roughness.

Part I- Preparation of Test Samples

a) Preparation of acrylic resin test samples (n=40)

Preparation of gypsum mould to obtain the test samples: A standardised mild stainless steel mould (according to International Standards Organisation Specification No. 27) was used for fabrication of the master die measuring 25 mm long, 2 mm wide and 2 mm thick [Table/Fig-3] for flexural strength [6,7]. For surface roughness, the dimensions were calculated up to 20 mm long, 10 mm wide, and 3 mm thick [Table/Fig-4] [8].



[Table/Fig-3]: Stainless steel master die for flexural strength.
[Table/Fig-4]: Stainless steel master die for surface roughness. (Images from left to right)

A mould of the master die was created into which molten modeling wax was poured to obtain wax blocks followed by the traditional process of flasking to obtain the acrylic resin samples which were further finished and polished.

Finishing of samples [1,3,8]: For flexural strength tungsten carbide burs WL-B2 and WL-B11 attached to the lathe were used for finishing. For surface roughness tungsten carbide burs were used along with emery sandpaper no. 100, 400, 800 and 1200 together with polishing using pumice and buff.

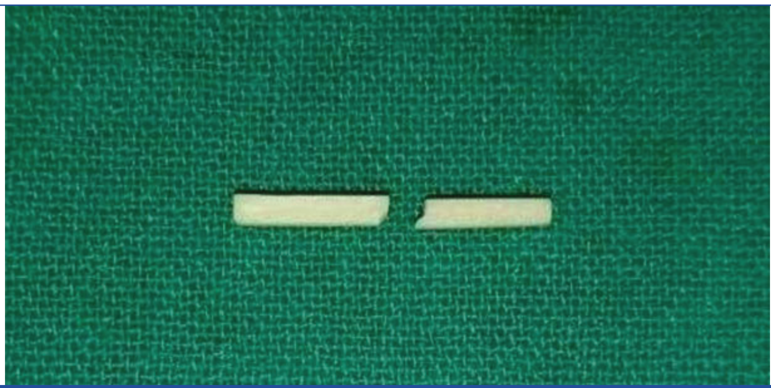
b) Preparation of Bis-GMA test samples (n=40): Sample moulds were fabricated by duplicating the master die to make Protemp 4 restorative material. Gun dispenser was used to fill in the moulds and shaped using a plastic filling instrument. As instructed by the manufacturer, the material was allowed to auto-cure for 5-7 minutes and then retrieved.

Finishing of samples [9,10]: An oxygen inhibition layer was formed on the surface of test samples during self-cure which was removed by gauze soaked in alcohol after polymerisation of the material. Red-coded tungsten carbides were used for finishing of samples. For surface roughness: After tungsten carbide super finishing bur, the Shofu super snap composite polishing kit was employed for polishing to measure surface roughness.

c) Preparation of urethane dimethacrylate test samples (n=40): The sample moulds obtained after duplication were packed with Revotek LC packable consistency in small increments and adapted well. According to the manufacturer's instructions, a light cure unit (Ivoclar Vivadent Bluephase N LED) was used for curing for 30 to 60 seconds, henceforth retrieval.

Finishing of sample [1,3,8]: For flexural strength the set of test samples were finished with tungsten carbide super finishing bur. For surface roughness: Samples were finished with carbide super finishing bur and polished using shofu super snap composite polishing kit.

The samples thus obtained were divided into groups mentioned earlier and were stored in artificial saliva for seven days and 30 days respectively.



[Table/Fig-5]: Universal testing machine. **[Table/Fig-6]:** Fractured sample after testing. **[Table/Fig-7]:** Perthometer evaluating the surface roughness of Protemp 4. (Images from left to right)

PART II- Evaluation of Test Samples

a) Evaluation of test samples for flexural strength: Flexural strength determination of test samples was done using a universal testing machine (UTEST Material testing Equipment, Model No. WAW-2000Y) [Table/Fig-5] of 1 mm/min crosshead speed. The progressive load was applied and reading was recorded on the software at the fracture of the test samples [Table/Fig-6].

b) Evaluation of test samples for surface roughness: Test samples were subjected to surface roughness evaluation immediately. Quantitative judgment was done with the aid of a Perthometer (Mahr Perthometer PGK plus). The stylus Perthometer utilises a probe to identify the surface. It is moved along the surface to analyse the surface height. A feedback loop monitors the force from the sample that pushes up against the probe [Table/Fig-7].

STATISTICAL ANALYSIS

The data obtained were tabulated and subjected to statistical analysis using the IBM Statistical Package for the Social Sciences software for Windows version 23.0 (Armonk, NY: IBM Corporation. Released 2015). The significance level was fixed at 5% (α=0.05). Parametric tests namely one-way ANOVA and the post-hoc test were used to analyse the data. Statistical significance was set at p-value<0.05. One-way ANOVA is dedicated to comparing means of two or higher groups to determine any statistical evidence. In this study, one-way ANOVA test was used to compare the mean values of surface roughness (postfinishing of the samples) between the three subgroups. The Post-hoc test form an important component of ANOVA. However, ANOVA results do not signify particular differences between means that are significant. Post-hoc tests revealed differences between means of multiple groups while controlling the error rate.

RESULTS

The mean flexural strength of the subgroups PF1, BF1, UF1 after 24 hours [Table/Fig-8] demonstrate a higher flexural strength for PF1 (377.11 MPa) than BF1 (320.85 MPa) and UF1 (215.96 MPa) and it was statistically significant (p-value=0.001).

Flexural strength after 24 hours				
Subgroup	N	Mean	SD	F-value, p-value
PF1	10	377.1120	49.06768	30.315, 0.001*
BF1	10	320.8500	45.86025	
UF1	10	215.9625	45.92434	
Total	30	304.6415	81.65638	

[Table/Fig-8]: Statistical comparison of mean flexural strength (in MPa) of subgroups PF1, BF1 and UF1 after 24 hours (by one-way ANOVA followed by post-hoc).
Post-hoc pair;* Significant difference; SD: Standard Deviation; *p-value <0.05 was considered statistically significant

Mean flexural strength after 7 days [Table/Fig-9] was least for UF2 (155.43 MPa), followed by BF2 (284.25 MPa) and the highest for PF2 (307.23 MPa) (p-value=0.001).

Following 30 days [Table/Fig-10], the mean flexural strength was maximum for PF3 (342.37 MPa) and the lowest for UF3 (160.31 MPa) (p-value=0.001).

Flexural strength after 7 days				
Subgroup	N	Mean	SD	F-value, p-value
PF2	10	307.2375	59.64637	24.135, 0.001*
BF2	10	284.2500	44.96526	
UF2	10	155.4375	52.35613	
Total	30	248.9750	84.84624	

[Table/Fig-9]: Statistical comparison of mean flexural strength (in MPa) of subgroups PF2, BF2 and UF2 after 7 days (by one-way ANOVA followed by post-hoc).
Post-hoc pair; SD: Standard deviation; p-value <0.05 was considered statistically significant

Flexural strength after 30 days				
Subgroup	N	Mean	SD	F-value, p-value
PF3	10	342.3750	75.16461	28.902, 0.001*
BF3	10	284.3250	28.17734	
UF3	10	160.3125	50.34017	
Total	30	262.3375	93.54804	

[Table/Fig-10]: Statistical comparison of mean flexural strength (in MPa) of subgroups PF3, BF3 and UF3 after 30 days (by one-way ANOVA followed by post-hoc).
Post-hoc pair; SD: Standard deviation; *p-value <0.05 was considered statistically significant

[Table/Fig-11] depicts the surface roughness values for subgroups PS4, BS4 and US4. Surface roughness values for PS4 (0.23 Ra) specimens were found to be lower than the BS4 (0.24 Ra) and US4 (0.30 Ra) specimens (p-value=0.002).

Mean surface roughness				
Subgroup	N	Mean	SD	F-value, p-value
PS4	10	0.2390	0.03843	7.999, 0.002*
BS4	10	0.2470	0.03683	
US4	10	0.3010	0.03784	
Total	30	0.2623	0.04591	

[Table/Fig-11]: Statistical comparison of surface roughness (in Ra) of subgroups PS4, BS4 and US4 (by one-way ANOVA followed by post-hoc).
Post-hoc pair; SD: Standard deviation; *p-value <0.05 was considered statistically significant

DISCUSSION

Stability as a mechanical property of provisional crown materials is essential to avoid failure of restorations from the start till the end. It must be protected to the pulp, positionally stable, easy to clean, have accurate margins, resistant to wear, and dimensionally stable [2].

It can be predicted that interactions between saliva, food components, beverages in the oral environment, and these materials impair and deteriorate dental restorations [11]. Flexural strength is thus a relevant characteristic property for a provisional restorative material to long term provisionalisation. They are a crucial diagnostic aid for the success of fixed prosthodontic treatment [2]. For treatment planning of complex cases when the final prosthesis is delayed, the long term dimensional stability of provisional restorations in the oral environment is desirable. The clinically acceptable critical value for a hard surface in the oral environment is 0.2 microns, above which bacterial colonisation takes place. This substantiates the need for a smooth and glossy surface. Also, greater the surface smoothness of a restorative material, lower the capability to retain microorganisms and dental biofilm formation [2,6].

A study conducted by Sharma SP et al., in 2013 showed that the flexural strength of PMMA is finer than UDMA [12]. Also, PMMA proves as a better provisional material for a long period, in patients with parafunction. Yanikoğlu N et al., evaluated the flexural strength of temporary restorative materials stored in different solutions of one methacrylate based resin and three bis-acryl resin provisional materials [11]. Protemp 4 displayed the highest fracture strength amongst the bis-acryl materials during the 14 days inspection interval. Hence, this study was organised with the intent to determine which provisional restorative material would fulfill most requirements of long term provisionalisation.

Lang R et al., tested Polymethylmethacrylate (PMMA) and composite based Fixed Partial Denture (FPD) for their resistance to fracture [13]. They found that PMMA materials showed, low mechanical fracture behaviour because of deformation during oral stimulation. While in this study the mean flexural strength of DPI was higher at 24 hours than post 7 days and 30 days. A reason for this result could be the breaking down of the resultant cross-linking chain after water absorption that leads to degradation of the mechanical properties of PMMA. Another reason might be the polar properties of the resin molecules, which can act as plasticisers hence decreasing the fracture strength of the materials [5].

In this experiment, the average flexural strength of Bis-GMA obtained was greater at 24 hours than after 7 days and 30 days. The reason for this could be credited to the swelling of bis-acrylate and the breaking of cross-link groups after water absorption. The Bis-GMA based polymer is vulnerable to swelling and softening by organic solvent covering a spectrum of the solubility parameter. The microvoids within the subsurface damaged region of the solvent treated specimens are believed to be caused by leaching out of unreacted monomer, in addition to the swelling process [5]. In 1984 Wu W et al., studied the subsurface damage layer of composite restoration by testing three materials of bis-acrylate (Adaptic, Profile, Concise) via an optical microscope [14]. They concluded that Bis-GMA based polymers are highly susceptible to softening by organic solvents. Binalrimal SR et al., studied the flexural strength of immediate and aged provisional restorative materials and observed that Integrity was significantly higher than Jet and Tuff-Temp Plus, while Jet was higher than Tuff-Temp Plus. Integrity has two methacrylate groups (bi-functional) one group is used to form a polymer, other for cross-linking. Cross-link group breakdown in the oral environment depends on the storage of period [15].

The study demonstrates a higher strength in flexion of Revotek LC at 24 hours than after 7 days and 30 days. The reason for this result can be absence of phenol rings in Revotek LC (UDMA), because of which the material is soft and after water absorption, it becomes more rubber like. The composition of Revotek LC includes dimethacrylate and crystalline silica powder as filler. The minimal amount by weight of fillers is found in interim composites when compared to normal composites [9]. This might be the reason for the decreased strength of the material. The fillers eventually leach out in the presence of saliva, indicating the reduction in mechanical properties of the interim composite after storage [5]. This result is similar to a study done by Poonacha V et al., in 2013 wherein the authors studied the flexural strength and elastic modulus of three provisional crown materials (DPI self-cure India, Protemp-2 Germany, Revotek GC Dental product, Japan) used in fixed prosthodontics and found that the methacrylate resin exhibited excellent flexural strength when compared to light polymerised and bis-acrylic composite [7]. They also studied the mechanical properties of provisional restoration and made a note of methacrylate resin which again displayed superior flexural strength in comparison to the other materials used [7].

Gujjari AK et al., examined the colour stability and flexural strength of PMMA and bis-acrylic resins subjected to beverages and food dye. They observed that PMMA is a better provisional restorative material than bis-acrylate [16]. Koumjian JH and Nimmo A studied the fracture resistance of resins used for provisional restoration and summarised that dissimilarities in flexural strength appearance were material specific even without the evidence of data to compare the filler content of bis-acrylic composite materials [17].

The present study showed a higher flexural strength of DPI when compared to Bis-GMA and UDMA. This is in correlation with the study conducted by Binalrimal SR et al. Authors studied the flexural strength for determination of immediate and aged provisional restorative materials and observed that Integrity was significantly higher than Jet and Tuff-Temp Plus. The monomer in Tuff-Temp Plus has no phenol rings. As a result, UDMA has low mechanical strength and higher flexibility so it is called rubberised urethane resin [15]. The reason for a decrease in the flexural strength of Bis-GMA and UDMA in the present study is attributed to the two molecules of Bis-GMA and post water absorption cross-linking molecules breakdown thus a decrease in its mechanical properties. Bis-acryl polymers are more polar than PMMA polymers and absorb water at a higher rate because of a high diffusion coefficient in comparison to PMMA based resins. PMMA was more resistant to damage in the oral environment as related to bis-acrylate material [5,18].

The results of the present study depicted a lower surface roughness for DPI in comparison to Protemp 4 and Revotek LC. This is not per the study performed by Tupinambá ÍVM et al., [10]. Authors concluded that bis-acrylic resins displayed a considerably smoother surface than acrylic resins. But in this study, no significant differences were found between Protemp (Bis-GMA) and DPI (PMMA). The reason can be the mixing of appropriate quantities and the curing procedure of PMMA that leads to less surface roughness in comparison to Bis-GMA and UDMA [5].

Due to reduced exothermic and polymerisation shrinkage as well as ease in handling of Bis-acrylic resins they have gained popularity. This novelty has lead to decreased roughness values of the bis-acryl resins [18].

As per the study conducted by Mehrpour H et al., on flexural strength of UDMA, Methyl methacrylate, Bis-acryl, and Vinyl ethyl methacrylate, it was seen that Bis-acryl material for provisional restoration showed the highest flexural strength [6], whereas the study carried out by Poonacha V et al., revealed that methacrylate resin bagged the maximum flexural strength postfabrication and storage in artificial saliva for seven days while bis-acrylic composite resin displayed the minimum [7]. In a study done by Kumar GV et al., comparison between various provisinal restorative materials showed that Protemp had minimal porosities and surface roughness followed by Tempofit and DPI [8]. Previous studies on surface roughness and porosity of various provisional restorative materials conducted are compared with the present study in [Table/Fig-12] [3,8,12,16,18].

Author's name and year	Place of study	Number of samples	Materials compared	Parameters compared	Conclusion
Jo LJ et al., 2011 [18]	Kozhikode, Kerala and Mangalore, Karnataka, India	50 (10 samples per group)	Revotek LC, Protemp II, Acry-lux V™ with regular monomer, Acry-lux V™ with self-cure monomer, DPI™ self-cure tooth moulding powder	Flexural strength and hardness	Acry-lux V™ representing a heat polymerising resin, showed the highest flexural strength and hardness values as compared to auto-polymerising resins and light-polymerising resin.
Gujjari AK et al., 2013 [16]	Mysore, Karnataka, India	60 (30 samples per group)	Poly (methyl methacrylate) and bis-acrylic auto-polymerising resins	Colour stability and flexural strength	PMMA was more colour stable than bis-acrylic composite based resin. PMMA based material was more resistant to damage from dietary beverages as compared to bis-acrylic composite based provisional crown and bridge resin.
Sharma SP et al., 2013 [12]	Chidambaram, Tamil Nadu, India.	40 (20 samples per group)	Polymethyl Methacrylate (PMMA), Urethane dimethacrylate (UDMA)	Flexural strength	The flexural strength of PMMA is better than UDMA.
Kadiyala KK et al., 2016 [3]	Guntur, Andhra Pradesh, India.	40 (10 samples per group)	Autopolymerising Poly Methyl Methacrylate (PMMA), heat-activated PMMA, Bis-GMA composite resin, light-activated Urethane Dimethacrylate Resin (UDMA)	Flexural strength	Bis-GMA displayed the highest flexural strength followed by heat cure methacrylate resins, autopolymerising methacrylate resins and light-cure resins.
Kumar GV et al., 2016 [8]	Davangere, Karnataka, India	36 (12 samples per group)	Autopolymerised PMMA, Protemp, Duralay, Tempofit	Surface roughness, porosity	Surface roughness and porosity were best with Protemp material
Present study	Greater Noida, Uttar Pradesh, India	120 (40 samples per group)	DPI heat cure acrylic, Protemp 4 and Revotek LC	Flexural strength and surface roughness	DPI showed higher flexural strength at 24 hours. Revotek LC exhibited better surface roughness.

[Table/Fig-12]: Various studies were conducted to know the flexural strength and surface hardness of provisional restorative materials.

Limitation(s)

The study presents with limitations that require further research as well as studies that simulate the natural oral environment better to mimic intraoral conditions. In addition to this, scanning electron microscopy of the test samples can be taken into account for surface roughness and to demonstrate excellent results. Future studies can also include different polishing systems for finishing and polishing the samples.

CONCLUSION(S)

Within the constraints of this in-vitro study, it can be concluded that the mean flexural strength of DPI was highest at 24 hours when compared to its flexural strength at seven days and 30 days. In addition to this after storage in saliva for seven days it was observed that there was a decrease in the flexural strength of all the three commercially available provisional materials. DPI exhibited the highest mean value in addition to a statistically significant difference. Also, after storage in saliva for 30 days, there was a decrease in the flexural strength of all the three commercially available provisional materials. Furthermore, the mean surface roughness of Revotek LC was found to be better than DPI and Protemp 4.

Future outlook involves assessment of colour stability of different provisional restorations, impact strength and marginal fit assessment in a bridge. More number of commercially available provisional restorative materials can be taken into consideration in further studies as well as studies on CAD-CAM generated provisional restorations can be carried out.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jul 24, 2021
- Manual Googling: Oct 28, 2021
- iThenticate Software: Nov 25, 2021 (10%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **Jul 23, 2021**
Date of Peer Review: **Sep 06, 2021**
Date of Acceptance: **Oct 30, 2021**
Date of Publishing: **Jan 01, 2022**