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Research Article

Comparison of Flexural Strength and Color Stability of three Commercially Available Temporizing Resins - An *In vitro* Study

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Abstract

Aim: The purpose of this study was to compare and evaluate the flexural strength and color stability of three commercially available temporizing resins.

Materials and Methodology: Bar type specimens (65*10*3mm) and square type specimens (10*10*1mm) were fabricated of each material according to the manufacturer's instructions. A total of 60 samples were selected out of which, 20 samples were fabricated using DPI conventional heat cure resin, 20 samples using 3M ESPE Protemp 4 and the other 20 samples with polymer resin using 3D printer. The specimens were stored in artificial saliva at 37 degrees for 3 months. During this period, specimens were placed in thermocycler for a minimum of 2500 cycles. 10 samples from each group were tested for flexural strength using Universal testing machine and the remaining 10 samples were tested for color stability using spectrophotometer. Comparison of the flexural strength and color stability between 3 types of resins was made.

Results: PROTEMP has the highest flexural strength and color stability when compared with DPI and the 3D Printing materials

Conclusion: Among the three materials compared, bis-acryl composite resin (Protemp-4) can be considered as the best material for long term provisionalization, as it exhibited greater flexural strength. Bis-acryl composite resin (protemp-4) is the most color stable provisional restorative material followed by polymethyl methacrylate (DPI) and 3D printing resin.

Keywords: PROTEMP; 3D Printing, Flexural Strength, Colour Stability

Introduction

Provisional or interim restorations are increasingly being used in dentistry today. They are an integral part of fixed prosthodontic treatment and provide with a protective coverage for teeth right from the initial tooth preparation until the definitive prosthesis is given to the patient.

The interim treatment focuses on protecting pulpal and periodontal health, promoting guided tissue healing to achieve an acceptable emergence profile, evaluating Preventing abutment migration, providing an adequate occlusal scheme, and assessing maxillary-mandibular relationships are all part of the hygiene procedures.

With the benefits of auto-mixing, easier handling, improved compressive and tensile strengths, less water sorption, and less shrinkage, the advancement of provisional materials to bis-acrylics has resulted in chair side provisional restorations that are better than ever [1].

With the increasing availability of 3D printers, digitally designed provisional restorations can now be printed. When compared to milling, additive manufacturing generates less raw material waste, reduces manufacturing time, and enables mass production [2].

Multiple factors must be considered when selecting a material for the fabrication of a single crown or a multi-unit interim restoration, such as physical properties (e.g., flexural strength, surface hardness, wear resistance, dimensional stability, polymerisation shrinkage, colour range and stability, and radiopacity), handling properties (e.g., mixing time, working time, predictable and consistent setting time, ease of trimming and polishability, and repairability), and repairability. There is no single material that can meet all of the requirements [2].

Provisional restoration must maintain its appearance throughout its service life. The material's acceptability may be jeopardised if the colour changes noticeably. As a result, stainability may be an important criterion in the selection of a specific provisional material for use in an aesthetically sensitive area [3].

The purpose of this study was to compare and evaluate the flexural strength and color stability of three commercially available temporizing resins

- Poly (methyl methacrylate)
- Bis-acryl composite resin
- Visible light cure resin

Materials and Methodology

Mould space preparation

Three milled wax block sample analogues with 65mm x 10mm x 3mm dimension and 1 wax milled bar with 10mmx10mmx1mm dimensions were prepared as per ISO norms.

Putty indices of the specimens were made and a flat layer of putty was placed over them. Prior to the fabrication of samples, flasks and sample analogues were coated with thin layer of petroleum jelly for easy removal of sample analogues as well as to aid deflasking.

The progress the two halves of the flask were gently separated with a plaster knife once the investing medium had reached its final set. The sample analogues were examined. lifted from investing medium, thereby creating mould space into which resin could be packed.

Mould space preparation

Figure1: Flasking.

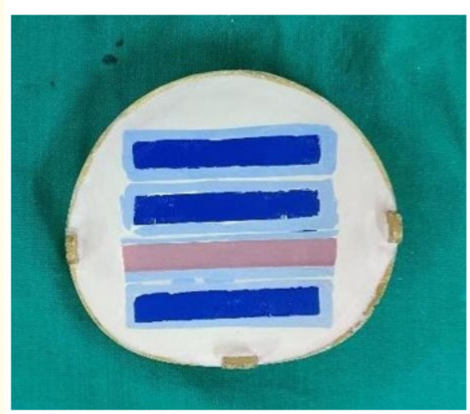


Figure 2: Milled Wax bar specimens invested in brass varsity flask.

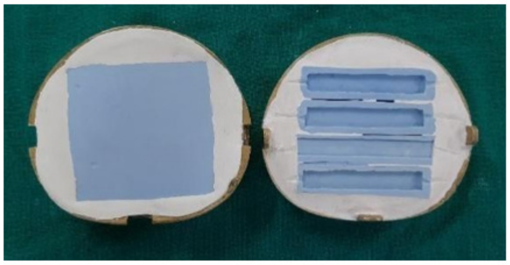


Figure 3: Mould space obtained after retrieval of wax bars. Fabrication of group A specimens (heat cure polymethyl methacrylate resin).

The material is available in powder and liquid form as polymer and monomer, respectively, and its main component is polymethyl methacrylate. They were placed in an acrylisation unit and polymerised for 1 hour at a temperature of 100°C. Later, the samples were retrieved and polished. Similarly, all the 20 samples were fabricated. Two bar specimens of dimensions 65mmx10mmx1mm were cut into 10 square shaped specimens of dimensions 10mm x 10mm x1mm.

Figure 4: Fabrication of the PMMA resin samples.

Fabrication of group B specimens (bis- acrylic composite resin)

The material is delivered in cartridge form as base and catalyst pastes, with BIS- GMA serving as the primary component. After loading the cartridge into the mixing gun, the material was loaded into the mould spaces of the lubricated brass flask. The flask compartments were approximated, and the samples were retrieved and polished after five minutes. The 20samples were all made in the same way. Two bar specimens measuring 65mm x 10mm x 1mm were cut into ten square specimens measuring 10mm x 10mm x 1mm.

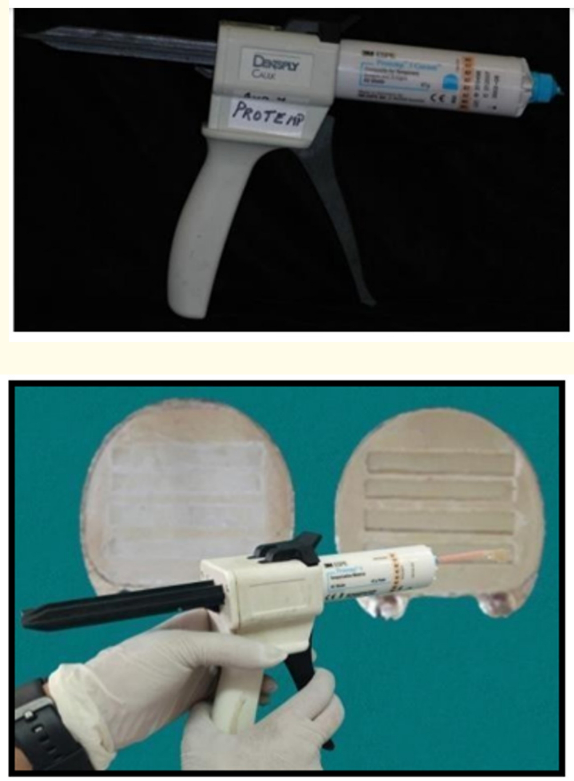


Figure 5: Fabrication of the BIS- ACRYL samples.

Fabrication of group C specimens (visible light cure resin).

The specimens were directly 3D printed i.e., BY Additive Manufacturing through 3D printer using visible light cure resin. CAD models of ten bar shaped specimens of dimensions 65mm x 10mm x 3mm and ten square shaped specimens of dimensions 10mm x 10mm x 1mm were converted to a STL file to tesellate the 3D shape and sliced into digital layers. 3D models of the specimens were created using CAD software or a 3D object scanner. STL file was then transferred to the printer using custom machine software. Printer builds the model by depositing material layer by layer. Finally post-processing cleaning and polishing were done. All the 20 samples were fabricated in the same way.

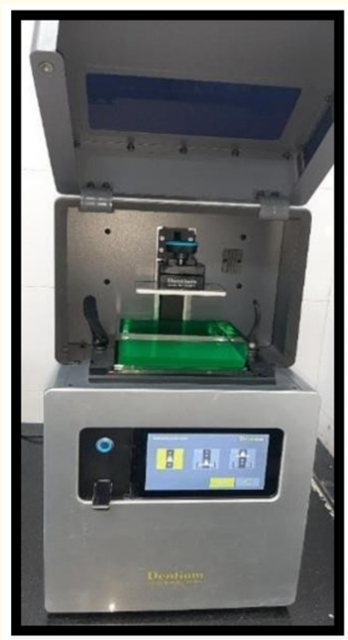


Figure 6: 3D Printer.

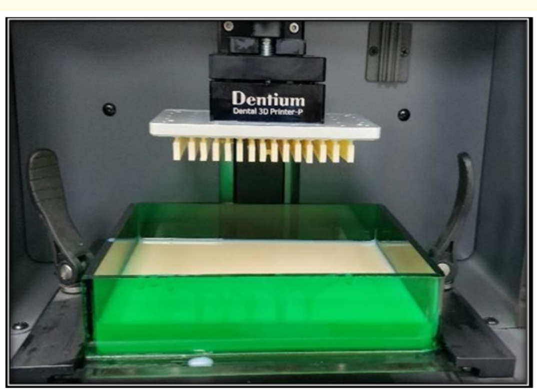
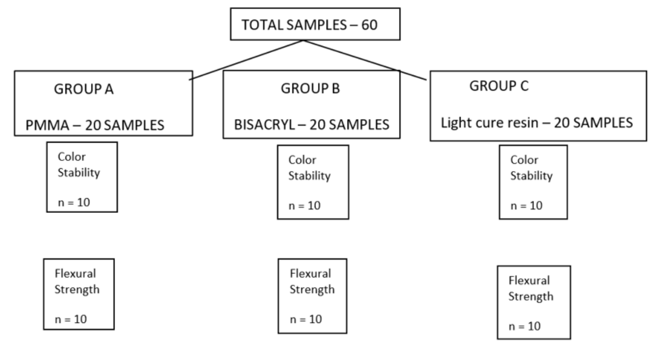


Figure 7: Fabrication of the Visible light cure samples.

Grouping of samples



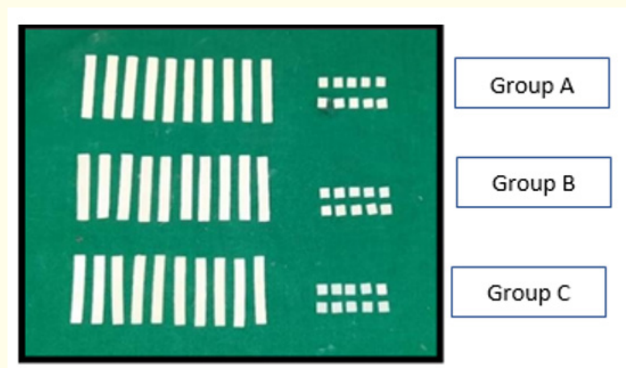


Figure 8: Grouping of samples.

Conditioning of the specimens

All the 60 specimens prepared were stored in artificial saliva for 7 days. Thermal cycling was done using two water baths: one at 5°C and the other at 55°C. The temperatures in each water bath were digitally controlled and dwelling time of 6 seconds was maintained in each. A total of 2500 cycles were carried out in the similar manner. Then, the samples were subjected to 3-point bending test and spectrophotometer test.

Testing of the specimens for flexural strength using universal testing machine

Each specimen was subjected to three-point bend test.

The flexural strength value obtained was in Mega Pascals (MPA).

Figure9: Thermocycling of Test Samples.

Figure 10: Testing of flexural strength using universal testing machine.

Testing of the specimens for color stability using spectrophotometer

After 7 days of immersion in various solutions and thermocycling, specimens were evaluated for colour change. The specimens were rinsed with water for 30 seconds before each colour measurement, gently cleansed with a soft bristle toothbrush to remove any loose sediment, and then blotted dry with tissue paper. A spectrophotometer was used to measure the colour.

Color difference ΔE was calculated from the mean ΔL*, Δa*, Δb* values for each specimen with the formula:

$$\Delta E = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{½}$$

The L* coordinate (from 0 to 100) quantifies the amount of white, black in the sample; the higher the L* value, the whiter the sample (0 = black, 100 = white). Color is measured along the red-green axis using A* coordinates: The amount of red in the sample is represented by a positive value, while the amount of green is represented by a negative value; the b* coordinate measures colour along the yellow-blue axis: A positive b* value is shown in yellow, while a negative b* value is shown in blue.

The device can analyse 100 specimens per hour and is linked to a computer to record colorimetric data.

Figure 11: Testing of color stability using spectrophotometer.

Statistical analysis

The mean and standard deviationcalculated from the specimens were statistically analysed for each subgroup. The mean values were compared using a one-way analysis of variance (ANOVA). To compare the groups, the Paired Sample T test was used. The level of significance in the current study was set at p 0.05.

Results

The CIELAB system determines colour stability by comparing values to NBS units. The National Bureau of Standards (NBS) rates how the human eye evaluates colour changes (Table 1). As a result, the colour change values of all three materials were multiplied by 0.92 to yield the NBS values.

Critical remarks of color difference	△E NBS units
Trace	From 0.0 to < 0.5
Slight	From 0.5 to < 1.5
Noticeable	From 1.5 to < 3.0
Appreciable	From 3.0 to < 6.0
Much	From 6.0 to <12.0
Very much	≥ 12.0

Table 1: The Color difference between the three materials using One Way ANOVA test.

The CIELAB system for measuring the color difference of the three materials is obtained by the following formula:

ΔE (Color difference) = $(\Delta L^2 + \Delta a^2 + \Delta b^2)$ ^1/2

The lesser the value, the materials will have a duller and lighter appearance when compared with base line values of the materials.

The table depicts the color difference values between the materials and their mean and standard deviation values accordingly. The values show that the color stability is least in 3D PRINTED PROVSIONAL CROWNS followed by DPI HEAT CURED RESIN and the highest being the PRO TEMP provisional crowns.

The NBS units have also been displayed in the table which entails that there is a noticeable change in the color value in PRO TEMP materials and being the material with highest color stability when compared to the other two materials

DPI	Δe NBS units	3.498392 3.202521
PROTEMP	Δe NBS units	3.09884 3.00939
3d Printing	ΔE NBS units	3.906633 3.864900

Table 2: Means and SD- DPI, PROTEMP and 3D printing.

The following table depicts the mean values and the standard deviation of the materials, the means values determine the average of all the 10 samples tested for color stability with PROTEMP ranking first in slight change in color stability while the least color stable being the 3D PRINTING resin. The standard deviation explains the dispersion of the data set lesser the deviation the greater will be the chances of variance and the nearer to mean which is the baseline for the statistical analysis significance of the data set.

		ΔL^2	Δa^2	Δb^2
DPI	Mean	3.2788	0.23391	2.8524
	SD	1.6323	0.21649	2.2858
PROTEMP	Mean	2.0984	0.3376	2.5307
	SD	1.6939	0.8134	1.7571
3D Printing	Mean	3.201601	2.519841	1.0718
	SD	1.50306	2.07845	3.9835

	ΔE Values Before	ΔE Values After	P values
ΔE DPI	2.517929	3.871405	P < 0.023*
ΔE PROTEMP	2.141232	3.460387	P < 0.02*
ΔE 3D Printing	2.383285	3.99195	P < 0.04*

Table 3: ΔE value before and after thermocycling using Paired t- test.

The table depicts the ΔE values of all the three materials before and after thermocycling and it describes that the color change values with the least being in the Protemp with a value before being

ΔE while after thermocycling being ΔE 3.46 followed by DPI with a value before being ΔE 2.14 while after thermocycling

being ΔE 3.96 and the high color change or color difference being in 3D printing with a value before being ΔE 2.14 while after thermocycling being ΔE 3.96.

FLEXURAL STRENGTH of all the three materials is tested and the comparative analysis is determined by the mean variables of the 30 samples with 10 each being DPI, PROTEMP and 3D

	N	Mean	Std. Deviation	P Value
DPI	10	80.30	2.858	0.02*
3D PRINTING	10	42.52	1.61	0.04*
PRO TEMP	10	90.92	1.04	0.02*

Table 4: The Mean and SD of DPI, PROTEMP and 3D Printing.

Provisional restorative resins have been used to fabricate custom-made restorations using direct and indirect techniques [5]. In the recent times, CAD- CAM technology is being emphasized for their fabrication [6].

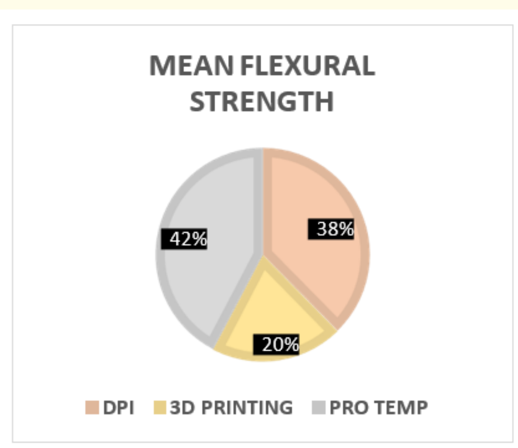


Chart 1: Mean flexural strength of the materials.

The above values depict the stress bearing capacity and the flexural stability of the materials with the statistical acceptable data. As the values suggest PROTEMP has the highest flexural strength when compared with DPI and the 3D Printing materials.

PROTEMP with MEAN 90.92

± 1.04 SD > DPI with MEAN 80.32 ± 2.8

SD > 3D Printing with MEAN 42.52

± 1.6SD

Discussion

Provisional restoration is an important component of fixed prosthodontics, designed to improve aesthetics, stability, and function during the transition period before a definitive prosthesis is placed [4].

Poly methyl methacrylate (PMMA), poly ethyl or butylmethacrylate (PEMA), microfilled bisphenol A-glycidyl dimethacrylate (Bis-GMA) composite resin, and urethane dimethacrylate (UDMA) composite resin are the fourtypes of provisional restorative materials [7].

In this study, the flexural strength and color stability of three commercially available provisional restorative resin materials were compared after storing in artificial saliva and thermal cycling.

Flexural strength tests evaluate stresses as compressive at the point of application and tensile and shear at the point of resistance, which is similar to the stresses produced by multi-unit fixed partial dentures. A universal testing machine and a 3-point bend test can be used to determine flexural strength.

Furthermore, when a material is subjected to different temperature regulations, the changes that occur should be evaluated when the material is used overtime. Specimens were stored in artificial saliva for a few days to simulate the oral environment before being thermocycled for 2,500 cycles (5°C to 55°C) to assess various thermal regulations. Following that, the specimens were subjected to a standard three-point bending test.

Flexural strength was tested on 30 of the 60 specimens, 10 from each group, and the mean, standard deviation, and test of significance were calculated for all groups. One-way analyses of variance were used to examine the statistics for each group (ANOVA).

Table 4 shows that the mean flexural strength comparisons between Groups A, B, and C are statistically significant (P = 0.045) because the values differ. Bis-acryl composite resin (Group B) had the highest flexural strength, followed by PMMA (Group A) and 3D printingresin (Group C). The mean and standard deviation of flexural strength for PROTEMP is 90.22 ± 1.04 SD > DPI

80.34 ± 1.6 SD > 3D PRINTING 42.52

± 2.8SD

At this time interval, the fracture toughness of both groups was comparable. However, Protemp, a bis-acryl composite resin, had the highest flexural strength value. and Osman YI*., et al*. in 1993, and Koumjian JH., *et al.* in 1990, found no There is a significant difference between interim methyl methacrylate and bis-acryl resins. Haselton DR., *et al.* discovered that the majority of bis-acryl composites were stronger when they compared the transverse strength of five auto-polymerizing PMMA resins and eight bis-acryl composite resins.

To compare the groups, the Independent sample t test was used. The results also revealed that the Bis-acryl composite resin material had greater flexural strength than the other material, which could be attributed to multifunctional monomers that increase strength through crosslinking with other monomers [7]. They also contain inorganic nano fillers, which increase the material's strength. The cartridge delivery system accurately dispensed Bis-acryl resin, and the auto mixing system ensured complete polymerisation. It is hydrophobic in nature, so it absorbs little water and thus has less plasticiser action when stored in artificial saliva. Traditional methacrylate resins are monofunctional, low molecular weight, linear molecules with reduced strength and rigidity [8].

The current study also discovered that the flexural strength of Bis-acryl resin (Protemp-4) after thermocycling was significantly higher than that of PMMA (DPI) and 3D Printing specimens.

This study's findings are consistent with those of previous studies by Nejatidanesh F., *et al.* Hasselton., *et al.* in which the flexural strength of Bis-acryl resins was found to be greater than that of conventional provisional restorative materials.

Color stability of provisional crown and bridge resins is a concern, particularly when the provisional restoration is in the aesthetic zone and must be worn for an extended period of time [9].

The results of the present study revealed that Bis-acryl composite resin (Protemp-4) is more color stable than and PMMA (DPI) and the least being the Visible light cure resin (3D Printing resin), the possible explanation for the for the lower color stability for of 3D printing resins could be that various factors can influence resin polymerisation, such as curing time, orientation, and post- processing, resulting in incomplete polymerisation and affecting the overall properties of the material.

Song SY [10] also concluded that, regardless of the materials and solutions used, the degree of discoloration increased over time, resulting in a visually perceptible colour difference value (E). After 8 weeks, discoloration changed faster in PMMA milled and 3 D-printed materials.

DPI (polymethyl methacrylate- based resin) has lower colour stability than Bis-acryl composites due to higher resin content and porosity. Furthermore, according to the manufacturer, Protemp-4 employs modified bowen resin, which corresponds to hydrophobic derivatives of Bis-acryl compounds. This significantly reduces the water absorption of these materials and may account for Protemp-4's higher colour stability in all solutions [11].

The results of the present study are similar to those studies conducted by Turker SB., *et al*. [12] Braden., *et al*. [13] which concluded that Bis-acryl resins are more color stable than PMMA.

Limitations of the Study

- Although the study was designed to simulate in-vivo conditions, the experimental design had limitations in accurately replicating clinical conditions.
- The problem encountered in all *in vitro* studies, that is, the correlation of laboratory bench properties with clinical conditions.
- The test specimens were stored in only artificial saliva and were not subjected to different staining solutions, which could have an effect on the colour change because the oral cavity is normally subjected to different solutions.

Conclusions

Within the limitations of the study, the following conclusions were drawn:

- Among the three materials compared, Bis-acryl composite resin (Protemp-4) had exhibited highest flexural strength and color stability.
- Among the three materials compared, Bis-acryl composite resin (Protemp-4) Because of its higher flexural strength, can be considered the best material for long-term provisionalization. Also, because Bis-acrylic composite resin is delivered in cartridge form, it makes provisional crown fabrication much easier.
- Among three materials compared in this study, Bis-acryl composite resin (Protemp-4) and Polymethyl methacrylate, can be used as long- term provisional materials as they met the minimum requirement of 50MPa flexural strength, even after thermal cycling.
- Bis-acryl composite resin (Protemp-4) is the most color stable provisional restorative material followed by polymethyl methacrylate (DPI) and 3D Printing resin.

Conflict of Interest

The authors declare that no financial interest or any conflict of interest exists with regard to the present study.

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