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Evaluation of microhardness and color stability in PMMA and BIS-acryl as provisional restorative materials: A clinical study

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Abstract:
Selecting provisional materials when esthetics and short-term mechanical stability are priorities remains a tedious task for clinicians. Therefore, it is of interest to compare the microhardness and colour stability of four common provisional materials (DPI, Trulon, Protemp and Cooltemp). Eighty specimens of PMMA and bis-acryl were fabricated each. Results showed that Protemp had the best overall performance among the tested materials. Thus, turmeric is a stronger colourant than coffee and Cooltemp showed the highest ΔE values.

Keywords: Polymethyl methacrylate (PMMA), BIS-acryl, microhardness, color stability, coffee, turmeric

Background:
Provisional or interim prosthesis or restoration is a fixed or removable dental or maxillofacial prosthesis designed to enhance esthetics, stabilization and function for a limited period of time, after which it is to be replaced by a definitive dental or maxillofacial prosthesis **[1]**. To be successful, these restorations should fulfill biological, mechanical and esthetic requirements **[2]**. Interim fixed restorative materials can be divided into four groups based on their composition as Polymethyl methacrylate (PMMA), polymethyl or butyl methacrylate, micro filled bisphenol A-glycidyldimethacrylate (Bis-GMA) composite resin and Urethane Methacrylate (UDMA) (light-polymerizing resins) **[3]**. PMMA because of its biocompatibility, low cost, ease of production, stability in the oral environment, excellent aesthetics, advantageous properties, ease of processing, precise fit, low equipment requirements for the fabrication process, low water sorption and adequate strength, it has been the material of choice. Due to certain drawbacks like poor mechanical strength, low fatigue strength, poor thermal conduction, a high thermal expansion coefficient, low impact strength, a low elastic coefficient, low resistance to fatigue brittleness and low hardness, PMMA is still far from ideal interim restorative material **[4]**. Bis-acryl composite resins offer additional advantages such as minimal polymerization shrinkage, lower exothermic reaction, superior wear resistance and enhanced strength, although their disadvantages include higher cost, brittleness and reduced polish ability **[3]**. Provisional restorations should provide an acceptable initial shade match, as well as colour stability during their service life. The concern is particularly relevant when provisional restorations are needed for long periods of time and the evaluation of colour stability becomes a decisive aspect in the choice of material **[5, 6]**. Another important property is hardness which measures the density of the material. Higher density is correlated with a better resistance to wear and surface degradation and therefore is a predictive parameter for the wear behaviour of the material. Moreover, the surface finish and polishability are strongly correlated with hardness **[7]**. Therefore, it is of interest to report the microhardness and colour stability of PMMA and Bis-acryl provisional restorative materials after immersion in saliva, coffee and turmeric in the absence of studies.

Materials and Methods:

Sample preparation:

Polymethyl Methacrylate (PMMA):
80 PMMA specimens were prepared in total: 40 disc-shaped specimens (for colour stability testing) and 40 rectangular specimens (for microhardness testing). A glass slab was kept on a metal mould. Petroleum jelly was applied on the inner surface of the mould to get the cast out easily. The material was poured into the mould and another glass plate placed on top to give a smooth surface. The specimens were carefully removed after polymerisation and their dimensions were standardised using a vernier calliper.

Bis-acryl composite resin:
Eighty specimens were prepared from bis-acryl composite resin, 40 disc-shaped specimens for colour stability and 40 rectangular specimens for microhardness tests. The composite was directly dispensed with a mixing tip from the cartridge into a metal mould placed on a glass slab lubricated with petroleum jelly. The material was spread evenly with a spatula, covered with a glass slab and allowed to set. Once retrieved, the finishing and polishing was done. Dimensional accuracy was verified by means of a vernier calliper and each specimen was numbered to allow for consistent evaluation at baseline and after immersion.

Colour stability testing:
Baseline colour of disc-shaped specimens was measured using a reflectance spectrophotometer in CIE Lab* colour system. Each sample was loaded on the aperture, covered with the lid and analysed through the software command. The staining solutions were prepared as follows:

Coffee solution:
1.5 g coffee powder dissolved in 1000 mL of boiling water and cooled to room temperature.

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Turmeric solution:
1.5 g of turmeric powder in 1000 mL of water. The specimens were immersed in either solution for 14 days, changing the solutions every fourth day. At the end of the immersion period, the specimens were rinsed with tap water, air-dried and re-evaluated with the spectrophotometer. Colour difference (Δ E) was calculated by the following formula:

Microhardness tests:
Surface hardness of the rectangular specimens was initially measured using a Vickers microhardness tester with a digital recording system and a maximum load capacity of 9.8 N. The load used in the three-point indentation test on each specimen was 0.098 N for a period of 10s. The indentation left a rhomboidal shaped impression which was measured digitally. Then, the specimens were immersed in artificial saliva for 14 days and hardness values were reassessed. The Vickers Hardness Number (VHN) was measured.

Results:
DPI showed the highest microhardness at baseline (18.33) followed by Trulon (14.77). Protemp (7.80) and Cooltemp (6.40) showed lower values. The differences between groups were highly significant (p = 0.000). DPI (6.65), Trulon (9.16) and Cooltemp (5.76) showed significant decreases after 14 days in artificial saliva, while Protemp (7.01) remained stable (p = 0.326). The percentage reduction analysis indicated that DPI lost almost two-thirds of its hardness (63.7%), Trulon lost a moderate amount (38.0%), whereas Protemp (10.1%) and Cooltemp (10.0%) lost very little, which was confirmed by Cohen's d effect sizes (DPI: extremely large, Trulon: very large, Cooltemp: medium, Protemp: small and non-significant). Colour stability Coffee immersion No significant intergroup difference was observed (p = 0.083). However, Protemp (ΔE = 2.84) was clinically acceptable (≤ 3.3) unlike DPI (3.82), Trulon (4.21) and Cooltemp (4.31). Turmeric immersion resulted in significantly higher discolouration with highly significant differences (p = 0.000); Protemp (ΔE = 17.67) was the most stable but still unacceptable, Trulon (18.95) and DPI (24.02) showed intermediate discolouration, while Cooltemp (40.81) was the most severely affected (**Table 1, Figure 1**).

Table 1: Pairwise comparison of microhardness before and after immersion in saliva

Group	Condition	Mean	N	Std. Deviation	Std. Error Mean	p-value	Interpretation
A1 (DPI)	Before	18.34	20	3.9	0.87	**0.000**	Highly significant decrease
	After	6.65	20	2.84	0.63		
A2 (Trulon)	Before	14.77	20	3.2	0.71	**0.000**	Highly significant decrease
	After	9.16	20	0.96	0.21		
B1 (Protemp)	Before	7.8	20	3.58	0.8	0.326 (NS)	No significant change
	After	7.01	20	2.12	0.47		
B2 (Cooltemp)	Before	6.41	20	1.42	0.32	**0.000**	Highly significant decrease
	After	5.76	20	1.25	0.28		

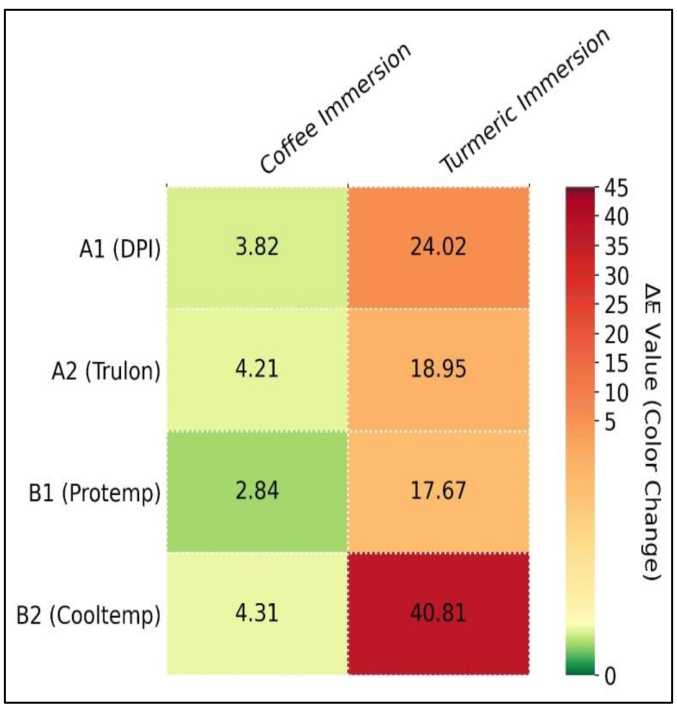

Figure 1: Clinical acceptability if color stability of coffee versus turmeric immersion

Discussion:
While selection of provisional interim restorations both hardness and color stability play a major decisive role **[5, 6]**. Extensive research done in the past failed to identify the color stability of provisional restorative material that can withstand color changes **[8]**. Thereby, present study was conducted to evaluate the microhardness and color stability of PMMA and Bis-Acryl provisional restorative materials after saliva, coffee and turmeric immersion. In the present study, two commonly available categories of provisional restorative materials, PMMA-based resins and bis-acryl composite resins, were selected due to their wide clinical usage **[3, 4]**. The staining solutions used in the present study were coffee and turmeric, as they are among the most common dietary colorants encountered in daily life. Color stability is generally tested by immersing materials in such staining media to simulate clinical exposure. Results of the study can be concluded that PMMA showed significant reduction in microhardness after immersion in artificial saliva compared to bis-acryl composites. Turmeric was identified as a more potent colorant than coffee and Cooltemp exhibited the highest ΔE values, confirming its inferior color stability. Banode & Deshpande *et al*. **[9]** attributed this to curcumin, the principal yellow pigment in turmeric, which has a higher polarity and smaller molecular size, thereby increasing staining potential. The water sorption property of bis-acryl composites further enhances curcumin uptake. Protemp performed best overall in both

microhardness and color stability, making it more clinically reliable among the tested materials. It can be attributed to its fabrication process, which involves high-temperature polymerization under pressure, resulting in more complete monomer conversion, higher molecular weight and denser cross-linked network. This enhances the ability of the material to resist plastic deformation under loading as reported by Mehraj *et al.* 2020 **[10]** and Yerra *et al.* 2025 **[11]**. The manufacturers of Protemp utilize modified Bowen resin which is hydrophobic in nature. Due to this character of this provisional material of being hydrophobic, there is markedly less amount of water absorption observed being the reason for higher color stability when compared to DPI. The DPI material seems to be very less color stable because of its contents which are mainly higher resin level leading to higher porosity of these materials when compared to other materials. Furthermore, the resin content is highly prone for water sorption by means of two processes of absorption and adsorption as reported by Osiceanu *et al.* **[12]**. According to a study by Bassenheim *et al.* the reason for discoloration seems to contribute for oxidation of the polymer matrix or the unreacted double bonds in the residual monomers leading to the subsequent formation of degradation products from water diffusion process **[13]**. In most of these studies, water proves to be acting as a penetration vehicle. Henceforth, the present study revealed that the most reliable temporary restorative material was Protemp, with better overall efficacy, minimal hardness deterioration and perfect colour stability which were in accordance to the study conducted by Sokhal *et al.* **[14]** wherein Bis-acryl composite materials demonstrated a significantly higher surface hardness than PMMA-based materials. 3M Protemp 4 showed the greatest hardness and could be best suited for long-term provisional restorations. The present study is, however, not without limitations. Only two properties (microhardness and colour stability) were investigated, while other clinically relevant properties such as surface roughness, translucency and wear resistance were not taken into account. Furthermore, the tests were carried out on flat specimens, while real clinical restorations are made on curved crown surfaces, which may influence the staining and hardness results.

Conclusion:

Protemp, being a bis-acryl substance, showed better hardness retention after immersion in saliva, while PMMA materials had higher initial hardness. Turmeric caused significantly more discolouration than coffee and resulted in clinically unsatisfactory staining of all substrates. The most reliable temporary restorative material was Protemp, with better overall efficacy, minimal hardness deterioration and perfect colour stability.

Conflict of interest: None

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