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Comprehensive Evaluation of Physical Properties Between PMMA, Bio HPP, and HIPC Resin Material for Temporary Crown Application in Dental Implant

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Abstract

Introduction
Interim crowns are essential in restorative dentistry to protect prepared teeth and maintain aesthetics before definitive restoration. This study aimed to evaluate and compare the color stability and marginal adaptation of three interim restorative materials—PMMA, HIPC, and BioHPP—used in temporary crown applications for dental implants.
Materials and Methods:
A total of 36 temporary crown specimens were fabricated, with 12 specimens each of PMMA, HIPC, and BioHPP. Color stability was assessed using a spectrophotometer before and after brushing, chewing, and thermocycling simulations to replicate oral conditions. Marginal adaptation was evaluated under a stereomicroscope both before and after these simulations to determine changes in fit. The data obtained were statistically analyzed using one-way ANOVA and post hoc Tukey's HSD test, with a significance level set at $p < 0.05$.
Results:
The results indicated no statistically significant difference in color stability among the three materials, suggesting that all exhibited comparable resistance to discoloration under simulated oral conditions. However, significant differences were noted in marginal adaptation. BioHPP demonstrated the poorest marginal fit after simulation, whereas PMMA exhibited the most favorable marginal adaptation. HIPC showed intermediate performance with acceptable marginal accuracy.
Conclusion:
While all materials demonstrated satisfactory color stability, PMMA showed the best marginal adaptation, followed by HIPC, with BioHPP exhibiting the least accurate fit. These findings highlight the importance of material selection for optimal interim restoration performance. Further clinical studies are warranted to assess long-term durability and other mechanical properties.

INTRODUCTION

In dental implantology, the choice of materials for temporary crowns is a crucial factor influencing the overall success of treatment. Temporary crowns, also referred to as provisional restorations, serve multiple essential functions during the period between implant placement and the placement of the final prosthesis. They protect the surgical site, preserve aesthetics, and maintain functional integrity and patient comfort. Among the commonly used materials for temporary crowns, Polymethyl Methacrylate (PMMA) and High-Impact Polystyrene Composite (HIPC) resins are widely recognized for their distinct performance characteristics and material properties[1] (Alageel et al., 2022).

Polymethyl Methacrylate (PMMA) has been a fundamental material in dentistry for several decades, primarily due to its favorable attributes such as ease of manipulation, cost-effectiveness, and satisfactory aesthetics. PMMA is a transparent thermoplastic polymer used extensively in diverse fields, including optical devices, orthopedic bone cement, and dental restorations[2] (Astudillo-Rubio et al., 2018). Its popularity in dental applications is attributed to its biocompatibility, sufficient mechanical strength, and adaptability to various fabrication methods. Despite these advantages, PMMA presents several limitations such as polymerization shrinkage, relatively low wear resistance, and susceptibility to fracture under high masticatory stress, which restrict its long-term applicability and encourage the exploration of alternative materials.

High-Impact Polystyrene Composite (HIPC) resins have recently gained attention as a potential alternative to PMMA, offering enhanced mechanical and aesthetic performance. HIPC is designed to improve toughness and impact resistance by incorporating elastomeric components into the polystyrene matrix, thereby increasing its flexibility and resilience[2] (Astudillo-Rubio et al., 2018). These modifications make HIPC particularly suitable for provisional restorations exposed to repetitive loading and stress. Additionally, HIPC resins exhibit improved aesthetic characteristics, including better color stability and translucency, which are critical for restorations in the anterior region[3] (Reda et al., 2022).

Another advanced material used in temporary crown fabrication is BioHPP (biocompatible high-performance polymer). BioHPP is a high-performance polymer reinforced with ceramic, combining the advantageous properties of both materials[3] (Reda et al., 2022). It offers superior biocompatibility, making it ideal for intraoral applications. BioHPP crowns display excellent mechanical properties such as high fracture toughness, superior wear resistance, and long-term durability that closely mimic natural dentition. Their stability under masticatory load and ability to achieve highly aesthetic outcomes make them a valuable choice for extended provisional restorations.

A comparative assessment of PMMA, HIPC, and BioHPP involves analyzing their physical and mechanical properties, which have direct clinical implications. Parameters such as compressive strength, flexural strength, wear resistance, hardness, and color stability determine the performance and longevity of provisional crowns[4] (Karaokutan, Sayin and Kara, 2015). Compressive and flexural strengths are essential for withstanding occlusal forces, while wear resistance and hardness ensure material durability. Aesthetic factors like color matching, translucency, and surface smoothness are equally significant, as they contribute to patient satisfaction and treatment success.

Recent advancements in dental material science have led to the development of resin-based materials with enhanced and targeted properties suited for various clinical applications. Comparative studies between PMMA, HIPC, and BioHPP resins demonstrate distinct variations in their mechanical, physical, and aesthetic attributes[5] (Kim, Kwak and Kim, 2020). For instance, PMMA is often selected for short-term use due to its simplicity and affordability, while HIPC resins are favored for their superior mechanical strength and aesthetic quality. Conversely, BioHPP stands out for its exceptional biocompatibility, fracture resistance, and long-term stability, making it an optimal choice for extended provisional use.

Therefore, the present study aims to comprehensively evaluate and compare various physical properties—such as color stability, marginal integrity, fit, and surface finish—of PMMA and HIPC resin materials. Additionally, parameters like mechanical strength, wear resistance, and biocompatibility will be analyzed to determine the most suitable material for temporary crown fabrication in implant-supported restorations.

Materials and Methods

This in-vitro study was carried out at the white lab of Saveetha dental college,The study was registered and approved by the Institutional Review Board of Saveetha Dental College. SRB reference No. SRB/SDC/MSIMPLANT-2306/24/055

Preparation of samples

To establish a standardised and clinically relevant experimental framework, intraoral impressions were captured from consenting patients requiring implant-supported restorations. Simultaneously, impression copings and analogues were recorded to facilitate subsequent model fabrication. The collected impressions were meticulously poured to create accurate gypsum models, which were subsequently digitised using an intraoral scanner.

Leveraging the digital model, a comprehensive three-dimensional virtual design of the desired crown was executed employing 3Shapes software. The finalized design was then exported as a standard tessellation language (STL) file, serving as a blueprint for the subsequent manufacturing process.

Utilizing computer-aided manufacturing (CAM) technology, temporary crown prototypes were milled from prefabricated blanks of PMMA, HIPC, and BioHPP resins. To simulate clinical conditions, these milled crowns were precisely fitted onto standardized abutment and analogue fixtures. A total of 24 crowns, meticulously divided into three experimental groups (n=8 per group), were fabricated in conjunction with an equal number of abutments and analogues, forming the foundation for the subsequent experimental protocols.

This standardized approach ensured consistency and replicability across all experimental specimens, enhancing the reliability and validity of the study findings.

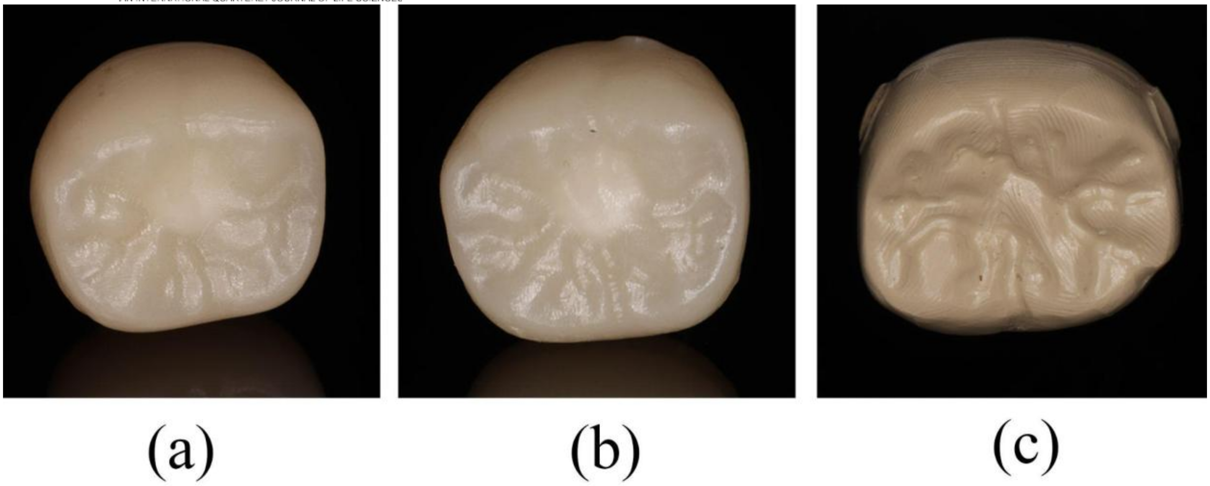


Figure 1. Temporary crowns : (a) PMMA, (b) HIPC, and (c) BioHPP

Testing

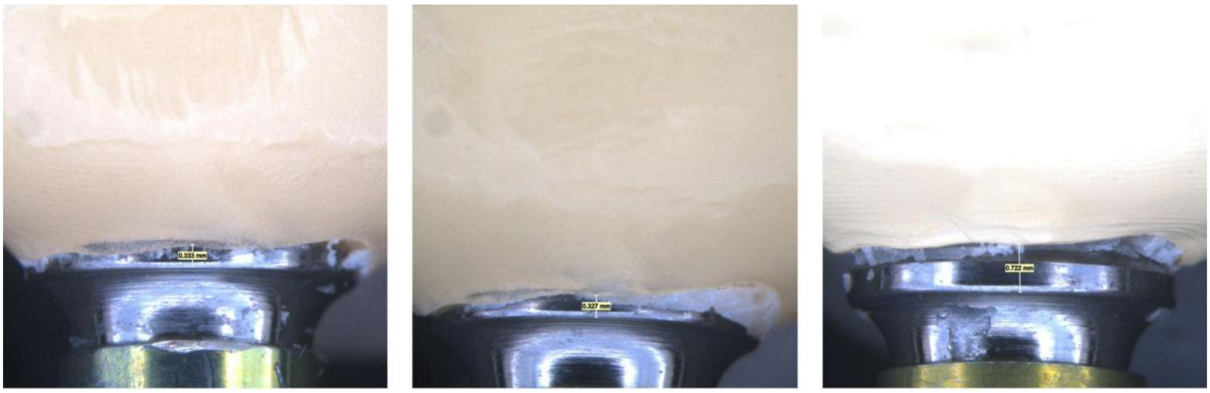
Colour stability test

A spectrophotometer measures the intensity of light when it passes through a material. It captures the colour and gives the data in terms of L*a*b* values which can also be derived as ΔE values for the colour stability of the material. In our research, we utilised an ultraviolet and visible light digital spectrophotometer to assess samples' colour stability before and after brushing simulation, chewing simulation and thermocycling. The colour stability tests were conducted without exposing the materials to coloured solutions like tea or coffee. The spectrophotometer was connected to a computer system for measuring colour. At the same time, the software was employed to record spectrophotometric data and calculate the total colour difference (ΔE) for each disc sample. Colourimetric measurements in the CIELab colour space captured the L*, a*, and b* values against a white background. These measurements were conducted on each specimen, and the mean values for L*, a*, and b* were computed based on three separate measurements at different time intervals. All recordings of L*, a*, and b* values were conducted by a single examiner. To determine the overall colour difference between the two instances in the three-dimensional L*a*b* colour space, we applied Hunter's equation, $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{(1/2)}$, yielding a single value, ΔE.

Figure 2. Color parameter measurement of the specimens using a spectrophotometer.

Marginal adaptation

Crowns were fitted on the mater die and tested for marginal adaptation using a stereo microscope at x40 magnification (name of the microscope) and photographed (name of the camera). The vertical marginal gap between the finish line and the crown margin was measured to the nearest 0.01µm at each of the four engraved reference points. The average marginal gap was calculated and tabulated for each sample.



(a) (b) (c)

Figure 3. Vertical Marginal Gap measurement of the specimens using a Steriomicroscope.

Brushing simulation

The sample consists of 16 temporary crowns (8 samples each in two groups). The marginal adaptation was measured using a stereomicroscope and the colour stability was measured using a spectrophotometer (Konica Minolta - Spectrophotometer). The samples were mounted over die stone to ensure better retention, while brushing with a toothbrush simulator (ZM3.8 SD Mechatronik) with a brush weight of 300 grams. The samples were brushed with (name of the toothpaste). There were 30,000 cycles of brushing, 10,000 times in the x-axis direction, 10,000 in the y-axis direction, and 5000 times in the clockwise and counterclockwise direction. The marginal fit and colour stability were re-evaluated post-brushing simulation and the values were compared. The data of both pre and post-brushing values were recorded manually and statistically uploaded on SPSS software version 23 (IBM SPSS Statistics for Windows, Version 23.0) and values were represented in bar graph forms.-----

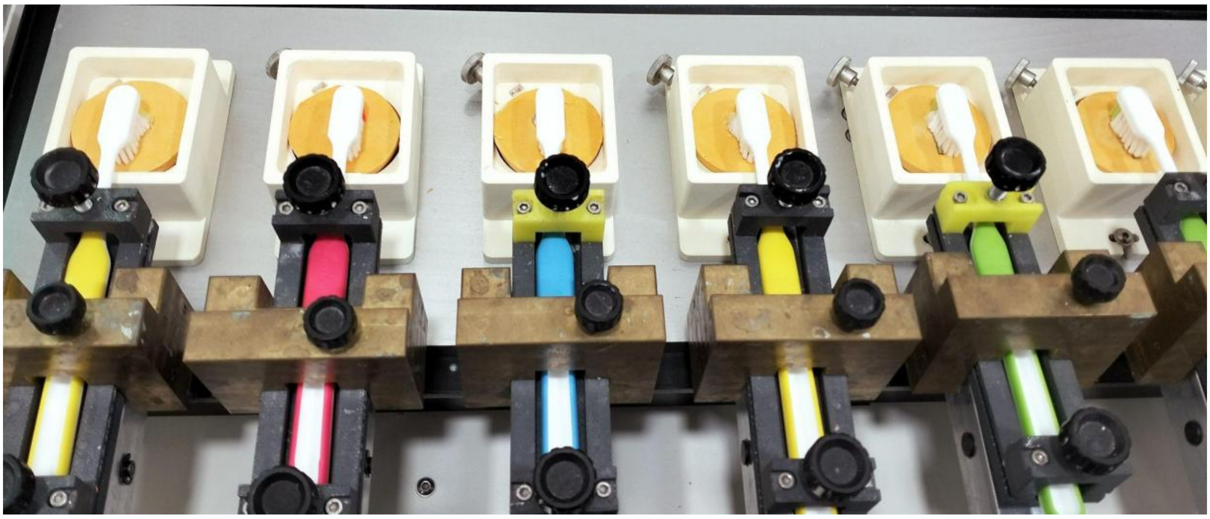


Figure 4. Toothbrush Simulation was done using ZM3.8 SD Mechatronik.

Chewing simulation

Chewing simulators were used to evaluate the wear resistance, fatigue testing and marginal adaptation over a prolonged period corresponding to more than 60,000 cycles. The Chewing simulator (CS-4, SD Mechatronik) has four testing chambers. It has two moving parts, the vertical bar (Z-axis), and the horizontal table (X-axis). The samples were mounted onto the table, which can move back and forth. Customised antagonists measuring 4mm in diameter were connected to the vertical bar, which moves up and down with a load of 5N and 50N at 15 Hz applied to the samples simulating a masticatory load intraorally. The linear movement was applied to the samples in a bucco-lingual motion. The axis of movement of the antagonist was 2mm in diameter on the X-axis, Y-axis and Z-axis. The circular movements had a diameter of 4mm, intrusion depth of 2mm and a speed of 20mm/s. The evaluation of the marginal fit was done using a stereomicroscope, which analyses the gap between the crown and the abutment. The samples from all three groups were pretested in the stereomicroscope.

Figure 5. Chewing simulation was done using S.D.Mechatronnik Chewing Simulator CS 4.4

Thermocycling

Thermocycling is done to replicate the temperature fluctuation experienced in the oral cavity. All the samples for both groups were subjected to thermal cycling (name of the machine) in distilled water at 5°C-55°C for 10,000 cycles (5°C for 30s; 55°C for 30s; rest period for 10s), which corresponded to approximately 1 year in the clinical setting environment.

Figure 6. Thermocycling was done using HOLMARC Opto Mechatronics HO-THC-01

STATISTICAL ANALYSIS

A comprehensive statistical analysis was undertaken using the Statistical Package for Social Sciences (SPSS), version 23. This analysis aimed to characterize the distribution of the collected data for three key parameters: colour stability (ΔE value), marginal fit (micrometres, µm), and fracture resistance (Newtons, N). Descriptive statistics were employed, specifically presenting the **mean (M)** and **standard deviation (SD)** for each parameter (Table 1). This approach provides a concise yet informative summary of the central tendency and variability observed within the data sets.

The measurements were analyzed using one-way ANOVA test with a Tukey post hoc multiple comparison to determine any statistically significant difference in color change and marginal fit between the three groups. The level of statistical significance was set at $P < 0.05$.

RESULTS

Color stability

The comparison of color stability among PMMA, HIPC, and BioHPP using one-way ANOVA followed by Tukey HSD post hoc analysis revealed no statistically significant differences between the materials ($p > 0.05$). Although minor variations were observed in the mean color change values—PMMA (-0.01375 vs. HIPC; -0.11250 vs. BioHPP) and HIPC (-0.09875 vs. BioHPP)—these differences were not significant, indicating that all three materials exhibited comparable color stability. This suggests that, under the experimental conditions, PMMA, HIPC, and BioHPP maintain their color integrity similarly over time. The lack of significant difference implies that factors such as material composition, polymer matrix, and filler characteristics contribute equally to resistance against discoloration. Hence, from an aesthetic standpoint, all three materials can be considered clinically acceptable for provisional restorations where color stability is an important requirement. (Figure 7)

Table 1. One-way ANOVA comparison for the color change between groups.

Color Stability				
Multiple Comparisons - Tukey HSD				
(I) Group	(J) Group	Mean Difference (I-J)	Standard error	Significance
PMMA	HIPC	-0.01375	0.09044	0.987
	BioHPP	-0.11250	0.09044	0.442
HIPC	PMMA	-0.01375	0.09044	0.987
	BioHPP	-0.09875	0.09044	0.529
BioHPP	PMMA	-0.11250	0.09044	0.442
	HIPC	-0.09875	0.09044	0.529

****P value less than or equal to 0.05 is considered a statistically significant difference***

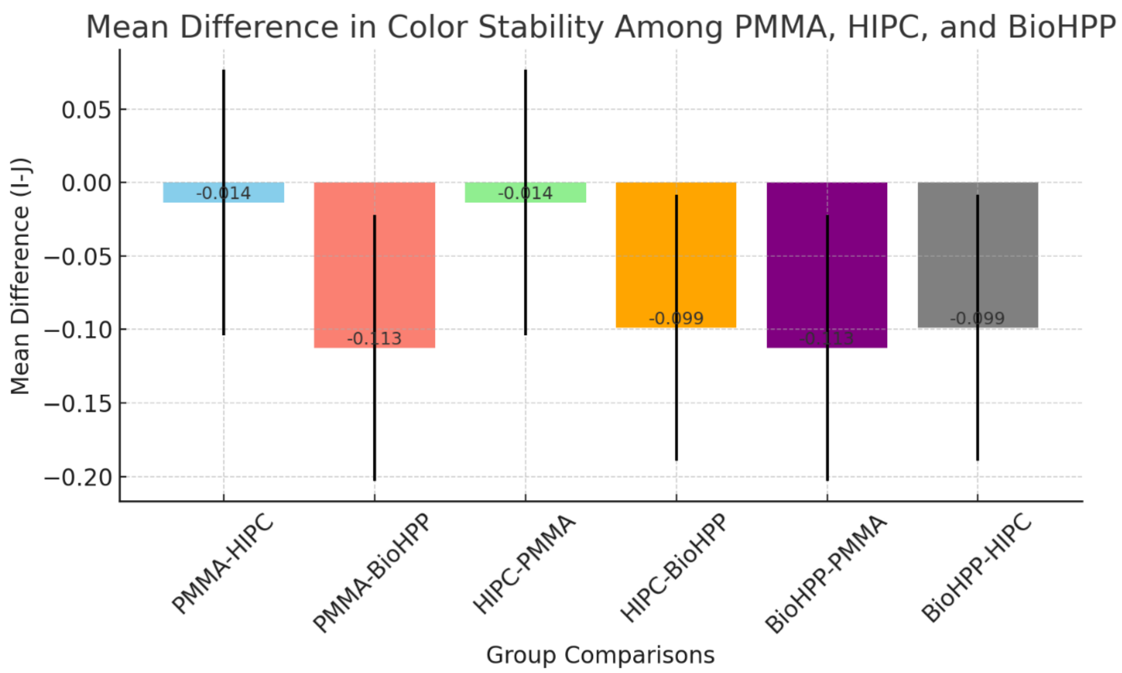


Figure 7. Mean of Color Stability

Marginal adaptation- Pre

The one-way ANOVA and Tukey HSD post hoc analysis for marginal fit (pre-treatment) among PMMA, HIPC, and BioHPP demonstrated a statistically significant difference between the three materials ($p = 0.05$). The results indicate that BioHPP exhibited the poorest marginal fit prior to treatment, as reflected by significantly higher mean difference values when compared to PMMA and HIPC ($p = 0.000$). In contrast, PMMA and HIPC showed comparable marginal fits, with no statistically significant difference between them ($p = 0.908$). This suggests that before any intervention, PMMA and HIPC provided a more accurate and consistent marginal adaptation than BioHPP. The reduced marginal accuracy of BioHPP may be attributed to its higher rigidity and different processing characteristics compared to resin-based materials. Thus, from a pre-treatment standpoint, PMMA and HIPC are more favorable for achieving better marginal adaptation in provisional crown fabrication.(Figure 8)

Table 2. One-way ANOVA comparison for the Marginal Gap (Before Intervention) between groups.

Marginal Fit (Pre)				
Multiple Comparisons - Tukey HSD				
(I) Group	(J) Group	Mean Difference (I-J)	Standard error	Significance
PMMA	HIPC	0.02262	0.05382	0.908
	BioHPP	-0.60613	0.05382	0.000
HIPC	PMMA	-0.02262	0.05382	0.908
	BioHPP	-0.62875	0.05382	0.000
BioHPP	PMMA	0.60613	0.05382	0.000
	HIPC	0.62875	0.05382	0.000

P value less than or equal to 0.05 is considered a statistically significant difference

Marginal adaptation- Post

The one-way ANOVA and Tukey HSD post hoc analysis for marginal fit (post-treatment) among PMMA, HIPC, and BioHPP revealed a highly significant difference between the materials ($p = 0.000$). Post-intervention comparisons demonstrated that PMMA exhibited the best marginal adaptation, followed by HIPC, while BioHPP showed the poorest marginal fit after treatment. The mean difference values indicate that BioHPP had significantly higher marginal discrepancies compared to both PMMA and HIPC, confirming inferior adaptation accuracy. Conversely, the minimal mean difference between PMMA and HIPC suggests that both materials maintained relatively stable and consistent marginal integrity after intervention, with PMMA showing a distinct advantage. These findings imply that PMMA's polymeric structure and processing characteristics may contribute to improved adaptation to the abutment surface, whereas the higher stiffness and ceramic reinforcement in BioHPP could lead to marginal discrepancies. Overall, PMMA remains superior in maintaining marginal accuracy post-treatment.(Figure 9)

Table 3. One-way ANOVA comparison for the Marginal Gap (After Intervention) between groups.

Marginal Fit (Post)				
Multiple Comparisons - Tukey HSD				
(I) Group	(J) Group	Mean Difference (I-J)	Standard error	Significance
PMMA	HIPC	0.08625	0.01300	0.000
	BioHPP	-0.70875	0.01300	0.000
HIPC	PMMA	-0.08625	0.01300	0.000
	BioHPP	-0.79500	0.01300	0.000
BioHPP	PMMA	0.70875	0.01300	0.000
	HIPC	0.79500	0.01300	0.000

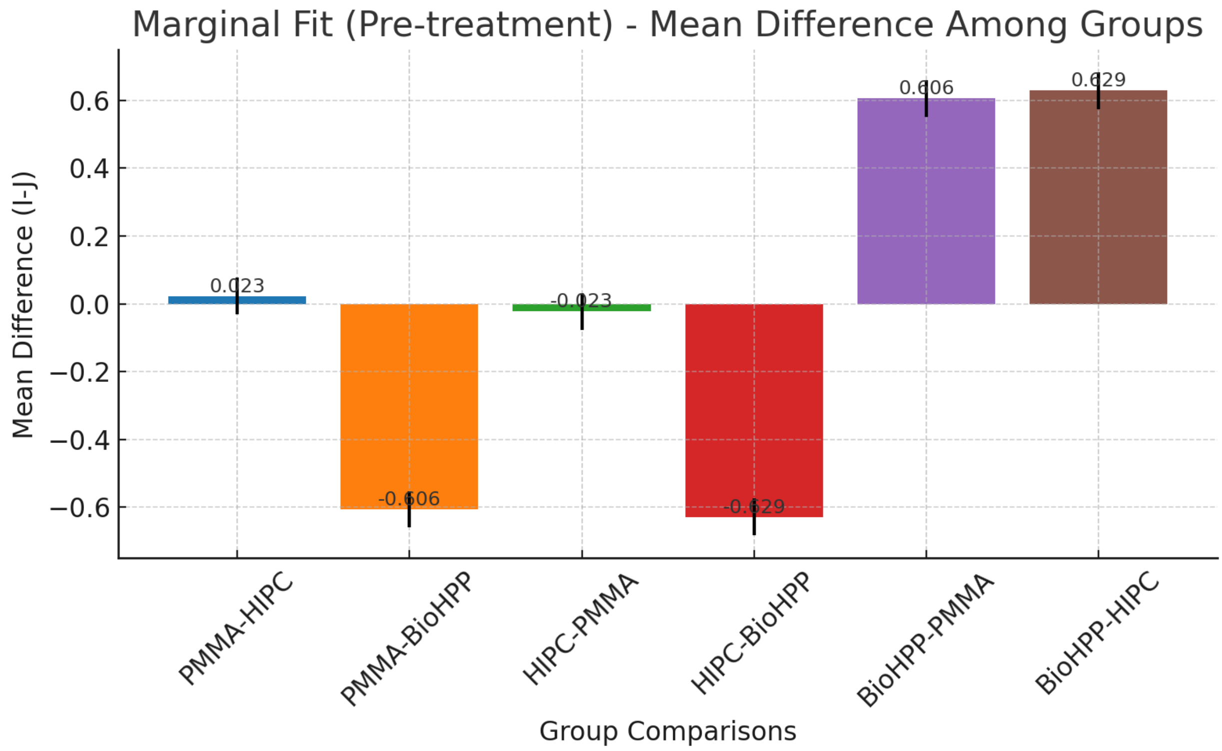


Figure 8. Mean Marginal Gap (Before Intervention)

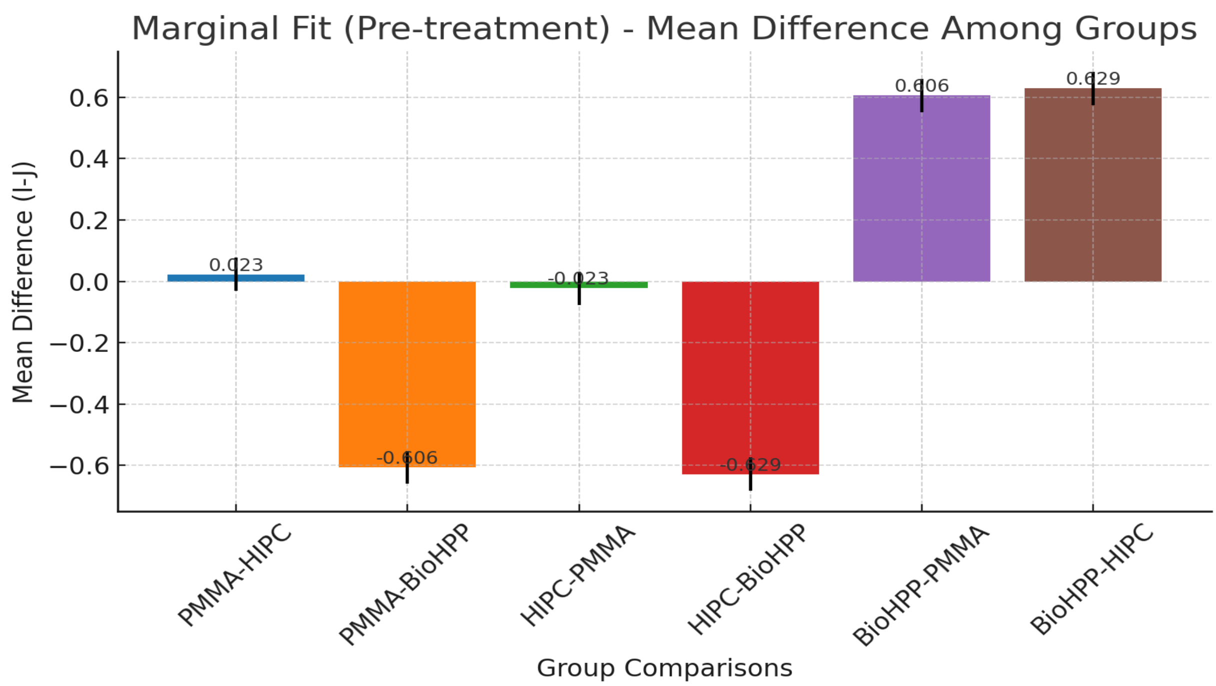


Figure 9. Mean Marginal Gap (After Intervention)

DISCUSSION

Despite their short-term application, the color stability and marginal adaptation of interim crowns remain critical, particularly when these restorations are placed in the aesthetic zone and must be retained for extended periods. Interim restorations serve as essential components in implant and fixed prosthodontic procedures, acting as protective barriers for the prepared tooth, preventing pulpal irritation, and reducing the risk of recurrent caries. However, numerous studies have reported that temporary restorations fabricated from different materials exhibit varying degrees of discoloration and marginal discrepancies over time. Hence, ensuring both aesthetic and functional integrity is vital, even for provisional restorations.

In the present study, specimens underwent brushing simulation, chewing simulation, thermocycling, and fracture resistance tests to evaluate color stability and marginal adaptation[5] (Kim, Kwak and Kim, 2020). Although these simulations do not perfectly replicate intraoral conditions, they are widely accepted as reliable indicators of clinical performance and have been utilized in previous studies evaluating interim restorative materials. These tests mimic the mechanical fatigue, thermal variations, and masticatory forces that restorations endure in the oral cavity. By adopting these standardized protocols, the study provides valuable insights into the behavior of different interim crown materials under clinically relevant stressors, helping clinicians make informed choices based on durability and color stability.

While these simulation-based assessments may not perfectly mirror real-life scenarios, they provide a consistent and reproducible framework for comparing the performance of materials[7] (Porojan et al., 2021). This allows for a better understanding of how interim materials may perform during prolonged use, particularly in patients requiring extended provisionalization. The findings contribute to optimizing the selection of materials that maintain both functional efficiency and aesthetic appearance throughout their service period.

The results of this study indicated that PMMA, HIPC, and BioHPP showed comparable color stability, with no statistically significant difference between them. This observation aligns with previous research evaluating color stability across a range of restorative materials such as PMMA and CAD-CAM ceramics. For instance, Elagra et al. (2017) found PMMA to have superior color stability over a short testing period[6]. BioHPP, a material derived from PE6EK and reinforced with ceramic fillers, is characterized by its dense polymer matrix and resistance to discoloration[3]. When fabricated using CAD/CAM technology, BioHPP demonstrates enhanced surface finish and color consistency[8,9] (Joshi, 2019; Chitsaz et al., 2023). These findings correlate with prior studies supporting the improved physical and mechanical performance of BioHPP in terms of durability and wear resistance.

PMMA (Polymethyl Methacrylate), while popular for its affordability and ease of fabrication, tends to have lower color stability than newer materials. Studies have shown PMMA to be more prone to discoloration upon exposure to beverages such as tea, coffee, and red wine[10,3] (Nazirkar et al., no date). Experimental studies immersing PMMA crowns in staining solutions reported significant changes in color, confirming its susceptibility to extrinsic staining. On the other hand, HIPC (High Impact Polymer Composite) crowns exhibited improved color stability compared to PMMA due to their advanced polymer matrix and higher resistance to pigment absorption[10] (Nazirkar et al., no date). Comparative findings revealed that HIPC and BioHPP performed better than PMMA in maintaining color integrity, underscoring their suitability for provisional restorations in aesthetic zones[10] (Nazirkar et al., no date).

Regarding marginal adaptation, a statistically significant difference was found among the materials. BioHPP demonstrated the poorest marginal fit, whereas PMMA exhibited the best adaptation, followed closely by HIPC. This outcome emphasizes the importance of selecting materials that ensure precision and minimize microgaps at the crown margins. A study published in *BMC Oral Health* reported that PEEK crowns demonstrated satisfactory marginal adaptation, comparable to zirconia restorations[11] (Emam and Metwally, 2023). The use of CAD/CAM fabrication techniques enhances precision, reducing the likelihood of marginal discrepancies and thereby preventing microleakage and periodontal complications[12] (Astudillo-Rubio et al., 2018).

Although PMMA is widely used for provisional crowns due to its cost-effectiveness and ease of handling[10] (Nazirkar et al., no date), it is prone to polymerization shrinkage, contributing to marginal discrepancies. Deshpande and Banode (2023) found that conventionally fabricated PMMA crowns displayed higher marginal gaps compared to those produced by CAD/CAM or 3D printing methods[13]. Conversely, HIPC crowns, when produced using CAD/CAM milling, demonstrated enhanced marginal accuracy and dimensional stability[14] (Meshreky, Halim and Katamish, 2020). This improvement can be attributed to the precise machining and the material's inherent resistance to deformation.

Overall, BioHPP crowns, despite their superior mechanical properties, showed greater marginal discrepancies than PMMA and HIPC. In contrast, PMMA and HIPC crowns fabricated with CAD/CAM technology exhibited superior marginal adaptation, a critical factor influencing restoration longevity[15] (Roy et al., 2019). Consequently, for temporary crowns requiring high precision and minimal marginal gaps, PMMA and HIPC remain more favorable choices than BioHPP.

Strengths and Limitations of the Study

The primary strength of this study lies in its comparative design, which evaluates multiple key physical properties—color stability, marginal adaptation, and structural durability—under standardized simulated conditions. The inclusion of three different materials (PMMA, HIPC, and BioHPP) provides a comprehensive understanding of their relative performance. Furthermore, the use of chewing, brushing, and thermocycling simulations adds clinical relevance by closely approximating intraoral stresses. However, the study is limited by its in vitro design, which may not completely replicate the complex oral environment involving saliva, pH fluctuations, and microbial interactions. Additionally, the sample size and duration of testing may restrict generalizability to long-term clinical scenarios. Future in vivo studies with extended observation periods are recommended to validate these findings and provide deeper insights into the long-term behavior of these interim restorative materials.

CONCLUSION:

The present study provides valuable insights into the comparative evaluation of color stability and marginal adaptation among three commonly used interim restorative materials — PMMA, HIPC, and BioHPP. The findings revealed that while there was no statistically significant difference in the color stability of the tested materials, variations were observed in their marginal fit. PMMA demonstrated the most favorable marginal adaptation, suggesting its continued reliability for achieving precise interim restorations. In contrast, BioHPP exhibited the poorest marginal fit, indicating potential limitations in its adaptation accuracy despite its promising physical and esthetic properties. HIPC, on the other hand, showed intermediate performance, displaying good color stability and an acceptable level of marginal adaptation, making it a balanced option for temporary restorations in esthetically demanding situations.

These results emphasize that while the choice of material does not greatly influence color retention under simulated clinical conditions, marginal accuracy remains a critical factor that differentiates material performance. Clinicians must therefore consider both esthetic and functional aspects when selecting interim restoration materials, particularly for cases requiring extended wear.

Nevertheless, the study was conducted under in-vitro conditions, which may not fully replicate the complex oral environment, including variations in pH, temperature, and salivary enzymes. Hence, further long-term clinical studies with larger sample sizes are warranted to validate these findings, assess additional parameters such as wear resistance, flexural strength, and surface roughness, and provide a more comprehensive understanding of the clinical behavior of PMMA, HIPC, and BioHPP. Ultimately, such evidence-based comparisons will guide clinicians in making more informed material choices to ensure the longevity, functionality, and esthetics of interim restorations

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