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Colorimetric Stability of CAD/CAM Milled Polymethyl Methacrylate Provisional Restoration Material (Bloomden) Exposed to Antimicrobial Mouthrinses: An In Vitro Study

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Abstract

Background: Polymethyl methacrylate (PMMA) provisional restorations serve critical biological, structural, and aesthetic functions during prosthodontic treatment. Patients wearing long-term provisionals are frequently prescribed antimicrobial mouthrinses to maintain periodontal health. Colour stability of these restorations under chemical exposure is a key determinant of clinical acceptability.

Aims: To evaluate and compare the colorimetric stability of CAD/CAM milled PMMA (Bloomden) provisional material following immersion in chlorhexidine and octenidine mouthrinses at simulated clinical exposure intervals.

Material and Methods: Twelve standardised disc-shaped specimens (diameter 3.5 cm, thickness 1.5 mm) were milled from shade A2 Bloomden PMMA blocks and polished to a high-gloss finish. Specimens were divided into two groups (n = 6 each) and immersed in 0.2% chlorhexidine digluconate (Group 1) and 0.1% octenidine dihydrochloride (Group 2) at 37°C. CIE L*a*b* colour coordinates were recorded using a calibrated spectrophotometer under D65 illumination at baseline, 12 hours, and 24 hours. Total colour change (ΔE) and National Bureau of Standards (NBS) units were calculated. One-way analysis of variance (ANOVA) with Tukey's HSD post hoc test was applied ($\alpha = 0.05$).

Results: Mean ΔE values for chlorhexidine were 0.217 ± 0.050 (12 h) and 0.346 ± 0.212 (24 h); for octenidine, 0.179 ± 0.100 (12 h) and 0.304 ± 0.135 (24 h). All NBS unit values were below 0.5, classifying colour changes as 'Trace'. ANOVA demonstrated no statistically significant difference between groups or time intervals ($F = 2.09$; $P = 0.1330$).

Conclusions: CAD/CAM milled PMMA (Bloomden) demonstrates excellent colorimetric stability when exposed to chlorhexidine and octenidine mouthrinses. All colour changes are clinically imperceptible, supporting its use in long-term provisional restorations without compromising aesthetic outcomes.

Keywords: Bloomden; CAD/CAM; Chlorhexidine; Colour stability; Octenidine; Polymethyl methacrylate; Provisional restoration

Introduction

Provisional restorations occupy a pivotal role in fixed prosthodontic treatment. Far from acting as mere placeholders, they serve as biological seals protecting prepared dentinal surfaces from thermal, chemical, and microbial insults; they maintain the spatial relationships of the dentition; and they allow clinicians and patients to evaluate the aesthetic and functional outcome prior to delivery of the definitive prosthesis.[1]

In complex rehabilitative scenarios — including full-arch implant treatments, occlusal reconstruction, and pre-prosthetic adjunctive procedures — provisional restorations may remain in clinical service for several weeks to months. During this extended period, antimicrobial mouthrinses are routinely prescribed to control bacterial plaque and promote periodontal healing around prepared tissues.[2] Chlorhexidine digluconate is the most widely used agent for this purpose, given its broad-spectrum antimicrobial efficacy and substantivity. It is, however, well-established that chlorhexidine promotes extrinsic discolouration of oral tissues and dental materials through non-enzymatic browning reactions and precipitation of dietary chromogens.[3,5]

Octenidine dihydrochloride has emerged as a clinically comparable antimicrobial agent with a theoretically reduced staining potential, owing to its distinct biochemical interaction profile.[6] Whilst its periodontal benefits are established, its colorimetric impact on provisional restorative materials remains incompletely investigated.

Conventional chairside-fabricated PMMA provisionals produced through auto-polymerisation are inherently susceptible to porosity, residual monomer entrapment, and the development of an open micro-architecture that facilitates fluid sorption and chromogen diffusion.[4,7] The consequent colour instability frequently necessitates premature replacement of provisional restorations, causing patient dissatisfaction and increased clinical time.

CAD/CAM milled PMMA blocks — manufactured under precisely controlled industrial conditions of elevated temperature and isostatic pressure — achieve near-complete polymerisation, minimal residual monomer content, and negligible porosity, all of which theoretically enhance resistance to colorimetric degradation.[4] Despite these theoretical advantages, published in vitro evidence specifically examining the colour stability of CAD/CAM milled PMMA against antimicrobial mouthrinses at clinically simulated exposure intervals is limited. The purpose of this study was, therefore, to evaluate and compare the colorimetric stability of CAD/CAM milled PMMA (Bloomden Bioceramics Co., Ltd., China) following accelerated immersion in chlorhexidine and octenidine mouthrinses.

Material and Methods

Ethics

This study was a purely in vitro laboratory investigation. No human subjects, human tissues, animal subjects, or biological materials were utilised. Patient data, clinical records, or any identifiable information were not accessed at any stage. Formal ethical approval was, therefore, not required. All materials were commercially available dental products obtained through standard procurement channels.

Specimen Preparation

Twelve disc-shaped specimens were milled from pre-polymerised CAD/CAM PMMA dental blocks (Bloomden Bioceramics Co., Ltd., China) of Vita classical shade A2 [Figure 1]. Digital design files (disc dimensions: diameter 3.5 cm, thickness 1.5 mm) were created in dental CAD software (EXOCAD; DentalCAD, Exocad GmbH, Darmstadt, Germany) [Figure 2] and exported to a multi-axis milling unit for standardised specimen fabrication.

All specimens were subjected to a standardised polishing protocol simulating the clinically delivered surface finish: sequential finishing with blue- and red-coded tungsten carbide burs, hand-polishing with 100 µm and 120 µm abrasive sandpapers, followed by polishing on a dental lathe using wet pumice and diamond polishing paste with a cotton buff. Specimens were ultrasonically cleaned with ethanol, then stored in distilled water at 37°C for 24 h prior to baseline measurements to ensure complete hydration and chemical equilibration. The twelve prepared specimens are illustrated in Figure 3.

Grouping and Immersion Protocol

Specimens were randomly allocated to two experimental groups (n = 6 per group):

Group 1 (Chlorhexidine): Continuous immersion in 0.2% chlorhexidine digluconate mouthrinse

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[Hexidine®; ICPA Health Products Ltd., India] [Figure 4b].

Group 2 (Octenidine): Continuous immersion in 0.1% octenidine dihydrochloride mouthrinse [Orahex Pro®; Abbott India Ltd., India] [Figure 4a].

All specimens were individually housed and maintained in a thermostatic incubator at 37°C ± 1°C to simulate intraoral temperature [Figure 5]. Continuous immersion for 24 h simulates approximately three to six months of daily clinical mouthrinse usage at the recommended frequency of one to two minutes per day. Colour measurements were recorded at baseline (T_0), 12 h (T_1), and 24 h (T_2). At each interval, specimens were removed with non-metallic forceps, rinsed with distilled water, blotted dry with lint-free tissue, measured, and returned to fresh mouthrinse.

Colour Measurement

Colour assessment was performed using a calibrated reflectance spectrophotometer (Premier Colorscan; Premier Instruments, Mumbai, India) [Figure 6] against a standardised white background under D65 illuminant (standard daylight, 6500 K). Three replicate readings were obtained at the centre of each specimen at each time point and the mean value recorded. Colour coordinates were recorded in the CIE L*a*b* colour space, where L* denotes lightness (zero = black; 100 = white), a* the green-to-red axis, and b* the blue-to-yellow axis.

Total colour change (ΔE) was calculated using the standard Euclidean formula:

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

ΔE values were converted to National Bureau of Standards (NBS) units using: NBS unit = ΔE × 0.92, as described by Paffenbarger.[8] The NBS scale provides a clinically meaningful classification of colour change perceptibility [Table 3].

Statistical Analysis

Descriptive statistics (mean and standard deviation) were calculated for ΔE values at each time point for both groups. One-way ANOVA was used to assess differences in colour change between groups and time intervals. Tukey's Honestly Significant Difference (HSD) post hoc test was applied for pairwise comparisons. Statistical analysis was performed using an online statistical calculator (www.statskingdom.com). The level of significance was set at $P < 0.05$.

Results

The baseline CIE L*a*b* colour coordinates and the corresponding changes at 12 h and 24 h are presented for the chlorhexidine group in Table 1, and for the octenidine group in Table 2.

Individual and mean ΔE values at both time intervals are presented in Table 4. For the chlorhexidine group, mean ΔE was 0.217 ± 0.050 at 12 h and 0.346 ± 0.212 at 24 h. For the octenidine group, mean ΔE was 0.179 ± 0.100 at 12 h and 0.304 ± 0.135 at 24 h. The maximum mean ΔE recorded across all conditions was 0.346, in the chlorhexidine group at 24 h.

NBS unit conversion is presented in Table 5. All NBS unit values ranged from 0.164 to 0.318, falling strictly within the 'Trace' category of the NBS scale (NBS unit < 0.5), indicating that all colour changes were clinically imperceptible under all experimental conditions.

One-way ANOVA [Table 6] revealed no statistically significant difference in colour change across all groups and time intervals ($F = 2.09$; $P = 0.1330$). Tukey's HSD post hoc test [Table 7] confirmed no statistically significant difference in any pairwise comparison (all $P > 0.05$).

Discussion

The present study evaluated the colorimetric stability of CAD/CAM milled PMMA (Bloomden) following immersion in chlorhexidine and octenidine mouthrinses at clinically simulated exposure intervals. All ΔE and NBS unit values remained well within the clinically imperceptible range under all conditions, providing strong support for the aesthetic longevity of this material in the presence of antimicrobial mouthrinses.

The threshold for clinically acceptable colour change in dental materials is broadly accepted to be a ΔE of 1.0 (perceptible to approximately 50% of trained observers under controlled conditions) and a ΔE of 3.3 (threshold of clinical unacceptability).[9,10] The maximum mean ΔE observed in this study (0.346, chlorhexidine group at 24 h) is considerably below the perceptibility threshold, confirming the clinical

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suitability of this material for long-term provisional use.

The superior colour stability can be attributed to the distinctive microstructural characteristics of industrially polymerised CAD/CAM PMMA. Chairside-fabricated acrylic provisionals produced through auto-polymerisation are characterised by incomplete monomer conversion, significant microporosity, and an open micro-architecture that facilitates fluid sorption and chromogen diffusion.[4,7] CAD/CAM processing achieves near-complete polymerisation under controlled high-pressure and high-temperature conditions, resulting in high cross-linking density, negligible residual monomer, and minimal porosity.[4] The diffusion coefficient for chromogenic molecules is consequently substantially reduced, and the polished, hydrophobic surface resists both mechanical entrapment and chemical adhesion of staining agents.

Chlorhexidine is known to exert its staining effect through direct adsorption of its dicationic form to anionic surface groups, precipitation of dietary chromogens, and facilitation of non-enzymatic browning reactions.[5,12] The near-impermeable structure of milled PMMA effectively denies these mechanisms the substrate required for stain propagation. Octenidine demonstrated marginally lower ΔE values than chlorhexidine at both time intervals, consistent with its established reduced chromogenic potential.[6] The difference between agents was not statistically significant (P = 0.1330), indicating that both are equally safe from a colorimetric standpoint when used with CAD/CAM PMMA provisionals.

These findings are consistent with Sham et al.,[3] who reported superior colour stability for pre-fabricated PMMA blocks compared with chairside-fabricated resins, and with Scotti et al.,[4] who demonstrated that the processing method significantly influences the optical properties of provisional acrylic materials.

Limitations

This study was conducted under controlled laboratory conditions, which do not fully replicate the complexity of the oral environment. The absence of a salivary pellicle — a proteinaceous film that forms over all oral surfaces and influences stain adhesion[11] — is a recognised limitation of in vitro immersion protocols. Dietary chromogens such as coffee and tea, which act synergistically with chlorhexidine in producing extrinsic staining,[12] were excluded to isolate the specific chemical effect of each mouthrinse. Future studies should incorporate artificial saliva, dietary chromogens, anatomically representative specimen geometries, and longitudinal clinical trials to validate these findings in clinical practice.

Conclusions

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. CAD/CAM milled PMMA (Bloomden) exhibits excellent colorimetric stability following exposure to both chlorhexidine and octenidine mouthrinses at simulated clinical exposure intervals.

2. All recorded colour changes were classified as 'Trace' on the NBS scale, indicating clinical imperceptibility.

3. No statistically significant difference was observed between the staining potential of chlorhexidine and octenidine on this material (P = 0.1330).

4. Clinicians may confidently prescribe antimicrobial mouthrinses, including chlorhexidine, without compromising the colour stability of CAD/CAM milled PMMA provisional restorations.

List of Abbreviations

ANOVA: Analysis of variance

CAD/CAM: Computer-aided design / Computer-aided manufacturing

CIE: Commission Internationale de l'Eclairage

ΔE: Total colour change (Euclidean distance in CIELAB colour space)

HSD: Honestly Significant Difference

NBS: National Bureau of Standards

PMMA: Polymethyl methacrylate

SD: Standard deviation

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Financial Disclosure

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Conflict of Interest

The authors declare that there are no conflicts of interest with respect to the publication of this article.

Data Availability Statement

The raw data supporting the results of this study are available from the corresponding author upon reasonable request.

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Table 1: CIE L*a*b* baseline values and colour co-ordinate changes – Chlorhexidine group

Sp.	L*	a*	b*	ΔL* (12h)	Δa* (12h)	Δb* (12h)	ΔL* (24h)	Δa* (24h)	Δb* (24h)
1	74.687	-1.018	10.560	0.074	0.028	0.291	0.021	-0.064	0.087
2	74.872	-0.955	11.175	-0.039	-0.030	-0.145	-0.147	-0.163	-0.645
3	75.165	-1.518	10.241	-0.116	-0.100	0.212	-0.151	0.022	-0.327
4	74.852	-1.118	10.367	-0.164	0.077	-0.085	-0.302	0.029	-0.015
5	75.121	-1.562	10.654	-0.125	0.096	-0.125	-0.361	-0.109	-0.035
6	74.965	-1.368	10.964	-0.149	0.165	-0.648	-0.415	-0.203	-0.125

Sp. = Specimen. L: Lightness (0 = darkest; 100 = lightest). a*: negative = green; positive = red. b*: negative = blue; positive = yellow. Δ = change from baseline. †Values represent means of three replicate readings.*

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Table 2: CIE L*a*b* baseline values and colour co-ordinate changes – Octenidine group

Sp.	L*	a*	b*	ΔL* (12h)	Δa* (12h)	Δb* (12h)	ΔL* (24h)	Δa* (24h)	Δb* (24h)
1	74.833	-0.951	11.061	0.008	-0.015	-0.013	0.034	-0.079	0.097
2	74.710	-0.841	10.663	0.066	0.168	0.236	-0.097	-0.054	-0.436
3	74.852	-1.118	10.367	-0.164	0.077	-0.085	-0.302	0.029	-0.015
4	75.121	-1.562	10.654	-0.125	0.096	-0.125	-0.361	-0.109	-0.035
5	74.872	-0.955	11.175	-0.039	-0.030	-0.145	-0.147	-0.163	-0.645
6	75.165	-1.518	10.241	-0.116	-0.100	0.212	-0.151	0.022	-0.327

Sp. = Specimen. L: Lightness (0 = darkest; 100 = lightest). a*: negative = green; positive = red. b*: negative = blue; positive = yellow. Δ = change from baseline. †Values represent means of three replicate readings.*

Table 3: National Bureau of Standards (NBS) scale for clinical colour change perceptibility

NBS Units	Perceived Difference	Definition
0.0–0.5	Trace	Extremely slight change
0.5–1.5	Slight	Slight change
1.5–3.0	Noticeable	Perceivable change
3.0–6.0	Appreciable	Marked change
6.0–12.0	Much	Extremely marked change
>12.0	Very Much	Change to a different colour

Source: Paffenbarger GC (1966).[8]

Table 4: Individual and mean total colour change (ΔE) values for CAD/CAM PMMA (Bloomden) following mouthrinse immersion

Mouthrinse	Duration	S1	S2	S3	S4	S5	S6	Mean ± SD
Chlorhexidine	12 hours	0.302	0.153	0.261	0.200	0.172	0.214	0.217 ± 0.050
Chlorhexidine	24 hours	0.681	0.110	0.392	0.303	0.140	0.451	0.346 ± 0.212
Octenidine	12 hours	0.021	0.297	0.158	0.175	0.146	0.280	0.179 ± 0.100
Octenidine	24 hours	0.130	0.450	0.295	0.190	0.293	0.468	0.304 ± 0.135

S1–S6 = Specimens 1–6. SD = Standard deviation. CAD/CAM = Computer-aided design/Computer-aided manufacturing. PMMA = Polymethyl methacrylate.

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Table 5: NBS unit conversion and clinical perceptibility classification

Mouthrinse	Duration	Mean ΔE ± SD	NBS Unit
Chlorhexidine	12 hours	0.217 ± 0.050	0.199
Chlorhexidine	24 hours	0.346 ± 0.212	0.318
Octenidine	12 hours	0.179 ± 0.100	0.164
Octenidine	24 hours	0.304 ± 0.135	0.279

NBS unit = ΔE × 0.92. All values < 0.5 NBS units, classified as 'Trace' (clinically imperceptible). SD = Standard deviation.

Table 6: One-way analysis of variance (ANOVA) for colour change (ΔE) across groups and time intervals

Source of Variation	SS	df	MS	F	P
Between groups	0.1391	3	0.0464	2.09	0.1330
Within groups	0.4443	20	0.0222	—	—
Total	0.5834	23	—	—	—

SS = Sum of squares. df = Degrees of freedom. MS = Mean square. F = F statistic. P = Probability value. P > 0.05 indicates no statistically significant difference.

Table 7: Tukey's HSD post hoc test – pairwise comparisons of ΔE across all groups

Pair	Groups Compared	Q Statistic	P Value	Significance
1 vs 2	CHX 12 h vs CHX 24 h	0.93	0.3925	NS
1 vs 3	CHX 12 h vs Oct 12 h	0.27	0.9650	NS
1 vs 4	CHX 12 h vs Oct 24 h	0.63	0.6979	NS
2 vs 3	CHX 24 h vs Oct 12 h	1.20	0.1919	NS
2 vs 4	CHX 24 h vs Oct 24 h	0.30	0.9524	NS
3 vs 4	Oct 12 h vs Oct 24 h	0.90	0.4216	NS

CHX = Chlorhexidine. Oct = Octenidine. h = hours. NS = Not significant (P > 0.05). HSD = Honestly Significant Difference.

Figure Legends

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Figure 1: Bloomden CAD/CAM polymethyl methacrylate (PMMA) block (Vita shade A2; Bloomden Bioceramics Co., Ltd., China) used for specimen fabrication in the present study.

Figure 2: Three-dimensional digital design of the disc-shaped specimen (diameter 3.5 cm, thickness 1.5 mm) as modelled in EXOCAD dental CAD software prior to milling.

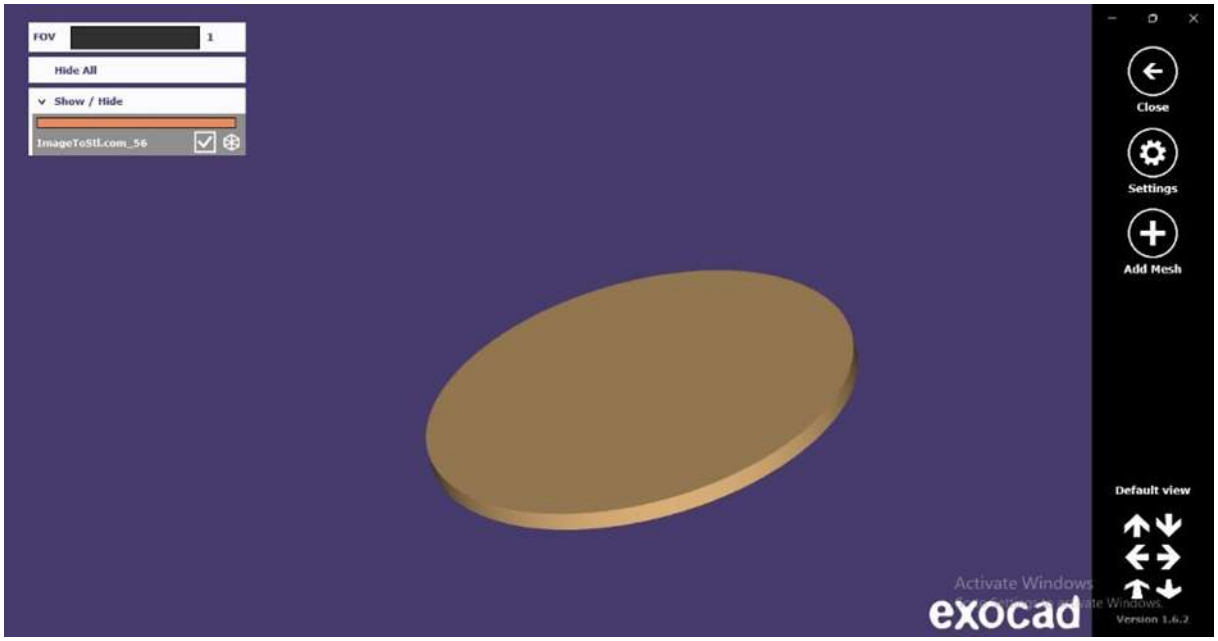

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Figure 3: Twelve Bloomden PMMA disc specimens following standardised polishing and prior to allocation to experimental groups and immersion in mouthrinses.

Figure 4: Mouthrinses used in the study. (a) Octenidine 0.1% mouthrinse (Orahex Pro®; Abbott India Ltd.). (b) Chlorhexidine digluconate 0.2% mouthrinse (Hexidine®; ICPA Health Products Ltd.).

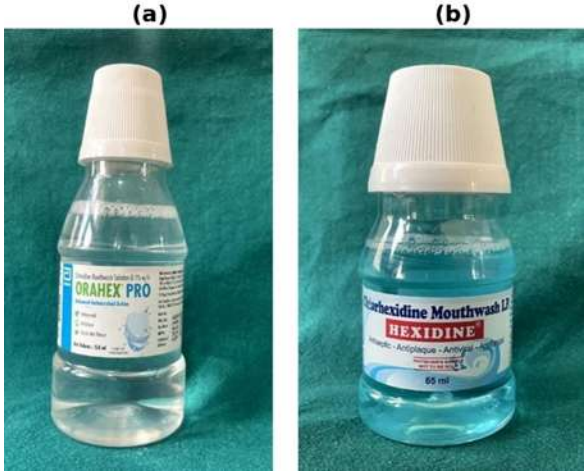

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Figure 5: Bloomden PMMA disc specimens submerged in mouthrinses during the immersion protocol. Specimens were maintained at 37°C ± 1°C throughout.

Figure 6: Premier Colorscan reflectance spectrophotometer (Premier Instruments, Mumbai, India) used for CIE L*a*b* colour co-ordinate measurement under D65 illumination.

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