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Comparative evaluation of the effect of single-step versus multi-step curing on the immediate dimensional stability of light-cured denture bases on different colored casts

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Abstract

Introduction: Light-cured denture bases have gained popularity as a trial denture base material due to their inherent qualities such as good rigidity and strength, ease of use, biocompatibility, uniform thickness and time efficiency. However, one of the major disadvantages is the dimensional instability due to processing shrinkage, that results in formation of a gap at the palatal concavity. Improving the dimensional stability is critical for light-cured bases to be widely accepted in removable prosthodontics.

Aim: To evaluate the effect of multistep curing on the dimensional stability of light-cured denture base resin on different coloured casts.

Materials and Methodology: A total of 24 visible light-cured denture bases were fabricated with two different techniques and divided into 4 groups.

Group I: Single-step curing for 5 minutes on green coloured cast (n=6)

Group II: Multi-step curing for 5+5 minutes on green coloured cast (n=6)

Group III: Single-step curing for 5 minutes on yellow coloured cast (n=6)

Group IV: Multi-step curing for 5+5 minutes on yellow coloured cast (n=6)

After 24 hours, the casts were sectioned in half and evaluated for dimensional stability using a stereomicroscope.

Results: The values obtained were analysed using the Mann-Whitney U test and Group II exhibited the lowest dimensional discrepancy in all three anatomical sites, followed by Group I and IV. Group III had the greatest dimensional discrepancy across all three sites.

Conclusion: Employing the multi-step curing protocol and using a dark-coloured cast has shown significant increase in the dimensional stability of light-cured denture bases.

Clinical Application: Dimensional stability can be significantly improved by using a dark coloured cast and employing a multi-step curing protocol.

Keywords: Light-Cured Denture Base, Dimensional Stability, Mutli-Step Curing, PMMA,

Introduction

The success of complete dentures largely depends on the accuracy and stability of the trial denture base. A well-adapted record base is critical for obtaining precise maxillomandibular relationships and for ensuring reliable evaluation of esthetics and phonetics during the trial stage. Inaccurate adaptation may compromise retention and stability, ultimately affecting patient comfort and function.[1,2]

For decades, heat-cured polymethyl methacrylate (PMMA) has been the material of choice for denture bases owing to its acceptable physical properties, affordability, esthetics and ease of use.[3,4] However, its inherent disadvantages, such as polymerization shrinkage and dimensional instability during processing, have been widely reported.[3,4,5] To overcome these drawbacks, alternative materials and curing techniques have been introduced, among which visible light-cured (VLC) urethane dimethacrylate resins have gained popularity. These materials offer several advantages such as rapid fabrication, uniform thickness, rigidity, and biocompatibility due to absence of residual monomer. These characteristics have made VLC resins increasingly popular as trial denture base materials in prosthodontic practice.[6,7]

Despite these benefits, dimensional instability remains a significant limitation of light-cured bases. Polymerization shrinkage, particularly in the palatal region, frequently results in lifting of the denture base and the formation of a gap between the denture base and cast, thereby jeopardizing the posterior palatal seal.[8-10] Various strategies have been proposed to minimize this discrepancy. Staged curing cycles have been shown to reduce the concentration of polymerization stresses and enhance adaptation compared with conventional single-step protocols.[8,11,12] Two-stage fabrication techniques and palatal segmentation have also demonstrated improvements in fit and dimensional accuracy.[8,9]

In addition to curing protocols, the colour of the cast has been shown to influence the adaptation of VLC bases. Dark-coloured casts have been reported to absorb scattered light and thereby improve polymerization uniformity, reducing dimensional changes compared with lighter casts.[13]

While studies have highlighted the effect of curing technique and cast color on the dimensional stability of light-cured denture bases, there is limited evidence assessing their combined influence. The aim of this study was evaluate and compare the dimensional stability of light-cured denture bases fabricated using single-step and multi-step curing protocols on casts of different colors.

Materials and Methodology

Maxillary cast was chosen for fabrication of light-cure denture base in this study as the palatal surface presents the most critical region of dimensional instability owing to its concavity. The polymerization shrinkage at this region readily lifts the denture base away from the concavity jeopardizing the intimate contact with the palatal contour, leading to loss of retention and stability.

A total of 24 samples were fabricated for this study and were divided into 4 groups based on the curing protocol and colour of the cast.

Group I: Single-step curing for 5 minutes on green coloured cast (n=6)

Group II: Multi-step curing for 5+5 minutes on green coloured cast (n=6)

Group III: Single-step curing for 5 minutes on yellow coloured cast (n=6)

Group IV: Multi-step curing for 5+5 minutes on yellow coloured cast (n=6)

Sample Preparation

Group I: VLC sheet was closely adapted on the green-coloured cast, starting from the center and proceeding peripherally. The excess was cut off using a Lecron carver. The cast along with the adapted VLC sheet was then light cured for 5 minutes in a light curing chamber with a fluorescent lamp of wavelength 400-500nm. (Figure 1a)

Group II: VLC sheet was adapted on the green-coloured cast in a similar manner, following which a 2-3mm wide U-shaped strip was cut at the junction of vertical and horizontal portion of the palate and removed. The cast with the adapted VLC sheet was then light cured for 5 minutes. After the initial curing, the U-shaped strip was adapted back on the cast and was cured for 5 minutes in a light curing chamber with a fluorescent lamp of wavelength 400-500nm. (Figure 1b)

Group III: VLC sheet was closely adapted on the yellow-coloured cast, starting from the center and proceeding peripherally. The excess was cut off using a Lecron carver. The cast along with the adapted VLC sheet was then light cured for 5 minutes in a light curing chamber with a fluorescent lamp of wavelength 400-500nm. (Figure 1c)

Group IV: VLC sheet was adapted on the yellow-coloured cast in a similar manner, following which a 2-3mm wide U-shaped strip was cut at the junction of vertical and horizontal portion of the palate and removed. The cast with the adapted VLC sheet was then light cured for 5 minutes. After the initial curing, the U-shaped strip was adapted back on the cast and was cured for 5 minutes in a light curing chamber with a fluorescent lamp of wavelength 400-500nm. (Figure 1d)

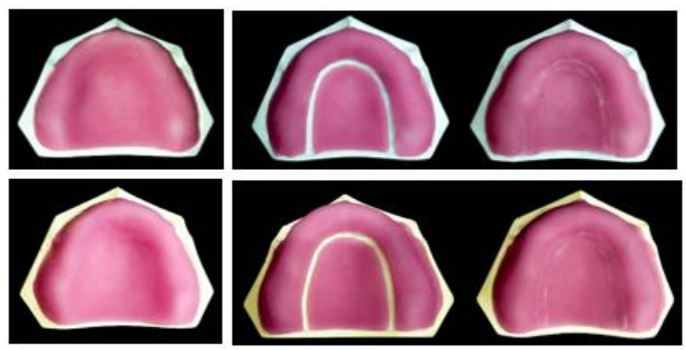


Figure 1a: Group I sample; 1b: Group II sample; 1c: Group III sample; 1d: Group IV sample.

After 24 hours, casts were sectioned midpalatally (Figure 2a) and viewed under stereomicroscope (Figure 2b). Dimensional discrepancy was measured at 3 different points (Figure 2c) A (left crest), B (mid palate), C (right crest)

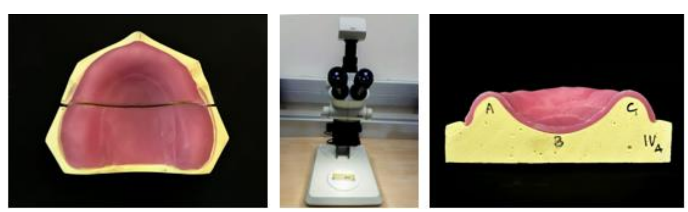


Figure 2a: Sectioned cast; 2b: Stereomicroscope; 2c: Three anatomical points evaluated.

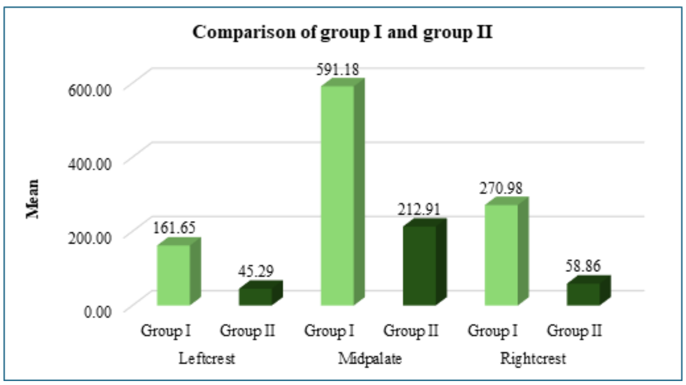
Results

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp. Results on continuous measurement were presented as Mean±SD. Considering the small sample size, the non-parametric test was applied. Comparisons between the groups were made using the Mann-Whitney U test. A p-value less than 0.05 was considered statistically significant.

Table 1: Comparison of group I and group II

Anatomical sites	Group	N	Mean	Std. Deviation	P value
Left crest	I	6	161.65	36.07	0.004*
	II	6	45.29	12.88	
Mid-palate	I	6	591.18	62.99	0.004*
	II	6	212.91	44.21	
Right crest	I	6	270.98	45.28	0.004*
	II	6	58.86	12.99	

Graph 1: Comparison of group I and group II

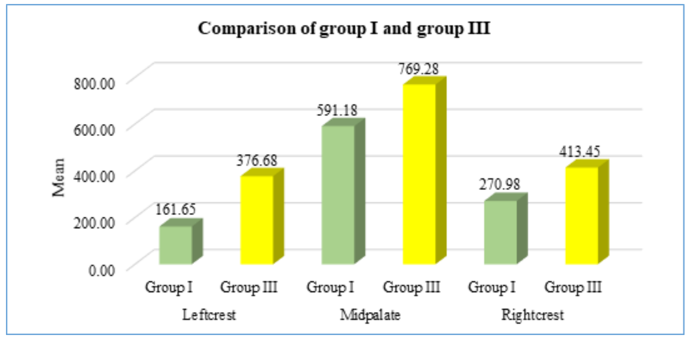


Across all three anatomical sites (left crest, mid-palate, and right crest), Group II consistently shows significantly higher dimensional stability than Group I.

Table 2: Comparison of group I and group III

Anatomical sites	Group	N	Mean	Std. Deviation	P value
Left crest	I	6	161.65	36.07	0.004*
	III	6	376.68	44.00	
Mid-palate	I	6	591.18	62.99	0.004*
	III	6	769.28	52.37	
Right crest	I	6	270.98	45.28	0.004*
	III	6	413.45	48.08	

Graph 2: Comparison of group I and group III

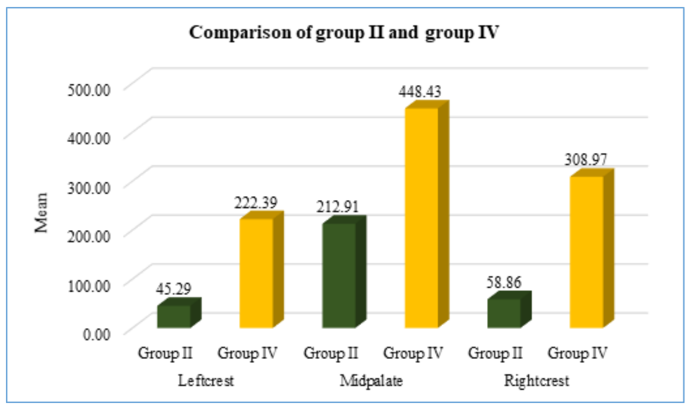


Across all anatomical sites (left crest, mid-palate, and right crest), Group I consistently exhibits significantly higher dimensional stability compared to Group III.

Table 3: Comparison of group II and group IV

Anatomical sites	Group	N	Mean	Std. Deviation	P value
Left crest	II	6	45.29	12.88	0.004*
	IV	6	222.39	30.26	
Mid-palate	II	6	212.91	44.21	0.004*
	IV	6	448.43	44.52	
Right crest	II	6	58.86	12.99	0.004*
	IV	6	308.97	26.83	

Graph 3: Comparison of group II and group IV

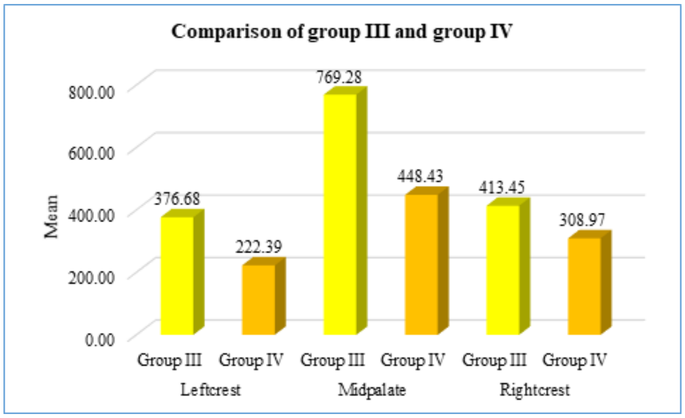


Across all anatomical sites (left crest, mid-palate, and right crest), Group II consistently shows significantly higher dimensional stability than Group IV.

Table 4: Comparison of group III and group IV

Anatomical sites	Group	N	Mean	Std. Deviation	P value
Left crest	III	6	376.68	44.00	0.004*
	IV	6	222.39	30.26	
Mid palate	III	6	769.28	52.37	0.004*
	IV	6	448.43	44.52	
Right crest	III	6	413.45	48.08	0.004*
	IV	6	308.97	26.83	

Graph 4: Comparison of group III and group IV



Across all anatomical sites (left crest, mid-palate, and right crest), Group IV consistently exhibits significantly higher dimensional stability compared to Group III.

Discussion

This study demonstrated that both curing protocol and colour of the cast have a significant influence on the dimensional stability of visible light-cured (VLC) denture bases. Adaptation was evaluated at three key sites—the left crest, mid-palate, and right crest—and the results showed that bases cured in a multi-step protocol and on darker casts exhibited the least dimensional discrepancy, while those cured in a single step on lighter casts showed the largest discrepancies. The findings indicate that multi-step curing and the use of darker casts can substantially improve the dimensional accuracy of VLC bases.

When single-step curing on green casts (Group I) was compared with multi-step curing on green casts (Group II), Group II demonstrated significantly (p=0.004*) smaller gaps at all anatomical sites (Left crest: 45.29µm; Mid-palate: 212.91 µm; Right crest: 58.86 µm), indicating superior dimensional stability. These results support the previous study by Mishra et al.[12] who demonstrated that staged curing improves adaptation by permitting stress relaxation and minimizing the concentration of polymerization shrinkage within a single cycle. They stated that VLC resins polymerize rapidly near the light source, and when large volumes are cured continuously, stress accumulates and the palatal vault lifts away from the cast. Multi-step curing interrupts this process, reduces the extent of instantaneous shrinkage, and allows readaptation of the base between exposures. The U-shaped strip that is sectioned from the light-cured denture base resin during the initial curing shifts the direction of shrinkage away from the palatal vault. This improves the adaptability of the denture base at the critical midpalatal region.[5,12]

Cast colour was also shown to significantly influence the dimensional stability (p=0.004). In the present study, denture bases fabricated on green casts (Groups I and II) consistently demonstrated smaller discrepancies compared with those on yellow casts (Groups III and IV), irrespective of the curing protocol employed. This observation aligns with the findings of Elkholy et al[13]. Elkholy suggested that the absorbed light energy in darker casts is greater than lighter casts. This absorbed light is partially converted into heat, producing a mild and controlled rise in temperature at the resin–cast interface. This localized thermal effect can accelerate polymerization in areas less directly exposed to light. By promoting polymerization from resin-cast interface, darker casts limit the shrinkage forces responsible for gap between the denture base and the cast.[13]

The present study has certain limitations that should be acknowledged. The sample size was relatively small. Only two cast colours (green and yellow) were evaluated, although other shades with different reflective or absorptive properties could influence adaptation outcomes. Only one type of palatal configuration was evaluated in this study. Dimensional changes were measured immediately after 24 hours later, without accounting for long-term water sorption or clinical function. Future studies incorporating larger sample sizes, different curing regimens, a wider range of cast colours, different palatal configuration and simulation of intraoral conditions are recommended to provide more comprehensive insights into the dimensional behaviour of VLC denture base resins.

Conclusion

Within the limitations of this study, it can be concluded that

1. Multi-step curing produced denture bases with significantly higher dimensional stability (p value= 0.004) when compared to single-step curing
2. VLC denture bases fabricated on a dark coloured cast showed significantly higher dimensional stability (p value= 0.004) when compared to light coloured cast

Clinical Implication

Choosing a dark coloured gypsum material for the fabrication of master cast and employing a multi-step curing protocol while using a light-cured denture base material will significantly improve the dimensional stability of the denture base which will in turn provide better adaptability of the trial denture during jaw relation and try in procedures.

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