Evaluation of different baseplate materials on casts with various palatal vault depths

MB Sitoe, LM Sykes, C Bradfield

ABSTRACT

Introduction
The choice of baseplate material for a trial complete maxillary denture is a critical decision in prosthodontic practice. One significant factor to consider is the depth of the palatal vault, which can influence the suitability of the baseplate material. Close adaptation of the denture base is essential in preventing lateral denture movement and enhancing denture retention and support.

Aims and objectives
This study was undertaken to evaluate and determine the most suitable baseplate material to use on casts of various palatal vault depths.

Methods
A total of 120 casts with varying palatal vault depths categorized as shallow, moderate, and deep were fabricated (40 per group). Denture bases, all designed to a uniform 2-mm thickness, were created using four different commonly used materials: pink baseplate wax, self-cured acrylic resin, light-cured acrylic resin, and 3D-printed photo-polymerized resin. Both the casts and the fabricated denture bases were sectioned down the midline. Measurements of adaptation were taken from the left halves. Readings were taken of the gap between the denture bases and the casts at three predefined positions (I – incisive papilla, II – mid-palatal area and III – posterior palatal seal area).

Results
For shallow palates the best material (i.e., most closely adapted) in position I was light-cured acrylic, in position II was self-cured acrylic and in position III was light-cured acrylic. For moderate depth palates the best material in position I was light-cured acrylic, in position II was self-cured acrylic and in position III was light-cured acrylic. For deep palates the best material in position I was self-cured acrylic, in position II was self-cured acrylic and in position III was light-cured acrylic.

Conclusions
For all three palatal depths, the material with the closest adaptation in position II (mid-palate) was the self-cured acrylic resin and in position III (the post-dam area) was the light-cured acrylic. In position I (incisive papilla) the light-cured resin performed slightly better in shallow and moderate palates and the self-cured resin in deep palates. It would thus seem that based on this study technicians and clinicians should consider using firstly light-cured acrylic resin or self-cured acrylic resin as opposed to the more commonly used pink baseplate wax for trial denture base plates.

Keywords
Baseplate materials, palatal vault shape, adaptation, dimensional stability.

INTRODUCTION
Removable dental prostheses can have a profound impact on a patient's physical, emotional, and social well-being.[1,2,3] They play an important role in restoring both oral function and self-confidence, ultimately improving the overall quality of life for those who require them.[1,2,3] Denture bases hold significant importance in various stages of the denture fabrication process, including the recording of jaw relations, the arrangement of artificial teeth, and the trial fitting of the setup within the oral cavity of the patient before the acrylic denture processing phase.[4,12].

The stress-bearing areas in the maxilla play a crucial role in providing support for the denture base and can be categorised as primary or secondary, based on the underlying bone and anatomical structures. The fit or adaptation of the denture bases has a significant impact on the overall quality of complete dentures, and can influence factors such as retention, stability, support, comfort, speech, and masticatory function.[4] During denture fabrication, the more dimensionally stable and precise the fit of the denture base, the better the final outcome should be..[4,13] The bases themselves are subsequently discarded during the final processing steps, but will have served the purpose of recording accurate jaw relationships and assessing the fit of the completed trial denture. Consequently, the correct choice of an appropriate baseplate material is of paramount importance during these critical stages. The success of dentures depends on many factors that are both patient and denture related.[5] The depth of the palate is believed to play a significant role in the retention and stability of maxillary dentures. Therefore, the consideration of various palatal vault depths on the fit of different baseplate materials and production techniques is important.[6,7,8] One of the

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main problems during the manufacturing procedure for a complete denture is adherence of the baseplate the dental cast, and fit intra-orally.[6]

Many studies have explored the influence of palatal vault depth on the retention of maxillary denture bases.[4,13] However, there remains a significant gap in the literature concerning the effects of all three categories of House's Classification of palatal vault depths on both conventional and modern 3D printing materials. The current study aimed to investigate the relationship between shallow, moderate and deep palatal vault depths, and denture base materials at three pre-determined positions. Results may guide clinicians in their choice of the most appropriate denture baseplate materials according to each individual patient's anatomy.

The goal is to enhance final denture retention, fit, support and accuracy, to improve patient comfort and satisfaction, and at the same time minimise the need for post-fitting adjustments and relines.

METHODS
The study was an in vitro laboratory-based experimental design. To ensure robust internal validity and reliability, re-measurement of half of the samples was done, amounting to 60 samples out of a total of 120 as part of a cross-validation process.

External validity and reliability were carried out in the measurement process by having two trained clinicians measure a random sample of all casts. This approach aimed to safeguard the quality and credibility of the research findings. One-way analysis of variance was applied to means of each sample to investigate if there were any significant differences. Measures of central tendencies i.e., the mean and median were also applied to summarise each component.
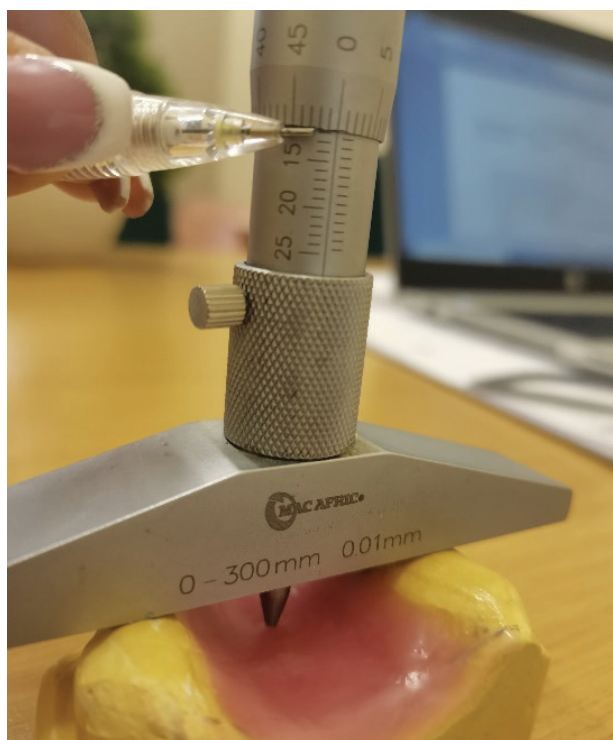

Figure 1: Wax adaptation of master casts to produce a medium and shallow depth palate.

Three identical master maxillary casts were modified by adapting baseplate wax to the palatal vault depth area.[6] The final casts then had one with a shallow vault depth (12 mm) the second moderate (16 mm), and the third deep (20 mm). Wax was only added to the mid-palatal areas thus the rest of the casts and ridge configuration remained unchanged (Figure 1).[4,6] The casts were duplicated using silicon elastomer moulds (interduplicast A & B) to obtain three silicon elastomer moulds. Type 3 hard modelling plaster was measured to a ratio of 30 ml of water in a glass measuring cylinder and 100 g Type 3 powder using a digital scale. A vacuum mixer-twister was used to reduce bubbles, with a rotational speed of 270 rmp for 30 seconds according to methods suggested by Laughlin et al. (2001).[4] The viscous mixture of Type 3 hard modelling plaster was then gently poured into the moulds and left to harden for 24 hours, to obtain 40 shallow, 40 moderate and 40 deep palatal vault casts.

The MAC AFRIC 9" Magnetic Torpedo Water Level was used to determine whether the alveolar ridges were parallel horizontal (level) before using the Vernier depth gauge. The edge of the tool was cleaned at the bottom edge and placed on the crest of the maxillary edentulous alveolar ridges to obtain the true horizontal (horizon) of the ridges. The bubble was allowed to flow on top of the spirit tube and was in the centre. Three reference lines were drawn to establish fixed points on the palate. The first line extended vertically from the central position of the incisive papilla (I) to the posterior palatal seal (III). The second line intersected the first one at its midpoint (II), and the third line spanned horizontally between the two hamular notches situated in the posterior palatal seal area (Fig 2).[10] The depth of the vestibule (deepest part of the sulcus area) was outlined providing relief of frenal attachment before fabrication of bases.

In the fabrication process of the bases, a single layer of baseplate wax measuring 1.75 mm in thickness (metrodent-metrowax NO 4) was adapted by manual means onto the casts.[6] For the group subjected to self-curing, the process involved the initial application of a single layer of cold mold seal onto the cast, which was subsequently allowed to air-dry before commencing the base fabrication procedure. Subsequently, a mixture of monomer (liquid) and powder (comprising Cold Cure Repair Monomer and Powder) was prepared in a 1:1 ratio.

Initially, the monomer was poured onto the cast, and an equivalent amount of powder was introduced in the same region where the monomer had been placed. This method was employed to facilitate the dissolution of the powder by the monomer. Subsequently, the cast, in conjunction with the self-cure acrylic, was immersed in a water-filled container (temperature maintained at 20°C for 5 minutes), until the bases had cured. For the light-cured specimens sheets of Urethane-Dimethacrylates (UDMA)(special tray LC intertray) were manually adjusted to the casts. These were then polymerized using a visible light source unit, (Light curing unit DDL Dental) for 2 minutes. For the3D printed bases a Desktop scanner inEos X5 was used to capture precise digital images of the cast. This was executed through the inLab software version 22.0, which possessed the capability to identify essential anatomical landmarks on the cast, facilitating the subsequent design of the denture base.

Figure 2: Fabricated casts and baseplates prior to sectioning and measuring.

Upon completion of the digital design phase for the denture base, the fabrication was carried out using a recommended acrylic resin (Asiga DentaBase resin). This was poured into the carbon container of the ASIGA MAX printer. This unit was chosen due to its impressive build speeds (60 mm/hr) and exceptional resolution of 62 microns. Additionally, it incorporates Asiga's unique Smart Positioning System (SPS) technology. The actual printing process involved the application of ultraviolet projection to cure the baseplate material onto the cast at the precise locations required, and this was executed on the high-tech carbon ASIGA MAX printer. The thickness of all bases was measured using a Iwanson Wax Calliper Gauge by Smile baseplates to ensure an even thickness across the entire palatal area.

Once all the base plates had been fabricated (Figure 2), a digital Vernier calliper was used to accurately measure the linear distance between the two hamular notches (recorded as 44 mm). This was then used to determine the exact midpoint of the casts at 22 mm. A vertical reference line was then marked on the casts, extending from the incisive papilla through the mid-palatal region to the posterior palatal seal area (Figure 3). This line served as a critical cross reference line where the cuts would be made. Cutting was then carried out using a Globe KB-36 band saw, with a blade width of 3.175 mm. This blade was used to cut both the casts and the baseplates simultaneously. Throughout the cutting process, the blade speed selector was set at a constant value of 47 blade speed units per minute. It must be noted that due to the continuous operation and friction generated by the saw blade, it produced heat during the cutting process. As a preventive measure, cutting was paused for 2 minutes between each cast to allow the blade to cool, and in addition, the blade was changed after every tenth cast to maintain the accuracy and precision of the cuts.

A digital Vernier calliper was used to obtain even measurement points of the left half of all casts and baseplates. The measurement of the distance from the incisive papilla (I) to the posterior palatal seal area (III) was 40 mm. Half the distance of 40 mm was measured on the same area and provided a mid-palatal area point of 20 mm (II). The digital Vernier calliper was used to measure the gap between baseplates and casts on the three predetermined points (I, II and III) for the four different baseplate materials on casts of the three palatal vault depths (Figure 4).

Figure 3: Cast and baseplate sectioned down the midline.

Figure 4: Measuring the gap distance between the baseplate and the cast at position II.

RESULTS

Table I presents the difference in Means between the four baseplate materials. The results showed no significant mean difference in fit between different baseplate materials of baseplate wax (mean= 0.01; p=0.53), self-cured acrylic (p=0.75), and light-cured acrylic (p=0.91). However, the results showed a significant difference for the 3D-printed (p=0.00) and wax bases (p=0.00).

Results show that baseplate wax, self-cured acrylic resin, and light-cured acrylic resin show no significant difference between various depths (p-value>0.05).

In the evaluation of baseplate wax (Table I), the F-value for shallow vs. moderate vs. deep is 0.6318 with a p-value of 0.5393, suggesting no statistically significant difference in means among these depths for baseplate Wax. The F-value of 21.1316 with a very low p-value (<0.0001) in the overall section indicates significant differences in means across different depths of the baseplate wax, with the deep depth group having the lowest mean (0.0105), indicating closer adaptation. There was a significantly difference with the measurements from the shallow (0.0122) and moderate depths (0.0170). For the self-cured acrylic (Table I), the F-value for shallow vs. moderate vs. deep was 0.2802 with a p-value of 0.7578. This suggests that there are no statistically significant differences in means among these depths for self-cured acrylic. Table I also shows that the deep depths (mean=0.0145) had the closest adaptation when compared to moderate (mean=0.0162) and shallow (mean=0.0164). Both baseplate wax and self-cured acrylic show no statistically significant differences in means among these depths. (baseplate Wax: p-value = 0.5393, self-cured acrylic: p-value = 0.7578).

For light-cured acrylic, the deep depth demonstrated the least amount of mean gap (0.0123) compared to moderate (0.0133) and shallow depths (0.0131). The F-value for shallow vs. moderate vs. deep is 0.0902 with a p-value of 0.9140. This suggests that there are no statistically significant differences in means among these depths for light-cured acrylic. The findings of the current study further indicate that light-cured acrylic resin shows a more significant difference (mean=0.0129, p-value<0.001) between the groups, suggesting that it may be the better baseplate material overall.

Material that had an overall least mean value was light-cured acrylic resin (mean=0.0123, p-value<0.0001).

There was a significant difference between the three groups (shallow, moderate, and deep) for the 3D-printed resin baseplate material (p-value<0.0001). The shallow had the least means compared to moderate and deep, mean=0.0125, p-value<0.0001. Post-hoc comparison using the Turkey HSD test indicated that the mean for shallow (mean 0.0215, SS=0.0025) and moderate (mean 0.0242, SS=0.0025) in terms of depth, did not show a statistical difference. There was a statistical difference between shallow (mean 0.0215, SS=0.0025) and deep (mean 0.0420, SS=0.0050).

When the four baseplate materials were compared, that the light-cured acrylic resin had the lowest mean of all the groups (mean 0.0129; p-value<0.00001).

DISCUSSION

House's Classification divides palatal forms or vaults into three categories namely, Class I, Class II, and Class III.

Table I: ANOVA results for Baseplate Materials							
Groups	**Number**	**Mean (mm)**	**SS**	**df**	**MS**	**F**	**P-value**
Baseplate wax S	10	0.0122	0.0002	2	0.00011	0.6318	0.5393
M	10	0.0170	0.0049	27	0.00018		
D	10	0.0105	0.0051	29			
Self-cured acrylic S	10	0.0164	0.0000	2	0.00001	0.2802	0.7578
M	10	0.0162	0.0010	27	0.00004		
D	10	0.0145	0.0011	29			
Light-cured acrylic S	10	0.0131	0.0000	2	0.00000	0.0902	0.9140
M	10	0.0133	0.0009	27	0.00003		
D	10	0.0123	0.0009	29			
3D-printed S							
	10	0.0215	0.0025	2	0.00124	13.1226	0.00001
M	10	0.0242	0.0025	27	0.00009		
D	10	0.0420	0.0050	29			
Overall **Baseplate wax**	30	0.0133	0.0018	3	0.00060	21.1316	<0.0001
Self-cured acrylic	30	0.0157	0.0010	36	0.00003		
Light-cured acrylic **3D printed**	30	0.0129					
	30	0.0292	0.0028	39			

Table I. Statistical analysis of results for all four materials in each palatal vault depth

In general, Class I have a shallow palatal vault depth and provide acceptable retention for maxillary dentures. Class II have moderate palatal vault depths and are the best for maxillary denture retention. Class III have deeper V-shaped (deep) palatal vault depths and provide poorer retention for maxillary dentures due to the pronounced elevation in the palate, accompanied by a steep decline and significant mobility in the soft palate.[5,7,9] In the current study, Class I represents shallow, Class II represents moderate, and Class III represents deep palatal vault depths.

Baseplate waxes are composed of a blend of paraffin, microcrystalline waxes, and both natural and synthetic ingredients and have drawbacks, such as limited stability and a tendency for volume instability after the heating and cooling process.[12] According to a study by Zbigniew et al. (2019),[12] the properties of these waxes, such as their flow characteristics and volumetric shrinkage, can change the re-melting process within wax warmers due to thermal degradation. In addition, MacMillan and Darvell (2000)[13] conducted research on the rheological properties of dental waxes. They observed that the field of wax rheology has been relatively understudied, and their uses are not widespread, which may be due to the challenges involved in handling these materials. The results of the present study concur with the findings and observations of Zbigniew et al. (2019)[12] and MacMillan and Darvell (2000),[13] in that baseplate wax did have a close and consistent adaptation to deep palatal vaults but performed less well compared to the light cured acrylic resin for medium and shallow palate depths.

Self-cured acrylic resins are versatile and used in many fields of dentistry.[14] They are preferred for their biocompatibility, lack of flavour or odour, satisfactory thermal properties, excellent polishing capabilities, and ease of use.[14] Given their wide use, it is crucial to assess their resistance to fractures, especially as repairing acrylic prostheses can be time consuming, inconvenient for patients and clinicians, and adds to costs.[14] Silva et al. (2021),[14] compared the fracture resistance of heat-cured and self-cured acrylic resins. Their results indicated that, on average, heat-cured resins exhibited greater resistance to fracture than self-cured resins. While the latter offer the advantage of reduced processing time,[6,14] they also come with drawbacks, such as the potential for denture tooth movement during polymerization and a lack of bonding between denture teeth and the base material. In another study by Akaltan et al. in 2020,[6] the authors investigated the denture base adaptation performance of the pour technique involving self-cured acrylic resin, in comparison to other conventional fabrication methods like light-polymerization, injection, and compression molding. The findings revealed that the pour technique for self-cured acrylic resin consistently demonstrated similar mean gap distances, regardless of the location on the denture bases. The findings of the current investigation concur with those of Akaltan et al. (2020),[6] where the mean gap distances in all palates are relatively consistent. Although innovative techniques for complete denture fabrication have emerged, cost efficiency and ease of production remain critical factors.

Light-cured acrylic resin denture materials represent an advancement in polymeric acrylic denture bases.[15] These materials are available in sheet and strip forms, as well as in powder and liquid systems.[15] They are versatile and can be used for a range of dental applications, offering swift service at an economical cost.[6,15] The manufacturers state several other advantages, such as the absence of residual methyl methacrylate monomer, ease of handling and manipulation, and improved dimensional precision.[19] However, Akaltan et al.(2020), observed that light-cured acrylic resin displayed the highest average gap distance between the denture base and the cast, regardless of whether the palatal vault depth was shallow or deep, in most of the tested locations.[6] In a study conducted by Wahab et al. in 2012,[15] a comparison was made between the tensile strength of heat-cured and visible light-cured acrylic resin denture bases. The findings revealed that the heat-cured acrylic denture base resin exhibited superior tensile strength values when compared to the visible light-cured acrylic denture base material.

Recent advances in 3D printing are promising. Advantages include cost-efficiency (with regards material and time, but initial outlay for equipment is costly), the absence of rotary tool wear, reduced waste of raw materials, and the ability to simultaneously produce multiple items which can lead to quicker patient rehabilitation times.[15,16] Gad (2021)[16] studied the strength and surface properties of a 3D-printed denture base polymer, and found that the 3D-printed resin exhibited lower flexural strength, impact strength, and hardness values compared to heat-polymerized resin.[15,16] However, it displayed superior surface roughness. The primary drawbacks associated with heat-cured resins for removable dentures are their dependence on specialized equipment and skilled personnel.[16] In a recent study conducted by Dimitrova (2022),[16] a comparative analysis was performed between conventional polymethyl methacrylate (PMMA) and 3D-printed resins for denture bases. They highlighted certain limitations of 3D printed materials, including issues related to aesthetics and retention, the inability to achieve occlusal balance, and lower printer resolution. In contrast, heat-cured PMMA demonstrated superior flexural strength, bonding properties, and impact resistance compared to 3D-printed materials for removable dentures. It was observed that 3D-printed resins exhibited better surface roughness and lower hardness values when compared to conventional materials. Additionally, in comparison to heat-cured acrylics used for denture bases, the 3D-printed materials demonstrated enhanced colour stability over time.

CLINICAL APPLICATION
This finding of this study highlights the importance of evaluating patients' palatal vault shapes before choosing which baseplate material to use. From a clinical perspective, prolonged heating, and re-melting of baseplate waxes, particularly at elevated temperatures, is not advisable.[12] And although the result of the current study shows no significant difference between the shallow, moderate, and deep groups, it is recommended to refrain from using baseplate wax in situations where they may be exposed to elevated temperatures that could potentially cause material distortion.

In evaluating four different baseplate materials on various palatal vault depths, the 3D-printed resin had the least mean on shallow compared to other depths. While self-cured acrylic resin showed the lowest mean on deep palatal vault depth compared to other depths. In this study, the recommended baseplate material is light-cured acrylic resin since it had the least gaps compared to other materials. This study indicates that light-cured acrylic resin closely followed by self-cured acrylic resin may be the best material to use for denture bases in terms of adaptation

and stability in changing temperature environments. The disadvantage is that both materials are more costly and take longer to fabricate than conventional pink baseplate wax. While 3D printing is promising and offers many advantages, including customized designs and accurate details, it is important to consider the associated costs. The decision to use 3D-printed base plates should be made with an understanding of both the benefits and challenges posed by this advanced manufacturing technology.

CONCLUSION

For all three palatal depths, the material with the closest adaptation in position II (mid-palate) was the self-cured acrylic resin and in position III (the post-dam area) was the light-cured acrylic. In position I (incisive papilla) the light-cured performed slightly better than the self-cured resin. It would seem that based on this study technicians and clinicians should consider using firstly light cure acrylic resin or self-cured acrylic resin as opposed to the more commonly used pink baseplate wax for trial denture base plates.

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