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Influence of Palatal Vault Depths on Denture Base Adaptation at Post Palatal Seal Area Using Conventional and Palatal Anchoring Processing Techniques

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Abstract
The retention and stability of complete dentures are significantly influenced by the adaptation of the denture base to the supporting tissues of the edentulous ridge, particularly in the post-palatal seal area. This study explores the influence of palatal vault depths on denture base adaptation in the post-palatal seal region, comparing conventional processing techniques with those incorporating palatal anchoring. The retention of a complete denture is determined by the intimate fit between the denture base and the mucosal surface, with factors such as surface tension, adhesion, and saliva film thickness playing key roles. Conventional processing techniques for denture fabrication often face challenges related to dimensional changes in poly (methyl methacrylate) (PMMA) materials, which occur due to polymerization shrinkage and thermal contraction. These dimensional inaccuracies can lead to poor adaptation of the denture base, particularly in the posterior palatal seal area, compromising denture retention. This study highlights how variations in palatal vault depth influence these dimensional changes and the effectiveness of different processing techniques in ensuring accurate base adaptation. The findings suggest that incorporating palatal anchoring techniques may improve the adaptation of the denture base, minimizing distortions in the post-palatal seal area and enhancing retention. These insights provide valuable information for optimizing complete denture fabrication and improving clinical outcomes for edentulous patients.
Keywords: *Distortion, Polymerization shrinkage, Polymethyl methacrylate, Heat-polymerized*

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I. Introduction

The recognition, understanding and incorporation of certain mechanical, biological and physical factors are necessary to ensure optimal complete denture treatment. These factors are the determinants that promote the properties of retention, stability, and support in the finished prosthesis through their influence on the relationship between the tissue surface of the denture base and the mucosal surface of the edentulous ridge (1).

The retention of a complete denture is directly related to the adaptation of the base to the supporting oral tissues (1). The physical forces that determine the retention of a complete denture are surface tension, adhesion, cohesion, saliva film thickness, and atmospheric pressure (2). Retention is optimized when the interfacial film thickness is reduced, and a thin film of saliva exists between the mucosa and the tissue surface of the denture. The force required to dislodge a denture is inversely proportional to the fluid film thickness between the denture and the tissues. The more dimensionally stable and accurate the base, the more intimate the adaptation will be to the oral tissues and retention maximized (1). Denture bases fabricated of polymethyl methacrylate have many desirable qualities that satisfy the requirements of denture base material more completely than the material previously used (2).

Dimensional changes that occur during the processing of poly methyl methacrylate complete denture prosthesis are due to polymerization and thermal shrinkage, so minimizing these changes is important in the maintenance of post-palatal seal adaptation for proper retention of a maxillary denture (3). Accuracy of fit of denture base is critical to adequate retention. Problems that exist with denture base adaptation are volumetric shrinkage, high coefficient of thermal expansion, releasing of internal stresses, polymerization shrinkage, linear shrinkage, water sorption of acrylic resins, etc. Due to all these factors, the posterior mid-palatal seal area undergoes the greatest distortion. Special impression techniques and placement of post-palatal seals are commonly used to compensate for dimensional changes that occur during processing [7].

One of the properties encountered with methyl methacrylate resins is linear and volumetric changes, which occur after curing. Consequently, two methods for measuring this change were developed and described. However, the resins were all found to shrink during the curing process. However, upon immersion in water, the resins were found to expand. Due to this, most of the maxillary complete dentures do not adapt accurately to the casts because of the changes in the resin during polymerization [8].

II. Materials and Methodology

The present study was conducted in the Department of Prosthodontics including Crown and Bridge, Sudha Rustagi College of Dental Sciences and Research, Faridabad.

Material required for specimen preparation and processing:

- Modelling wax (Y Dent, India)
- Agar-Agar duplicating material (polyflex, Dentsply. USA)
- Improved die stone (Type 4 gypsum product) (Kalabhai, India)
- Dental plaster (Type 2 gypsum product) (Kalabhai, India)
- Heat activated polymethyl methacrylate resins (Heat cure Resins, DPI, Lucitone 199, Dentsply, India)
- Vacuum pressed sheets

Armamentarium used for specimen preparation and processing:

- Stereo microscope (MAGNUS MSZ-Bi)
- Micrometer point gauge (Mitutoyo, Japan)
- Micrometer Surface gauge (Mitutoyo, Japan)
- Abrasive burs
- Microsurveyor (DAS, Tech 21, India)
- Hydraulic press (Sirio, India)
- Straight hand piece (NSK, Japan)
- Micromotor (Marathon, Japan)
- Acrylizing flask and clamp
- Dewaxing unit
- Acrylizer unit (Unident, India)
- Metal die (Deep, medium and shallow palatal vault)
- Die cutting machine

Methodology

Distribution of samples

A total 60 specimens will be fabricated using 3 palatal vault configurations and diving them into three groups i.e GROUP A, GROUP B, GROUP C contain 20 specimens in each. Each group will be further subdivided into two subgroups i.e., A1, A2, B1, B2, C1, C2, on the basis of 2 processing techniques containing 10 specimens in each. Groups.

Based on palatal vault depth Subgroups: - Based on polymerization technique used Number of samples (n) Group A Shallow palatal vault A1- Conventional polymerization technique A2- Anchored polymerization technique 10 10 Group B Medium palatal vault B1- Conventional polymerization technique B2- Anchored polymerization technique 10 10 Group C Deep palatal vault C1- Conventional polymerization technique C2- Anchored polymerization technique

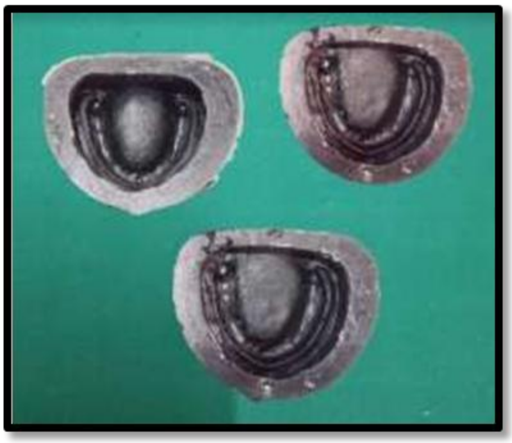
Groups: - Based on palatal vault depth	**Subgroups: - Based on polymerization technique used**	**Number of samples (n)**
Group A	A1- Conventional polymerization	10
Shallow palatal vault	technique	
	A2- Anchored polymerization technique	10
Group B	B1- Conventional polymerization	10
Medium palatal vault	technique	10
	B2- Anchored polymerization technique	
Group C	C1- Conventional polymerization	10
Deep palatal vault	technique	10
	C2- Anchored polymerization technique	

Table 1- Total Number of Samples (N=60)

For convenience, the methodology was divided into following steps: -
- Procuring metal dies from department
- Duplication of dies and get master casts
- Fabrication of test samples
- Testing of samples using measuring microscope
- Measurements and calculations
- Statistical analysis

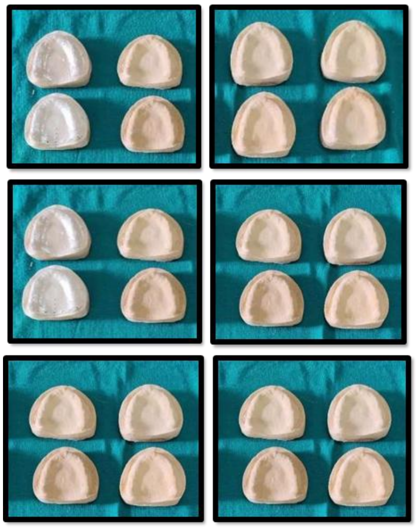
Step 2: - Fabrication of Test Samples (n=60) 20 casts each of deep, medium, and shallow palatal vault were duplicated using agar-agar duplicating material from the respective metal dies if deep, medium, and shallow palatal vault**.**

Metal Dies i.e. Deep, Moderate, Shallow palatal vaults

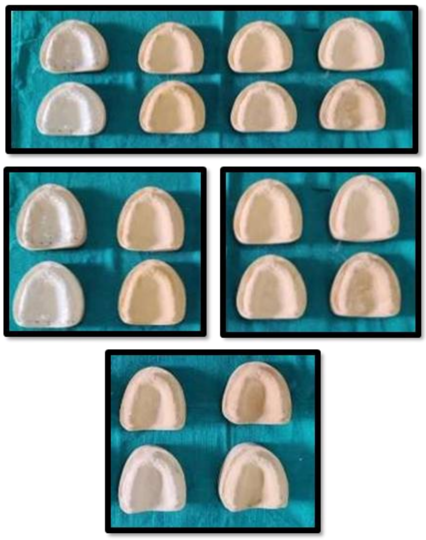


Duplication of Dies with Agar-Agar Impression Material

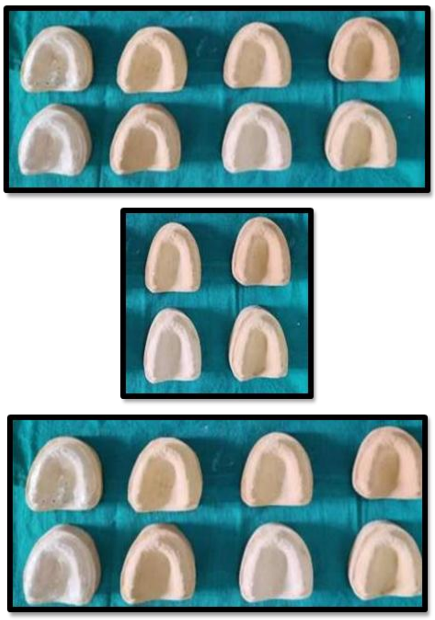
Master Casts



Duplicated cast with shallow palatal vault depth



Duplicated cast with medium palatal vault depth



Duplicated cast with deep palatal vault depth

After procuring casts of different palatal vault depths, all casts were marked to standardize the cast/base interface gap measurement location and the placement of the anchoring holes. Reference points were placed on the cast using templates fabricated for each palatal form made up of vacuum pressed sheets. The cast with template were placed on the platform of a surveyor. With the help of surveyor, reference points were marked on the templates, holes were placed in the underside of the cast to serve as markers for measurement.

The template was locating 7 sites along the posterior border of the denture base i.e.
1. The left vestibule area
2. The left ridge
3. Midway between left ridge and midline
4. The midline
5. Mid way between mid-line
6. The right ridge
7. The right vestibule area

Samples with templates (shallow, medium, and deep palatal vault)

Templates were again be used for standardized placements of reference points on each cast of same subgroups with anchored technique. The holes were placed with a standard #8 round bur to a depth of 5 mm. Mechanical anchorage was accomplished by placing holes in the cast at prescribed locations, along the posterior land area 1 mm distal to the posterior border of the denture base at the mid line and at 5 mm intervals laterally. Additionally, 3 holes were placed along the mid line of the palate, commencing 15 mm from the posterior border and progressing anteriorly.

This template acted as a standard guide in transferring the reference points on other sample cast as well as guided in the placement of the cast to drill holes with regards to the reference points. Corresponding sites were marked in the clear acrylic resin template along the posterior palatal seal area. Holes were drilled by using no 8-round bur with eccentric motion to a depth of 5 mm to make anchor extensions on the cast 1mm distal to the posterior land area.

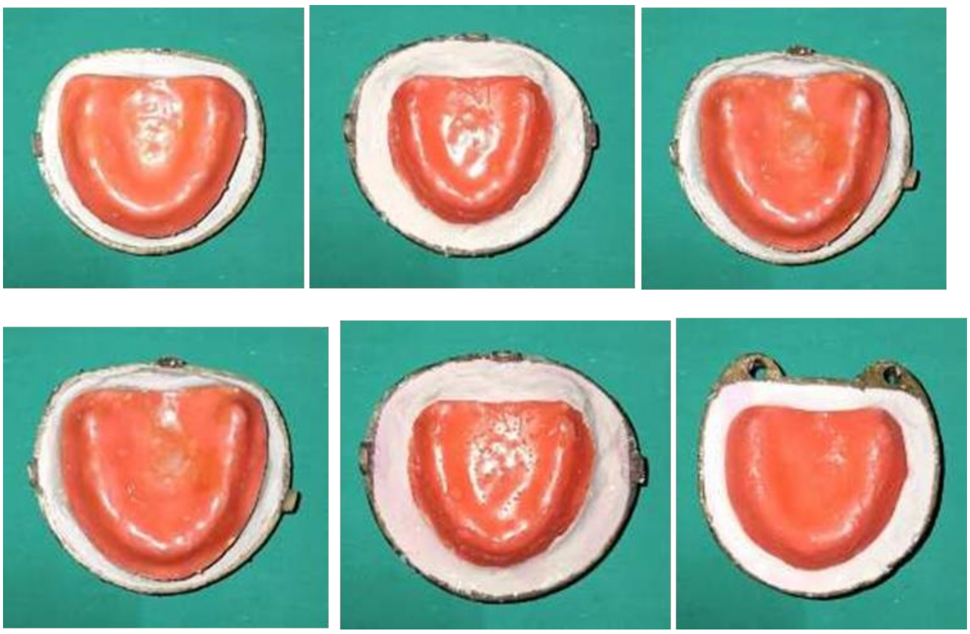
Anchoring holes in mounted casts (deep, moderate, and shallow palatal vault specimens

The thickness of wax sheet measured using digital surface micro meter. A uniform layer of 1.8 mm modelling wax sheet was adapted on each cast of deep, medium, and shallow depth.

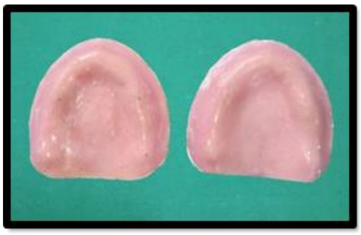
Adapting wax sheet on the cast (n=60)

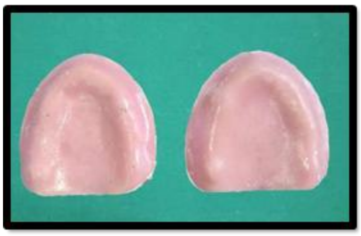
Measuring thickness of the modelling wax sheet using surface micrometre gauge

Finally, all casts with temporary denture bases were heat polymerized at 163°F for 9 hours. After polymerization, the flasks were allowed to bench cool and the lower compartment was separated from the flask.



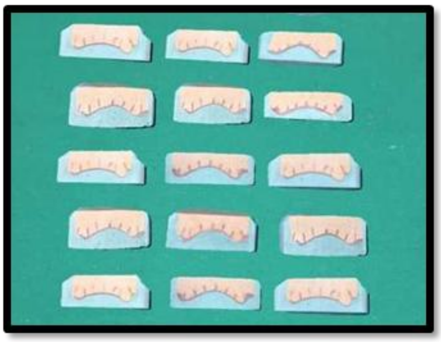
Flasking Of Samples





Finished test samples

Finishing and polishing procedures were carried out using conventional technique as used for complete denture. The finished samples were stored in water at room temperature. The specimens were then enclosed in an overlying matrix of dental stone to stabilize the bases on the casts during sectioning and measurement. The cast along with the denture base was trimmed on the posterior aspect with dental cast trimmer. The trimming was stopped before the measurement plane was reached and the acrylic resin anchoring studs became visible and were completely trimmed away.



Anchoring pegs exposed during trimming

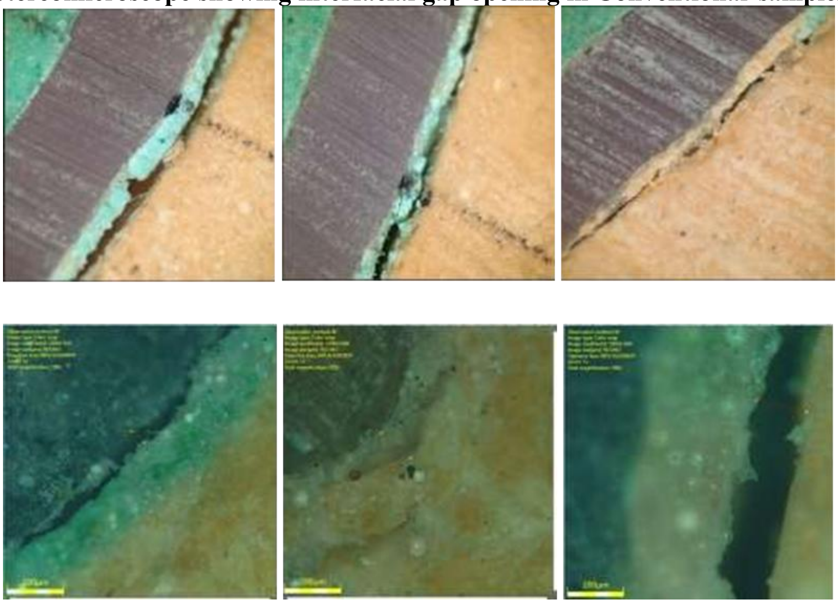
Trimmed specimens polymerized in conventional technique

Step 3: Sample testing using stereo microscope

Stereo microscope (MAGNUS MSZ-Bi) of 0.65x magnification with the help of image analysis software (IMACE PRO-INSIGHT VERSION 8) was used to measure the distance between each cast and its denture base. Each measurement was repeated five times. The average value represented the amount of discrepancy in each location.

Stereo Microscope

Stereomicroscope showing interfacial gap opening in Conventional samples

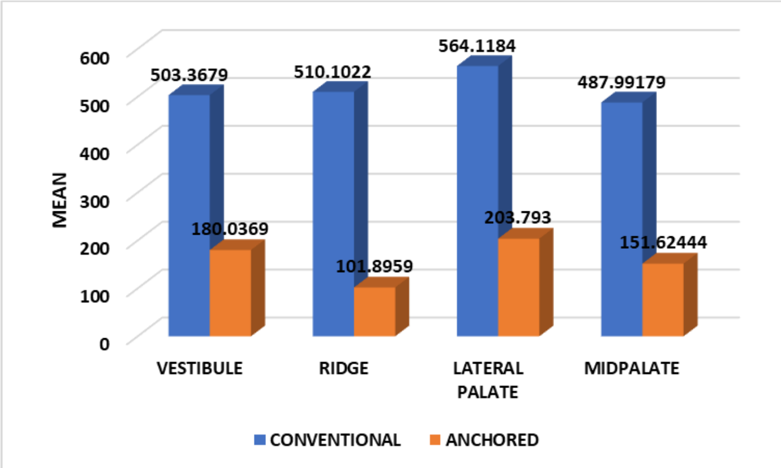


Stereomicroscope showing interfacial gap opening in Anchored samples

III. Results

Table 1: Intergroup Comparison of Measurement Values in Micrometer of the Interface Gap Distances between Denture Bases and Master Casts

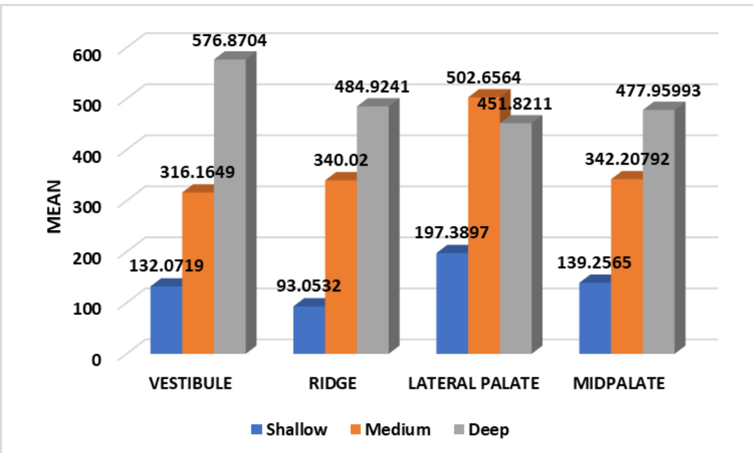
		Mean	Std. Deviation	Std. Error Mean	P Value
Vestibule	Conventional	503.3679	248.98882	26.24573	0.001
	Anchored	180.0369	119.53133	12.59971	
Ridge	Conventional	510.1022	234.16640	24.68331	0.001
	Anchored	101.8959	114.44301	12.06335	
Lateral Palate	Conventional	564.1184	200.61587	21.14677	0.001
	Anchored	203.7930	70.19238	7.39893	
Midpalate	Conventional	487.99179	225.394687	23.758686	0.001
	Anchored	151.62444	67.967994	7.164456	



Graph 1: Graphical Representation of Table 1 Data

Table 2: Overall Comparison of Measurement Values in Micrometer of the Interface Gap Distances between Denture Bases and Master Casts, on Shallow Medium and Deep Palatal Depth

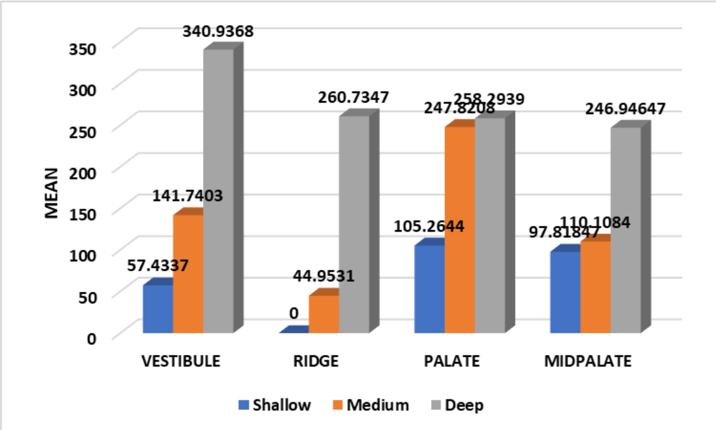
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval For Mean		Minimum	Maximum	P Value	Post Hoc
						Lower Bound	Upper Bound				
Vestibule	Shallow	60	132.0719	75.26808	9.71707	112.6281	151.5157	57.41	206.76	0.001	3>2>!
	Medium	60	316.1649	175.89662	22.70816	270.7260	361.6038	141.71	490.63		
	Deep	60	576.8704	237.92460	30.71593	515.4079	638.3328	340.91	812.85		
Ridge	Shallow	60	93.0532	100.31753	12.95094	67.1384	118.9679	.00	199.45	0.001	3>2>1
	Medium	60	340.0200	297.55699	38.41444	263.1529	416.8871	44.95	635.14		
	Deep	60	484.9241	226.08127	29.18697	426.5211	543.3271	260.71	709.16		
Lateral Apalate	Shallow	60	197.3897	92.90275	11.99369	173.3904	221.3891	105.21	289.57	0.001	3,2>1
	Medium	60	502.6564	256.98608	33.17676	436.2698	569.0429	247.77	757.54		
	Deep	60	451.8211	195.16043	25.19510	401.4059	502.2364	258.24	645.40		
Midpalate	Shallow	60	139.25650	41.787740	5.394774	128.46158	150.05142	97.763	180.747	0.001	3>2>1
	Medium	60	342.20792	234.058199	30.216784	281.74427	402.67156	110.053	574.358		
	Deep	60	477.95993	232.962984	30.075392	417.77921	538.14065	246.891	709.024		



Graph 2: Graphical Representation of Table 2 Data

Table 3: Comparison of Measurement Values in Micrometer of the Interface Gap Distances between Denture Bases and Master Casts, on Shallow Medium and Deep Palatal Depth on Anchored Site

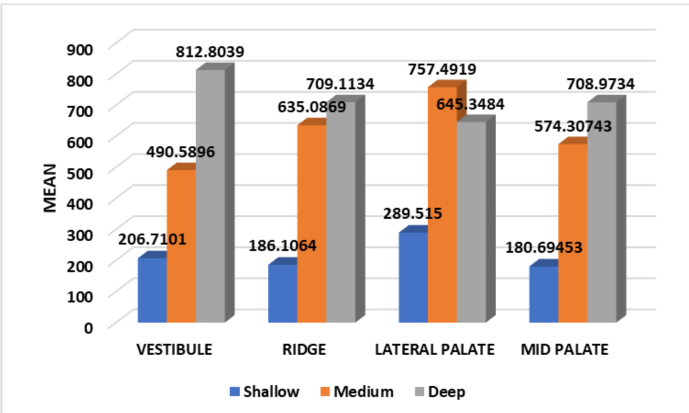
		Mean	Std. Deviation	Std. Error	95% Confidence Interval For Mean		Minimum	Maximum	P Value	Post Hoc
					Lower Bound	Upper Bound				
Vestibule	Shallow	57.4337	.01645	.00300	57.4275	57.4398	57.41	57.46	0.001	3>2>1
	Medium	141.7403	.01656	.00302	141.7341	141.7464	141.71	141.77		
	Deep	340.9368	.01664	.00304	340.9306	340.9430	340.91	340.96		
Ridge	Shallow	.0000	.00000	.00000	.0000	.0000	.00	.00	0.001	3>2>!
	Medium	44.9531	.00025	.00005	44.9530	44.9532	44.95	44.95		
	Deep	260.7347	.01653	.00302	260.7286	260.7409	260.71	260.76		
Palate	Shallow	105.2644	.03301	.00603	105.2521	105.2768	105.21	105.32	0.001	3>2>1
	Medium	247.8208	.03283	.00599	247.8086	247.8331	247.77	247.87		
	Deep	258.2939	.03293	.00601	258.2816	258.3062	258.24	258.34		
Midpalate	Shallow	97.81847	.033060	.006036	97.80612	97.83081	97.763	97.869	0.001	3>2>1
	Medium	110.10840	.032956	.006017	110.09609	110.12071	110.053	110.159		
	Deep	246.94647	.033060	.006036	246.93412	246.95881	246.891	246.997		



Graph 3: Graphical Representation of Table 3 Data

Table 4: Comparison of Measurement Values in Micrometer of the Interface Gap Distances between Denture Bases and Master Casts, on Shallow Medium and Deep Palatal Depth on Conventional Site

		Mean	Std. Deviation	Std. Error	95% Confidence Interval For Mean		Minimum	Maximum	P Value	Post Hoc
					Lower Bound	Upper Bound				
Vestibule	Shallow	206.7101	.03306	.00604	206.6978	206.7224	206.65	206.76	0.001	3>2>1
	Medium	490.5896	.03009	.00549	490.5783	490.6008	490.54	490.63		
	Deep	812.8039	.03298	.00602	812.7916	812.8162	812.75	812.85		
Ridge	Shallow	186.1064	50.58933	9.23631	167.2160	204.9967	.00	199.45	0.001	3>2>1
	Medium	635.0869	.03298	.00602	635.0746	635.0992	635.03	635.14		
	Deep	709.1134	.03298	.00602	709.1011	709.1257	709.06	709.16		
Lateral Palate	Shallow	289.5150	.03317	.00606	289.5026	289.5274	289.46	289.57	0.001	2>3>1
	Medium	757.4919	.03293	.00601	757.4796	757.5042	757.44	757.54		
	Deep	645.3484	.03296	.00602	645.3361	645.3607	645.29	645.40		
Midpalate	Shallow	180.69453	.033167	.006055	180.68215	180.70692	180.639	180.747	0.001	3>2>1
	Medium	574.30743	.033008	.006026	574.29511	574.31976	574.252	574.358		
	Deep	708.97340	.032956	.006017	708.96109	708.98571	708.918	709.024		



Graph 4: Graphical Representation of Table 4 Data

IV. Discussion

The palatal shape of edentulous patients has been the subject of various studies. The palatal shapes have been classified according to their cross-arch forms. The shape of the palate can greatly affect the stability and retention of the maxillary denture. So, the configuration of the maxillary ridge and palate appears to affect the adaptation of a denture base. Earlier researchers analyzed the contours of the palate and concluded that the cross-arch palatal forms could be categorized as V-shaped, U-shaped, flat, medium and their combinations. In the present study, palatal vault depths are classified on the method suggested by Jhonson et al-

Shallow palatal vault depth - less than ½ inch
Medium palatal vault depth - between and½ inch
Deep palatal vault depth - exceeding ½ inch

The accuracy of fit of a denture base is considered an important factor in the retention of the denture base. The better the adaptation of the denture based on the cast, the greater the retention of the denture in the mouth, as well as the greater comfort to the patient. However, polymerization shrinkage of the denture base is an unavoidable entity which would result in an improper fit of the denture base after processing, tooth movement, and incisal rod opening on the articulator. Literature evidence also suggests that there is a definite correlation present between the fit of the denture base and the anatomic morphology of the palate. Hence, the anchoring method and its effect on different palatal vault configurations were tested in the present study.

Effect of the Anchoring Technique - The results of this study clearly show that palatal adaptation was improved with mechanical anchorage placed along the posterior land area and mid-sagittal areas. At all locations except the ridge crest, anchoring significantly improved adaptation regardless of palatal depth. A statistically significant difference was observed between the conventional method and anchoring method ($p < 0.01$), especially in the lateral palate and mid-palate location in both types of palatal vault. We found that gap distances at all locations along the posterior border with the anchoring technique improved the denture base adaptation. The interface gap at the lateral palate and mid-palate would most directly affect the integrity of the seal. The improvement in these areas was approximately 67%, with the means decreasing from 0.20 to 0.07 mm at the lateral palate location and 0.31 to 0.10 mm at the mid-palate location. In addition to improving palatal adaptation, anchoring modifications could decrease the effects of other processing changes, such as movement of denture teeth and incisal pin opening.

Effect of Palatal Depth and Measurement- Locations of particular interest were the gap distances at the lateral palate and mid-palate locations, which present the greatest concern in maintaining a peripheral seal. A statistically significant difference in the gap distances between shallow, moderate and steep palatal depths at the lateral palate location was found, but the gaps for these two groups were the same at the mid-palate. Although no significant difference existed overall in palatal adaptation between steep and shallow palates, conclusions could be made regarding the pattern of adaptation. The interface means gap discrepancy was greater in the mid-palate location with the steep palatal form; the relatively parallel, vertical palatal surface at the lateral palate location was associated with a smaller mean discrepancy. In the shallow palatal form, the vertical palatal surface seen in the steep form was replaced with a generally horizontal plane across the area, and thus, the gap discrepancy resulting from polymerization shrinkage was wider. This was consistent with the findings of earlier studies regarding the greater discrepancies between U-shaped palates compared to V-shaped palates. The steep palatal vault showed more discrepancy at the mid-palate area and also showed less discrepancy at the vestibule and ridge area compared to the shallow palatal vault. The reason for this change is due to the convoluted form of the steep palate; dentures showed more shrinkage towards the central area of the cast. Despite the influence of palatal vault configurations on polymerization shrinkage, there are several studies which suggest that the incorporation of filler particles into polymethyl methacrylate would minimize the shrinkage to a certain extent.

V. Clinical Recommendations

From these results, when processing a denture for a patient with a steep palate, care should be taken to ensure that the post-palatal seal in the midline is adequate. If the patient has a shallow palate, an adequate bead of relief is required across the posterior border from ridge to ridge because the pattern of the gap is wider. Johnson and Duncanson also suggest that the post-palatal seal in cases with steep palatal depth be sufficiently bulky in the midline, whereas cases with shallow palatal depth necessitate a significant sealing from ridge to ridge. Anchoring significantly reduced gap distances at the lateral and mid-palate locations regardless of palatal form before removal of the denture from the master cast. It would seem that anchoring is beneficial for the fabrication of all complete dentures, but it offers particular benefits in shallow palate cases with a wide, ridge-to-ridge discrepancy. On denture insertion, this could lead to improved palatal adaptation to tissue, greater retention, and a favourable tissue response. The posterior palatal seal and pressure impression techniques are utilized to compensate clinically for the loss of tissue contact at the posterior border caused by polymerization shrinkage and distortion. However, the depth of relief placed on a master cast for the fabrication of the post-palatal seal is an empirical and rather arbitrary procedure. Anchoring could allow the practitioner to rely less on these compensating measures to maintain proper tissue contact because adaptation along the posterior border before removal from the cast is significantly improved. An effort to minimize processing error could be superior to attempts to clinically compensate for it. The advantages of using the anchoring processing technique are obvious. The technique improved adaptation and decreased interface gap distances. The anchoring technique could stabilize the denture base and thereby decrease other changes that result from polymerization, such as tooth movement, induced malocclusion, and incisal pin opening. Perhaps best of all is the anchoring technique's practical nature. It is easy, and there is no additional cost or special equipment requirement. Placement of the anchoring holes requires less than a minute of additional laboratory time. The resulting anchoring acrylic resin pegs placed distal to the posterior seal area, can be easily removed on a cast trimmer because they are not within the borders of the denture base.

VI. Limitations

This study examined the gap distances produced by polymerization shrinkage only. Deflasking, removal of the denture base from the cast, and water sorption during storage all have an influence on the ultimate adaptation. The present study has some limitations. The interfacial gaps were measured after curing, deflasking and minimal finishing and sectioning procedures. So, the observed gaps could be a combination of linear shrinkage obtained due to processing, deflasking and separation of denture base from the models, finishing and polishing procedures, water sorption during storage and presence of artificial teeth influence the adaptation. The effect of variable thickness of denture base in different locations was also not investigated. Studies that include these variables are suggested to enhance the results obtained from the present study despite the influence of palatal vault configurations on polymerization shrinkage. There are several studies that suggest that the incorporation of filler particles of poly methyl methacrylate would minimize shrinkage to a certain extent. The effects of these variables on the improved adaptation with anchoring are not known and could be an area of further research.

VII. Conclusions

The study investigated the effects of palatal depth and a resin anchoring system placed into an edentulous master cast on the palatal adaptation of denture base resin after polymerization.

Under the conditions of this study, the following conclusions were made: -

1. Mechanically anchoring the denture base onto the master cast significantly decreased gap distance at the vestibule, lateral palate, and mid palate locations.
2. The mean gap distances for the steep palate dentures were significantly less than the shallow palate dentures at the vestibule and lateral palate locations.

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