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Research Article

Evaluation of Different Molding Techniques and Variable Palatal Vaults on the Linear Dimensional Accuracy of Heat Polymerised Acrylic Resin

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Abstract

Aim: To comparatively evaluate the effect of two different molding techniques and two different palatal vault depths on the linear dimensional accuracy of acrylic resin denture bases.

Materials and Methods: Forty denture bases were processed by compression and injection molding techniques on casts with medium and deep palatal vaults respectively and grouped as, Groups IA and IB: Compression molded denture bases on casts with medium and deep palatal vaults and Groups IIA and IIB: Injection molded denture bases on casts with medium and deep palatal vaults respectively. The denture base-cast assemblies were sectioned 14 mm anterior from the posterior border in the frontal section and interface gap values between the denture base and cast were measured at selected reference areas using video measuring microscope. Results were analyzed using One Way Analysis of Variance (ANOVA), Post-hoc Tukey's HSD analysis and Independent ‚t' test.

Results: Mean interface gap values at the sulcus, crest of the ridge and mid palatal areas respectively were: 0.2817 mm, 0.2586 mm, 0.3306 mm for Group IA, 0.2474 mm, 0.2346 mm, 0.3541 mm for Group IB, 0.1011 mm, 0.1174 mm, 0.1202 mm, for Group IIA and 0.0898 mm, 0.1062 mm, 0.1486 mm for Group IIB. No significant differences were found between the gaps at different reference areas within Groups IA and IIA. Significant differences were found between mid palatal area and the sulcus and crest of the ridge areas within Groups IB and IIB. No significant differences were found between respective corresponding areas of Groups IA and IB and between Groups IIA and IIB. Significant differences were found between respective corresponding areas between Groups IA and IIA and between Groups IB and IIB.

Conclusion: Denture bases processed by injection molding technique exhibited a significantly lesser mean interface gap as compared to those processed by compression molding technique within a given palatal vault depth and vault depth did not significantly influence the linear dimensional accuracy of denture bases processed by anyone of the mentioned techniques.

Keywords: Denture Base; Denture Base Resin; Acrylic Resin; Palate; Hard Palate; Dimensional Measurement Accuracy; Dental Laboratory

Introduction

Removable dentures as a mode of treatment for replacing missing teeth have been practiced since 700 B.C [1]. The advent of acrylic resin polymers in 1937, was a major breakthrough in the annals of modern dentistry [2-6]. Among the polymer materials introduced, polymethyl methacrylate (PMMA) is the only proven material for fabrication of successful denture bases because of its optimal physical properties and relatively low toxicity compared to other plastic denture base materials [7-9]. Today more than 98% of all denture bases are fabricated from heat-cured PMMA. The relative ease with which PMMA can be manipulated and processed in the laboratory with less capital expenditure is its biggest advantage [5].

A long established method for processing PMMA is a closed-flask compression-molding procedure (conventional pressure-pack technique, pack-and-press technique) with heat activation in a water bath for resin polymerization [2,4,8,10-14]. Skinner and Cooper in 1943 and other researchers subsequently have universally shown that two unavoidable dimensional changes occur with respect to PMMA, namely, its comparatively large curing shrinkage during processing and expansion due to its relatively high water sorption [3,4,14-17]. The retention of a denture is optimized when the distance between the denture surface and the supporting tissues is at a minimum with a thin interfacial film of saliva between them [2,18]. The shrinkage associated with compression molding increases the gap between the denture base and underlying mucosa in the posterior palatal region compromising the hit of the dentures and also resulting in a derogation of occlusal function [19]. This adaptation is particularly important at the posterior border because it completes the peripheral seal formed by the entire border of the denture [20].

Volumetric shrinkage of the acrylic resin occurs during the polymerization process due to differences in densities of the monomer and the polymers [21]. Discrepancies are also introduced during cooling because of the differential in the coefficient of thermal expansion between the acrylic resin and the investing gypsum.19. The greatest amount of distortion is observed when the denture is deflasked and removed from the cast releasing internal stresses Shrinkage is also seen in the posterior mid palatal areas which undergoes the greatest distortion [19,22-25]. Linear processing shrinkage of acrylic resin denture has been studied extensively and the values ranges from 0.26% to 1.20%, but are considered to be approximately 0.50% for wet heat processed denture bases [17,21].

Although subsequent expansion due to water sorption occurs, there are differing opinions regarding the extent of compensation due to the latter. The expansion associated with water sorption has been reported to compensate [25], partly compensate or even overcompensate for processing shrinkage [12]. Sykora and Sutow have stated that a typical acrylic denture may require a period of almost seventeen days to become fully saturated when immersed in water at room temperature and that the majority of prostheses are delivered to patients before this state is achieved [26]. Despite differing opinions in the literature, it is generally believed that minimizing dimensional changes is crucial for the maintenance of the posterior palatal seal adaptation to ensure proper retention of the denture.

Hence, acrylic resin and processing methods have been modified to improve physical and chemical properties of denture bases [8]. In 1942 Pryor introduced injection molding technique to overcome the adverse effects of compression molding. Previous experiences reported by different researchers were not encouraging with a injection molded technique exhibiting no superiority over the compression molding procedures in terms of dimensional accuracy due to processing shrinkage and water sorption [26,27]. This has been attributed to the higher molding temperatures and use of vinyl plastics and polystyrene materials [26]. In 1970, Ivoclar (Schaan, Liechtenstein) introduced an injection-molding system, the SR-Ivocap that uses PMMA modified for the injection molding process [8].

Various studies have supported the manufacturer's claim that SR-Ivocap injection molded system results in denture bases exhibiting less linear dimensional change than compression molded PMMA denture bases [6,8,9,26-29]. Considerable amount of literature comparing linear dimensional accuracy of PMMA resins processed by compression and injection molding techniques are available. Most of the studies comparing dimensional accuracy by compression or injection molding have been carried out either on test blocks or on maxillary casts with one standard palatal vault depth.

The anatomic morphology of the palate has been shown to influence the linear dimensional changes in PMMA resins. Studies comparing the effect of different palatal vault depths on the linear dimensional accuracy are few [19,26,30]. Of these, two studies are on the effect of shallow and deep palatal vaults depths on the dimensional accuracy of maxillary denture bases processed by conventional compression molding technique [19,30]. Only one study has compared the influence of different processing techniques, palatal vault shapes and immersion on the linear dimensional accuracy of PMMA denture bases. In this study the comparisons were made between the flat and high palatal vaults [26].

It has also been reported in an epidemiological study, that medium and deep palatal vaults are a frequent occurrence in both males and females [31]. Despite the impact of linear shrinkage on fit and occlusion, previous reports have not adequately compared the combined influence of the effects of medium and deep palatal vault depths as well as the effects of compression and injection processing techniques on the linear dimensional accuracy of denture bases.

Various micrometer microscopes have been employed to measure the interfacial gaps between denture base and the casts [2,22,27,30,32-35]. A Video Measuring Microscope (VMM) is a sophisticated travelling microscope that enables linear measurements up to 1 µm sensitivity. It has the added advantage of visualizing, measuring and capturing the images at the test site along with automatic data storage and recall.

Aim of the present study was to comparatively evaluate the effect of two different molding techniques and two different palatal vault depths on the linear dimensional accuracy of acrylic resin denture bases. The interface gaps in the posterior region were measured using a video measuring microscope (VMM). The null hypothesis for this study was that there would be no difference in the adaptation of the denture bases to their test casts as a consequence of different palatal vault depths for a given type of processing technique.

Materials and Methods

In the present study, two edentulous maxillary acrylic resin master models were fabricated. The master models were fabricated such that one of the models had a medium palatal vault and the other had a deep palatal vault. The palatal vault depths were identified based on classification given by Avci M., *et al*. [31] and Jackson., *et al*. [34] and as follows.

The following steps were followed to fabricate the master models:

A maxillary rubber, edentulous mold (Ashosons, Delhi, India) was selected and molten modeling wax (Hindustan dental products, Hyderabad, India) was poured in to the mold. It was allowed to cool undisturbed for two hours and then the solidified wax model was retrieved from the mold. Two such wax models were obtained.

To standardise the palatal vault depth on the wax models, the measurement of the depth was done at the deepest portion of the palate. The procedure adopted was based on the method suggested by Reddy B M M., *et al*. The crest of the incisive papilla was marked as point X. The deepest points on both the hamular notches were marked as Y and Y' and a line Y, Y' was drawn joining these points. Then a perpendicular line was drawn from point X to the midpoint Z, of line Y.Y". The center of the line XZ was marked as point D. From point D a line was drawn to the arches on either sides and this line was marked as E. E'. The point D was used as the standard reference point for the determination of palatal vault depth (Figure 1).

Figure 1: Line diagram showing reference points for palatal vault depth measurements.

The wax models were placed on the surveying platform of a dental cast surveyor (Saeshin Precision Ind. Co., Korea) and the surveying platform of the dental surveyor was made parallel to the floor using spirit level indicators (Jinhua Hengda tools, China. A customized stainless steel measuring tool (Designed and Manufactured by Lokesh Industries, Chennai) was fabricated with 3 mm diameter, 4cm length and with 20 calibrations at the lower end. Each calibration was separated by a distance of Imm. The customized measuring tool was fitted on to the surveyor mandrel of the dental cast surveyor and was lowered down to contact point D on the wax models. A stainless steel 6" ruler (Imperial Measuring System, India) was placed on the ridge crest of the wax model such that it was positioned on the line E, E' and in contact with the measuring tool. The calibration that coincided with the metal scale was marked and noted as the depth of the palatal vault. The two wax models obtained were checked by the above method for palatal vault depth. They were identified to have a medium palatal vault depth in the "as obtained" condition which was Ilm. (Figure 2). One wax model was left unaltered and kept as the wax prototype for the master model with medium palatal vault. On the second model, the palatal vault arca was scraped with a wax carver (I.ecrons wax carver, German Dental Instruments) to get the wax prototype for the master model with deep palatal vault. The palatal vault depth was kept at 14 mm for the latter model. A small depression was made on the wax models at the midpoint, D, for standardising and transferring the measuring point to the master model (Figure 3). In this manner, two wax prototype models one each with medium and deep palatal vaults were obtained.

Figure 2: Transverse section of master model with medium palatal vault - 11 mm.

Figure 3: Transverse section of master model with medium palatal vault - 14 mm.

The wax prototypes were acrylized by injection molding technique with heal-cure clear acrylic resin (SR Ivocap High Impact Polymer and Monomer, Ivoclar Vivadent, Liechtenstein, Germany), to obtain master models with medium and deep palatal vaults respectively. The processed master models were deflasked and the models were finished taking care not to alter the anatomic areas. The models were placed one at a time on the surveying platform of the dental cast surveyor for reconfirmation of the respective palatal vault depths, following the procedure described previously, at point D which was transferred from the wax prototype.

Two, rigid plastic containers (JSN industries, Hyderabad, India) were selected as counters to carry the polyvinylsiloxane impression material. Equal amount of putty base and catalyst (Aquasil soft putty, Denstply, Germany) were hand mixed for about 30 seconds according to the manufacturer's instructions and loaded to three-fourths of the height of the counter. Light-body material (Aquasil, Denstply, Germany), was injected using auto-mixing spirals (Yellow-70 mm, Adenta, USA), attached to the dispensing gen (Heraeus Kulzer, Dormagen, Switzerland) over the master model as well as onto the mixed putty in the counter. The master model was inverted and centred over the counter and impressed into the impression material and held in place till the impression material was completely set. After the material had set, the master model was removed and the putty index was inspected for any defects. One defect- free putty index each was made for medium and deep palatal vault types.

A surfactant (Auro film Bego, Germany) was sprayed over the putty index to improve its wettability to the dental stone and air dried. Type IV die stone (Type IV Elite Rock, Zhermack), was mixed as per manufacturer's recommended water powder ratio in a rubber bowl with a stainless steel spatula for about 15 seconds and then the mix was mechanically spatulated under vacuum power mixer (Whipmix, Kentucky, U.S.A) for 60 seconds. The mixed stone was poured on to one side of the putty index and then it was placed on a model vibrator (Confident Dental Equipments Ltd Bangalore, India), and the rest of the die stone was poured to fill the putty index. It was left to set undisturbed for 45 min. After the die stone had completely set, the stone cast was retrieved from the putty index and inspected for any voids or defects. Defect-free stone casts were placed one at a time on the surveying platform of the dental cast surveyor for reconfirmation of palatal vault depth at point D. In the manner described previously. In this manner, twenty maxillary dental casts for medium palatal vault and twenty maxillary dental casts for deep palatal vault were obtained and assigned as the test casts.

A total of 40 test casts, 20 with medium palatal vault and 20 with deep palatal vault were categorized into 4 groups based on the processing method for obtaining denture bases as follows: Group IA: Heat-cure denture bases to be processed by compression molding technique on test casts with medium palatal vault. (n = 10), Group IB: Heat-cure denture bases to be processed by compression molding technique on test casts with deep palatal vault (n = 10), Group IIA: Heat-cure denture bases to be processed by injection molding technique on test casts with medium palatal vault (n = 10), Group IIB: Heat-cure denture bases to be processed, by injection molding technique on test casts with deep palatal vault (n = 10).

Modelling wax sheet (Hindustan dental products, Hyderabad, India) was adapted over all the test casts to obtain denture bases with a uniform thickness of 2 mm, b) using a wax knife (Vaishnav Surgical Co., India). The record bases were measured for uniform thickness at selected areas using a lwanson's wax caliper (Addler, Germany), at the incisive papilla region, first premolar and second molar regions on either sides and at the posterior border. The checked record bases were fused to their respective test casts. Group IA and IB test denture bases were processed by compression molding technique. The denture bases were luted onto their respective test casts by placing a drop of cyanoacrylate adhesive (Fevikwik, Pidilite Industries, India) on the right and left ridge crest of the cast. This was done to ensure that the denture bases maintained their positional relationship with their respective test casts during subsequent sectioning and measuring procedures.

To enable better visualization and measurement of the interface gap between the denture base and the test cast in the posterior region, catch denture base-test cast assembly was sectioned 14 mm anterior to the posterior border of the denture base in the frontal plane coinciding with the anterior end of the tuberosity area. A point was marked at this distance on the right and left ridge crest areas of the denture base using indelible marker. These points were then joined to form a line indicating the area to be sectioned. The denture base-test cast assembly was sectioned transversally up to the marked line using a diamond sectioning disc (Fein Power Tools India Ltd., Chennai mounted on a mandrel and attached to the micromotor handpiece (Saeyang dental micromotor unit Marathan N7, Zhengzhon Linker Trading Co., China). For better visualization of the interface, the sectioned surface was gently smoothened with emery papers of 120 and 320 grit sizes (Sof-Lex, 3M ESPE, Seefeld, Germany). The interfacial gap measurements were done at five selected reference areas as follows: The right (A) and left (A') sulcus areas, the right (B) and left (B') crest of the ridge areas and the mid palatal area (C). Five reference lines were marked vertically on the assembly coinciding with these areas.

The reference lines were marked on one denture base-test cast assembly each from medium and deep palatal vaults. They were transferred to the other denture base-test cast assemblies using a transfer template. A clear acrylic template was fabricated to standardize the marking of reference lines on all the assemblies to ensure uniformity of the areas where the interface gap was measured. A single thickness of modelling wax sheet was adapted over the sectioned posterior region. A putty index of this was obtained using addition silicone. The adapted wax was removed from the assembly and separating medium was applied on the stone surface. Autopolymerizing clear acrylic resin (RR Cold Cure, DPI, India) was mixed in a ceramic cup as per manufacturer's instructions and the mold space of the index was filled with this dough. The sectioned assembly was seated into the index and held firmly with positive finger pressure. After the material had set, the acrylic resin template was retrieved, finished and polished. It was checked and verified for fit over the sectioned assembly. The template was seated over the assembly and the reference lines were seen and marked on the template. The template was removed from the assembly and three points were marked on each reference line. Holes were drilled with a straight fissure bur coinciding with each of these points. One reference template each was fabricated for the denture base-test cast assemblies with medium and deep palatal vaults.

The transfer template was placed on one assembly at a time and points were marked on the test cast through the holes in the template. The template was removed and the points were joined to obtain the reference lines which were labeled as mentioned previously. This standardized the position of the reference lines facilitating measurements at the same locations for each test sample.

The interface gap values between the denture base and test cast at the sulcus areas (A,A), crest of the ridge areas (B,B') and mid palatal area (C) were measured using Video Measuring Microscope (Video Measuring System VMS- 2010F, CIP Corporation, Korea), (Figure 4). The samples were observed under a magnification of 30-190 X at each reference area. The interface gap measurements (in mm) were repeated three times for each area and the mean obtained was taken as the interface gap for that particular area. The mean interface gap for the sulcus areas and the crest of the ridge areas respectively were obtained from their respective means of the right and left sides [Mean of the sulcus areas = (A+A/2); Mean of the crest of the ridge areas = (B+B'/2)]. At the mid palatal area C, the readings were repeated three times ane the mean obtained was taken as the interface gap measurement at that area. An overview of entire methodology is presented in Figure 5.

Figure 4: Video measuring microscope.

Figure 5: Overview of methodology.

The data obtained were tabulated and these results were subjected to statistical analysis.

All statistical calculations were performed using Microsoft Excel (Microsoft, USA) and SPSs (SPSS for Windows 10.0.5, SPSS software Corp., Munich, Germany) student statistical software. One Way Analysis of Variance (ANOVA) was used to compare the mean interface gap values a different reference areas within each test group. Post-boc Tukey's HSD analysis was used for multiple comparisons of the mean interface gap values within each test group, where the results with ANOVA were significant. Independent t test was used to, compare the correspondıng mean interface gap values between test groups.

Results

The results of the present study were compared at the following levels:

- Comparison of interfacial gaps between different areas within each test group. (within Groups IA, IB, IIA and IIB)

- Comparison of interfacial gaps between corresponding reference areas of medium and deep palatal vaults processed by one particular technique. (between Group IA and Group IB and between Group IIA and IIB respectively)
- Comparison of interfacial gaps between corresponding reference areas of denture bases processed by either compression or injection molding techniques on casts with one particular palatal vault depth. (between Group IA and Group IIA and between Group IB and Group IIB).

The mean interface gap values between selected reference areas within Group IA samples statistically insignificant, but mean interface gap values between selected areas within Group IB were statistically significant. Post hoc revealed mean interface gap at the sulcus was marginally higher than crest but insignificant, and mean interface gap at the crest of ridge was significantly less than mid palatal area. (Tables 1-5). Mean interface gap values between selected reference areas within Group IIA was insignificant, whereas mean interface gap values between selected reference areas within Group IIB was insignificant. Independent t test of mean interface gap values between corresponding areas of Group IA and Group IB and between Group IIA and Group IIB was insignificant, whereas values between Group IA and Group IIA and values between Group IB and Group IIB was significant (Tables 6 - 10).

Group IA	Mean (interface gap values)	Standard Deviation	p - value
Sulcus Areas (A, A')	0.2817	±0.0884	0.121
Crest of the Ridge Areas (B, B')	0.2586	±0.0396	
Mid Palatal Area (C)	0.3306	±0.0913	

Table 1: Comparative evaluation of the mean interface gap values (in mm) and standard deviation between selected reference areas within Group IA test samples (Compression Molding; Medium Palatal Vault) using One Way Analysis of Variance (ANOVA).

P value > 0.05; statistically insignificant at 5% level.

Inference: On statistical analysis using one way analysis of variance (ANOVA), the mean interface gap values between selected reference areas within Group IA test samples were found to be statistically insignificant (p value > 0.05).

Group IB	Mean (interface gap values)	Standard Deviation	p - value
Sulcus Areas (A, A')	0.2474	±0.0469	0.052*
Crest of the Ridge Areas (B, B')	0.2346	±0.0579	
Mid Palatal Area (C)	0.3541	±0.1033	

Table 2: Comparative evaluation of the mean interface gap values (in mm) and standard deviation between selected reference areas within Group IB test samples (Compression Molding; Deep Palatal Vault) using One Way Analysis of Variance (ANOVA).

*P value < 0.05; statistically significant at 5% level.

Inference: On statistical analysis using one way analysis of variance (ANOVA), the mean interface gap values between selected reference areas within Group IB test samples were found to be statistically significant (p value < 0.05).

Group IB	Mean/±Standard Deviation	Mean difference	p-value
Sulcus Areas (A, A')	0.2474/±0.0469	0.0122	0.921
Crest of the Ridge Areas (B, B')	0.2346/±0.0579		
Sulcus Areas (A, A')	0.2474/±0.0469	-0.1066	0.009*
Mid Palatal Area (C)	0.3541/±0.1033		
Crest of the Ridge Areas (B, B')	0.2346/±0.0579	-0.1194	0.003*
Mid Palatal Area (C)	0.3541/±0.1033		

Table 3: Multiple comparisons of the mean interface gap values (in mm) and standard deviation between selected reference areas within Group IB test samples (Compression Molding; Deep Palatal Vault) using Post-hoc Tukey's HSD analysis.

Inference: Statistical analysis using Post-hoc Tukey's HSD test revealed that the mean interface gap value at the sulcus areas was marginally higher than that at the crest of the ridge areas and this difference was statistically insignificant (p value > 0.05). The mean interface gap value at the sulcus areas was significantly lesser than that at the mid palatal area (p value < 0.05). The mean interface gap value at the crest of the ridge areas was found to be significantly lesser than that at the mid palatal area (p value < 0.05).

Group IIA	Mean (interface gap values)	Standard Deviation	p - value
Sulcus Areas (A, A')	0.1011	±0.0290	0.543
Crest of the Ridge Areas (B, B')	0.1174	±0.0368	
Mid Palatal Area (C)	0.1202	±0.0540	

Table 4: Comparative evaluation of the mean interface gap values (in mm) and standard deviation between selected reference areas within Group IIA test samples (Injection Molding; Medium Palatal Vault) using One Way Analysis of Variance (ANOVA).

P value > 0.05; statistically insignificant at 5% level.

Inference: On statistical analysis using one way analysis of variance (ANOVA), the mean interface gap values between selected reference areas within Group IIA test samples were found to be statistically insignificant (p value >0.05).

Group IIB	Mean (interface gap values)	Standard Deviation	p - value
Sulcus Areas (A, A')	0.0898	±0.0288	0.005*
Crest of the Ridge Areas (B, B')	0.1062	±0.0353	
Mid Palatal Area (C)	0.1486	±0.0463	

Table 5: Comparative evaluation of the mean interface gap values (in mm) and standard deviation between selected reference areas within Group IIB test samples (Injection Molding; Deep Palatal Vault) using One Way Analysis of Variance (ANOVA).

*P value < 0.05; statistically significant at 5% level.

Inference: On statistical analysis using one way analysis of variance (ANOVA), the mean interface gap values between selected reference areas within Group IIB test samples were found to be statistically significant (p value < 0.05).

Group IIB	Mean/±Standard Deviation	Mean difference	p-value
Sulcus Areas (A, A')	0.0898/±0.0288	-0.0164	0.598
Crest of the Ridge Areas (B, B')	0.1062/±0.0353		
Sulcus Areas (A, A')	0.0898/±0.0288	-0.0588	0.004*
Mid Palatal Area (C)	0.1486/±0.0463		
Crest of the Ridge Areas (B, B')	0.1062/±0.0353	-0.0424	0.045*
Mid Palatal Area (C)	0.1486/±0.0463		

Table 6: Multiple comparisons of the mean interface gap values (in mm) and standard deviation between selected reference areas within Group IIB test samples (Injection Molding; Deep Palatal Vault) using Post hoc Tukey's HSD analysis.

*P value < 0.05; statistically significant at 5% level.

Inference: Statistical analysis using Post-hoc Tukey's HSD test revealed that the mean interface gap value at the sulcus areas was lesser than those at the crest of the ridge areas and mid palatal area. The mean interface gap value difference between the sulcus areas and the crest of the ridge areas was found to be statistically insignificant (p value > 0.05). The mean interface gap value difference between the sulcus areas and mid palatal area was found to be statistically significant (p value < 0.05). The mean interface gap value at the crest of the ridge areas was found to be significantly lesser than that at the mid palatal area (p value < 0.05).

Areas	Group IA Mean/S.D.	Group IB Mean/S.D	p-value
Sulcus Areas (A, A')	0.2817/±30.0884	0.2474/±0.0469	0.293
Crest of the Ridge Areas (B, B')	0.2586/±0.0396	0.2346/±0.0579	0.294
Mid Palatal Area (C)	0.3306/±0.0913	0.3541/±0.1033	0.597

Table 7: Comparative evaluation of the mean interface gap values in mm) and standard deviation between corresponding reference areas of Group IA test samples (Compression Molding; Medium Palatal Vault) and Group IB test samples (Compression Molding; Deep Palatal Vault) using Independent 't' test.

P value > 0.05; statistically insignificant at 5% level.

Inference: Statistical analysis using Independent 't' test of the mean interface gap values between corresponding areas of Group IA and Group IB test samples were found to be statistically insignificant (p value > 0.05).

Areas	Group IIA Mean/S.D.	Group IIB Mean/S.D	p-value
Sulcus Areas (A, A')	0.1011/+0.0290	0.0898/±0.0288	0.395
Crest of the Ridge Areas (B, B')	0.1174/+0.0368	0.1062/±0.0353	0.495
Mid Palatal Area (C)	0.1202/£0.0540	0.1486/±0.0463	0.223

Table 8: Comparative evaluation of the mean interface gap values (in mm) and standard deviation between corresponding reference areas of Group IIB test samples (Injection Molding; Deep Palatal Vault) using Group IIB test samples (Injection Molding; Deep Palatal Vault) using Independent 't' test.

P value > 0.05; statistically insignificant at 5% level.

Inference: Statistical analysis using Independent 't' test of the mean interface gap values between corresponding areas of Group IIA and Group IIB test samples were found to be statistically insignificant (p value > 0.05).

Areas	Group IA Mean/S.D.	Group IIA Mean/S.D	p-value
Sulcus Areas (A, A')	0.2817/0.0884	0.1010/±0.0290	0.000*
Crest of the Ridge Areas (B, B')	0.2586/30.0396	0.1174/±0.0368	0.000*
Mid Palatal Area (C)	0.3306/+0.0913	0.1201/±0.0540	0.000*

Table 9: Comparative evaluation of the mean interface gap values in mm) and standard deviation between corresponding reference areas of Group IA test samples (Compression Molding; Medium Palatal Vault) and Group IIA test samples (Injection Molding; Medium Palatal Vault) using Independent 't' test.

*P value < 0.05; statistically significant at 5% level.

Inference: Statistical analysis using Independent't' test of the mean interface gap values between corresponding areas of Group IA and Group IIA test samples showed that the mean interface gap values at all reference areas of Group IA test samples were higher than those of Group IIA test samples and this difference was found to be statistically significant (p value < 0.05).

Areas	Group IB Mean/S.D.	Group IIB Mean/S.D	p-value
Sulcus Areas (A, A')	0.2474/±0.0469	0.0898/±0.0288	0.000*
Crest of the Ridge Areas (B, B')	0.2346/±0.0579	0.1061/±0.0353	0.000*
Mid Palatal Area (C)	0.3541/±0.1033	0.1486/±0.0463	0.000*

Table 10: Comparative evaluation of the mean interface gap values (in mm) and standard deviation between corresponding reference areas of Group IB test samples (Compression Molding; Deep Palatal Vault) and Group IIB test samples (Injection Molding; Deep Palatal Vault) using Independent 't' test.

Type of Palatal Vault	Depth
Shallow	Less than 1/4 (<6 mm)
Medium	Between 1/4 and 1/2 (Between 6 mm-12.5 mm)
Deep	Exceeding 1/2 (>12.5 mm)

Table a

Discussion

Attempts to overcome the extent of polymerization shrinkage with the conventional compression molding brought the development of the continuous injection system by Pryor in 1937. A constant flow of material from the feeding sprue compensates for the polymerisation shrinkage. Several studies have supported this claim [11,26,36]. This combination of polymerization shrinkage and subsequent release of inherent strain due to deflasking causes diminished adaptation of the denture to the tissue.2 Previous studies have stated that greatest effect of linear shrinkage is observed in maxillary dentures at posterior palate.

There are studies comparing the effect of different acrylic-based denture base materials and/or processing techniques on linear dimensional accuracy of denturebases [6,8,9,11,22,26-30,34,37]. The linear dimensional accuracy of denture bases obtained by compression and injection molding techniques has also been studied. Most of these have shown the superiority denture bases processed by injection molding over those processed by the conventional compression molding technique in terms of linear interface gaps observed [6,8,9,26-29]. However, most of these studies have been conducted on maxillary edentulous models with one standard palatal vault type. It has been mentioned in the literature that palatal vault depth has a role to play in the linear dimensional shrinkage obtained at the denture base cast interface in the posterior region [8]. Studies comparing the combined influence of different processing techniques and shallow and deep palatal vault depths on the linear dimensional accuracy are spares [26]. Studies comparing the effect of medium and deep palatal vaults on the polymerisation shrinkage and linear dimensional change of denture bases are lacking.

Further, Avci M., *et al*. [31] clinically analysed edentulous maxillary palatal vault heights and concluded that the average palatal height for males and females is between 11.6 mm to 12.9 mm at an area between the mid and posterior palatal vaults. This area is usually the highest point of an edentulous patient can be categorized by measuring it at this highest region [31]. Considering that the likelihood of treating edentulous patients with medium and deep palatal vaults is higher and also considering the paucity of literature on the effect of medium and deep palatal vaults on the linear dimensional accuracy of denture bases, in the present *in vitro* study, it was decided to include these two palatal vault depths as influencing parameters.

Denture bases processed by either compression or injection molding techniques formed on maxillary models with either a medium or deep palatal vault depth were evaluated for linear dimensional accuracy at their interface in the posterior region using a video measuring microscope (VMM). The null hypothesis for this study was that there would be no difference in the adaptation of the denture bases to their test casts as a consequence of different palatal vault depth for a given type of processing technique. The edentulous maxillary model is usually preferred for studying linear dimensional changes over the edentulous mandibular model. Anthony and Peyton have studied that the shrinkage is somewhat lesser in the mandibular dentures because of the shorter linear distances between the labial/buccal and lingual borders [3].

Wax prototypes for both the master models with medium and deep palatal vaults were obtained from the same rubber mold. This ensured that the anatomical and dimensional specifications other than the palatal vault depth remained uniform for both the models. Johnson., *et al*. have classified the palatal vault depths to be shallow (< 6 mm), medium (6 mm to 12.5 mm) and deep (>12.5 mm), based on their depth from the ridge crest [38]. Based on this classification, the palatal vault depths for the medium and deep vaults were standardized at 11 mm and 14 mm respectively in the present study. The point at which the palatal vault depth was measured was at one particular point on all test models, based on that suggested by Reddy BMM., *et al*. in a previous study [48]. Master models for either palatal vault types were obtained to generate standardized test models for each palatal vault type.

It is established that the thickness of the denture base can also play a role in the magnitude of polymerization shrinkage [39]. Hence to avoid the impact of non-uniform denture base thickness on the magnitude of polymerization shrinkage, in the present *in vitro* study, the denture base thickness was standardized at 2 mm at all locations. Compression and injection processing were carried out based on recommendations given in standard literature and as recommended by manufacturers to optimize the outcome. Since finishing and polishing procedures generate too much heat that can contribute to dimensional changes and stress release in the denture base, vigorous finishing and polishing procedures were avoided in the present study. Care was taken in this regard for the compression molded test samples by doing trial closure. The injection molded test samples had negligible excess in the border region.

In the maxillary model, due to the inward contraction of the labial and buccal flanges towards the cast there is an upward lift of the denture base in the palatal region [37]. This gap is more pronounced across the posterior portion of a denture and can be visualized and measured with any micro meter microscope. Also, the changes occurring in the posterior region are the most important in the retention of denture because of the anatomy of the mouth and the shape of the denture [4]. Hence in the present *in vitro* study, the linear dimensional accuracy was evaluated on maxillary edentulous cast in the posterior region at the denture base-cast interface.

Interface gap measurements have been done at the posterior border of the denture base or at a distance anterior to the posterior border. Ono T., *et al*. have suggested that interface gap measurements could be best visualized between the denture base and cast when the cast is sectioned 14 mm anterior to the denture border, since this is the widest area of the cast in the posterior region and the gaps can be easily visualized. Further, this region corresponds to the area of maximum palatal vault depth and the shrinkage here is correspondingly more [40]. Hence, in the present *in vitro* study the interface gap measurements were carried out based on the above recommendation.

Different authors have studied the interface gap by measuring at various areas along the posterior border of the denture base [3,19,22,24,34,41]. It is well established that the maximum shrinkage occurs at the mid palatal area [19,22-24]. In the present *in vitro* study, the reference lines for interface gap measurements were standardized at right and left sulcus areas, right and left crest of the ridge areas and mid palatal area, which is in line with those followed in previous studies [32,40]. A customized transfer template for transferring the reference lines uniformly to all test samples was designed and fabricated in the present *in vitro* study. This ensured that the interfacial gap measurements were carried out on all test samples at the same positions at all the reference areas [22].

Linear interface gap measurements have been measured in previous studies by employing various measuring microscopes. In the present study, the linear interface gap measurements were done using a video measuring Microscope, the advantages of which have been previously described. Each measurement was repeated thrice at each location for precision of measurement as suggested by Laughlin., *et al*. in previous study [19]. It is well established that the greatest dimensional changes occur immediately after deflasking, when the denture base is separated from the cast. Hence, in the present study deflasked samples were subjected to sectioning and the linear gap measurements were done at this stage.

All the 40 specimens observed in the present study belonging to all 4 test groups showed interfacial gaps irrespective of denture base processing technique or palatal vault depth. This fact has been well stated in the literature [2,8,19,22,26-28,30,42-46]. This can be attributed to the polymerization shrinkage of the methyl methacrylate monomer. It has been reported by Anusavice that when methyl methacrylate is polymerized the density changes from 0.945 to l.19 g/cm^3, resulting in a volumetric shrinkage of 21% for pure monomer. The mixture used for fabrication of dentures at the suggested powder to liquid ratio has about 1/3rd of its mass as liquid monomer. The remainder of the mass is prepolymerized polymethyl methacrylate powder. Consequently, the polymer mass would be approximately 7%. Based on a projected volumetric shrinkage of 7%, an acrylic resin denture base should exhibit a linear shrinkage of approximately 2%. In reality, linear shrinkage rarely exceeds 1%.

Further, Anusavice has also stated that the thermal shrinkage of the resin is primarily responsible for the linear changes for the heat-activated system.in the initial stages of the cooling process, the resin is relatively soft. Hence, the resin mass contracts at about the same rate as the surrounding dental stone. As cooling continues the soft resin approaches its glass transition temperature (T_g). T_g is a thermal range in which the resin passes from a soft, rubbery state to a rigid, glassy state. When a denture base cools below T_g, it becomes a rigid mass. This rigid mass contracts at a rate different from that of surrounding dental stone resulting in thermal shrinkage. The glass transition temperature for polymethyl methacrylate is approximately 105°C. Therefore, when the denture base resin cools from this temperature to room temperature it undergoes a linear shrinkage. Linear shrinkage of 0.1-0.97% has been reported for various commercial denture resins [21].

Comparison of the interface gaps between the reference areas revealed that the gap was highest at the mid palatal area as compared to the sulcus areas and crest of the ridge areas for all 40 test specimens. This was independent of the palatal vault depth (Medium/Deep) and processing technique (Compression/ Injection). It is widely accepted that base adaptation to the cast is poorest at the posterior palatal area [4,22,26,32,41]. This has been attributed to the fact that the palatal contours here are concave antero-posteriorly and laterally, leading to greater rebound. Minimal gap was observed at the crest of the ridge areas and sulcus areas. The larger gap at the mid palatal region can be justified if the base is imagined as contracting while being relatively fixed at the ridge crest [22]. Since, in the present study the base thickness was kept uniform throughout, this could not be a contributing factor.

Laughlin., *et al*. have reported that palatal adaptation patterns may be influenced by the anatomic morphology of the palate. Shallow palatal vaults display interface gap openings spread over a wider area at the posterior border of the denture extending from ridge to ridge. Steep palatal vault usually have gap openings primarily at the mid palatal region. In the shallow palatal vaults the lateral palatal surface is a general horizontal plane across the area and hence the gap discrepancy is spread over a wider region, which explains the insignificant difference between the mean interface gaps at various reference areas (within Group IA and within Group IIA). However, in the deep palatal vault, the relatively parallel vertical palatal surfaces at the lateral palatal slopes restrict the discrepancy to the mid palatal region. Hence there is a significant difference observed between the interfacial gap measured at this region compared to the sulcus and ridge crest areas, which explains the results observed between those areas in the present study (within Group IB and within Group IIB) [19]. This has been validated in a similar study by Sykora and Sutow [26].

Although Laughlin., *et al*. compared between shallow and deep palatal vaults, the findings and justifications from that study can be extrapolated to the findings obtained in the present study where medium and deep palatal vaults have been compared. This is irrespective of the processing technique.

However, these significant differences observed within shallow and deep palates are with respect to the pattern of the gap openings only. The magnitude of the gap openings was not found to be significantly different (P value > 0.05) between corresponding areas of either palatal vaults for a given type of processing technique in this study (between Groups IA and IB and between Groups IIA and IIB). This is also in line with those reported in previous studies comparing the effect of shallow and deep palatal depths and linear interface gaps [19,26].

In the present study, all the 40 samples processed by compression molding technique exhibited a significantly higher (P value < 0.05) mean interface gap at each corresponding reference areas as compared to those processed by injection molding technique within a given palatal vault depth (between Group IA and Group IIA and between Group IB and Group IIB). Previous studies that have compared the linear interface gaps have reported that the injection molding technique yields significantly superior adaptation of the denture bases to their respective casts as compared to the conventional compression molding technique [5,6,9,26-29].

Jackson., *et al*. have attributed this to the homogenous dense structure of the injection-molded material which resists warpage that might otherwise occur [34]. The higher dimensional accuracy obtained with injection molding technique in comparison to the compression molding technique has been attributed to smaller resin particle compared to conventional resin, lesser polymerization time, absence of resin film formation between the two halves of the flask and absence of displacement of the two halves of the flask during resin packing [8].

In the SR-Ivocap system, injection molding allows directional control of the polymerization process through the flask design [11]. This is due to a new design in combination with a special heat insulation and a strictly controlled water boil of the curing unit. Sykora and Sutow have stated that the polymerization starts in the anterior segment of the flask, the furthest part of the denture base from the feeding funnel, the polymerization process then proceeds slowly towards the injection funnel. A constant flow of new material from the sprue compensates for the polymerization shrinkage [26].

The results from the present study show the linear interfacial gap across the posterior region for compression molded denture bases ranges from 0.1 mm to 0.5 mm. This range is in line with those observed in previous studies [3,17]. The linear interfacial gap for injection molded denture bases ranges from 0.03 mm to 0.2 mm. These results are also in agreement with another similar study by Parvizi., *et al*. [11]. Differences in palatal vault depth appears to significantly influence the pattern of gap distribution but not the magnitude of interface gaps at similar areas in the posterior region within a given type of processing technique and hence the null hypothesis for the present study is validated. Hence, it can be inferred reasonably that for a given thickness of denture base, the linear shrinkage is influenced significantly more by the processing technique rather than by the palatal vault depth.

The present study had some limitations. The interfacial gaps were measured after curing, deflasking and minimal finishing and sectioning procedures. So, the observed gap could be a combination of linear shrinkage obtained due to processing, deflasking and separation of the denture bases from the models. Finishing and polishing procedures [47], water sorption during storage and presence of artificial teeth influence the adaptation [10,26,36]. The effect of variable thickness of the 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.

Conclusions

- Denture bases processed by injection molding showed superior adaptation and linear dimensional accuracy over compression molding, irrespective of palatal vault depth.
- Palatal vault depthsignificantly affects the interface gap pattern,such that it shows more uniform diribution across the posterior regions for medium palatal vault, and restricted to mid palatal zone for deep palatal vault.
- Palatal vault depth doesnt significantly affect the magnitude of linear dimensional change in both of the molding techniques.

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