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How Some Ridge Shapes Affect the Fit of Denture Bases

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Abstract - *Polymerization shrinkage can result in poor denture fit. The aim of this study was to determine the accuracy of heat-polymerized acrylic bases on simulated edentulous metal ridges having simplified and standardized geometric configurations. Analysis of variance was used to explore the relationship between fit and ridge-slope/ridge-convergences. The outcome of that analysis revealed that the discrepancies between the base plates decreased significantly (p<0.05) as both the ridge slope decreased and the anterior-sagital convergence increased. These geometric correlations can help clinicians to anticipate potential areas of sore spots on residual ridges when delivering complete dentures.*

KEY WORDS: Denture base, ridge shape, fit

INTRODUCTION

Newly processed complete dentures often suffer from occlusal disharmonies and local pressure points. The combined effects of polymerization shrinkage of the poly methyl methacrylate (PMMA), its thermal contraction after polymerization, and the released stress during deflasking cause the poor adaptation of the denture base to the edentulous arch[1-3]. Unfortunately, as several authors have stated, the shrinkage of PMMA occurs in 3D and is not a simple linear [4,5] contraction, making it difficult to analyse and predict the way a denture will shrink and change shape in relationship to its support.

To measure and describe the effect of polymerization shrinkage on the adaptation of denture bases different approaches have been used [6,7]. Anthony et al[8] found that nearly all newly made maxillary dentures appeared to contact the model in the flange regions while they were deficient at the buccal borders. They also found that the dentures showed the greatest discrepancies across the central portion of the posterior border[8]. Sykora et al[9] measured the opening distance at the posterior palatal seal at 5 mm intervals. Takamata et al[10] flowed low viscosity addition polymerizing VPS material between the processed denture and the master die and then weighed the VPS on an accurate scale. Consani et al[11] placed processed resin bases on the master casts with an adhesive resin and then sectioned them laterally to measure the distance between the resin and the master cast at different anterior-posterior segments. These studies show that significant dimensional changes occur during polymerization.

Several articles have addressed the different steps in denture processing and how to reduce polymerization shrinkage[12]. Chen et al[13] and Woelfel et al[14] found that thicker dentures exhibited less molar to molar linear shrinkage but had larger gaps in the posterior palate region compared to thinner dentures. Sykora et al[15] investigated the type of stone used during flasking and found that the use of high expansion stone resulted in dentures with smaller gaps at the posterior palate compared to dentures fabricated with regular Type III stone. In another study, Skinner et al[16] varied the powder-liquid ratio of the resin to see how that ratio affected shrinkage and water sorption and found minor dimensional changes occurring during and after processing. The wide variation in powder-liquid ratio used by Kawara et al[17] revealed that a long, low-temperature processing technique was needed for the heat-activated PMMA to reduce polymerization shrinkage and prevent boiling of the monomer. Yeung et al[18] findings disagreed with those findings of Kawara et al[17], and claimed that differences in processing temperatures had been excluded by using a low-temperature processing technique in Kawara et al[17] studies, which decreased distortion of their dentures. To decrease distortion, Kobayashi et al[19] suggested a gradual cooling for 12h or more after processing of heat-polymerized acrylic dentures to effectively lessen the denture deformation. Kimoto et al.[20] concured with these findings. Komiyama et al.[21] on the other hand suggested bench cooling of the flask for a minimum of 1d before deflasking. After processing and retrieval of the denture, Sykora et al[9] and Anderson et al[22] agreed that immersion of the denture in water results in no statistically significant change in dimensions.

In addition to changes occurring during denture processing, the geometry of the jaws is also likely to affect the fit. Hedge et al[23] compared V-shaped, U-shaped and flat-shaped palates. They concluded that the V shaped palatal vault exhibited the highest dimensional change in the frontal and vertical planes. Körber studied the effect of ridge size and ridge shape and found that as the ridge size increased and the outer surfaces became more parallel, the larger the palatal discrepancy became[24]. Mandibular denture dimensional changes were measured by Lechner et al[25]. They found that linear shrinkage occurred in all dimensions with the greatest shrinkage in the anterior-posterior direction along the lingual flanges. A vast amount

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of literature is available comparing processing techniques of complete dentures and how they affect fit. Unfortunately, most of these studies lack geometrical analyses of the edentulous arches to be compared. The geometry usually includes the palatal vault shape and does not focus on other areas of the edentulous arch such as the outer slope of the buccal plates or the overall taper of the jaw when viewed occlusally.

Based on the above considerations, the aim of this study was to determine how standardized and simplified heat polymerized acrylic record bases fit simulated edentulous ridges with different geometric configurations. With that approach, an attempt would be made to explore relationships between ridge geometries (ridge slope and ridge convergency) and fit as a function of anterior displacements.

MATERIALS AND METHODS

Simulated Ridges: Sections of simulated maxillary edentulous arches were custom manufactured by attaching machined aluminum bars to aluminum plates. The palatal sections of these aluminum bars had a slope of 45 degrees, while the bar surfaces representing the outer slopes of the simulated ridges had three different slopes (Figure 1). The first ridge pair had an outer slope (OS) of 85 degrees (OS 85), The second ridge pair had a slope of 75 degrees (OS 75), and the third ridge pair had a slope of 60 degrees (OS 60). The ridge height of all three groups was kept constant at 10 mm.

In addition to the ridge slope variable, a second variable was the angle of convergency (AC) of the ridges in anterior-sagittal direction. These convergence angles were 5 (AC 5), 10 (AC 10) or 15 (AC 15) degrees. Thus, for each of the three ridge groups, three aluminium plates were prepared to meet the three anterior-sagittal conditions, resulting in a total of nine simulated ridge conditions (Figure 2).

Duplication: A vinylpolysiloxane (VPS) duplicating material was used according to manufacturer's instructions to replicate each of the nine aluminium ridge models. The area of impression making was standardized by boxing the area of the ridges with an aluminum cylinder (inner diameter of 120 mm and 80 mm high). With this approach, one PVS mould per ridge condition was made. The impressions were then poured with dental stone. Each PVS mould was poured six times to yield a total of 9 x 6 (54 stone casts).

Acrylic Base Manufacturing Process: In order to determine the number of specimens needed per group some preliminary samples were made and compared by use of a power analysis. The outcome of that analysis revealed that 5-6 specimens per group would be needed to prove significant differences ($p<0.05$). As a consequence of that analysis we included 6 specimens in each of the nine groups. The 54 acrylic record bases were processed as described by Becker[42]. The first step consisted of making 1 mm thick wax plates extending to the periphery of the ridge surrounded area on the gypsum cast. The wax plates with their stone dies were then flasked. After boil-out of the wax and a brief cooling period of 15 min, the monomer and polymer of the heat polymerized resin were mixed according to manufacturer's instructions at a room temperature of 23.5°C. One trial pack of the resin was needed due to the small amount needed to fill the lost wax mould. A packing force of 1120N was used for the trial pack. Final closure was done at a force of 20016N and the flask was transferred to a hand press. Polymerization was performed by immersing the flask in a 71°C water bath for 9h, whereupon the flask was bench-cooled for 12h in compliance with Kobayashi[19]. After separation from the flask; the acrylic record bases were recovered from the stone models and placed in an air tight plastic bag with water.

Figure 1. *Simulated ridge pairs with outer slopes of 85, 75 and 60 degrees from left to right respectively. Inner slope is 45 degrees for all three ridge types.*

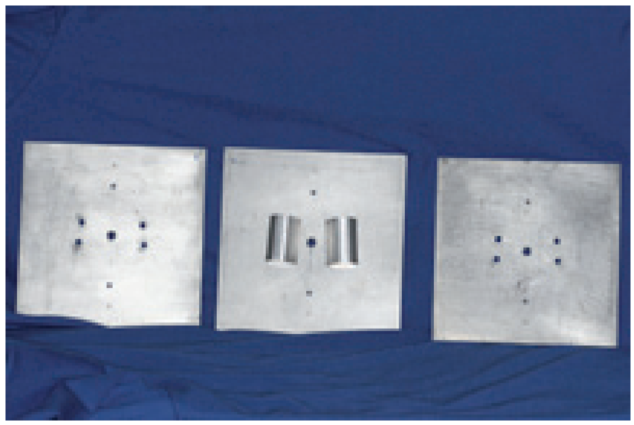

Figure 2. *Aluminium plates with holes that allow the ridge pairs to be screwed at different angles (5, 10, 15 degrees). Each ridge pair has three plates.*

Figure 3. *Apparatus used to measure fit of acrylic record base. Vertical micrometer reads distance between intaglio of record base and aluminium plate. The horizontal micrometre displaces the record base in anterior sagittal increments of 1mm.*

Measuring Approach: Measurements were made approximately 24h after recovery of the record bases. These measurements were conducted by mounting the partly simulated aluminium maxilla model to a four-legged measuring table (Figure 3). As seen from Figure 3, the aluminium ridges lacked anterior segments representing the premaxillae. That segment was left out intentionally due to the method we used to collect fitness data to avoid interferences as the base was displaced in anterior direction. The measurements were done using two micrometres attached to the aluminium plates to which the aluminium ridges had been mounted. The micrometres were attached by means of screws that were machined in each of the aluminium plates in exactly the same positions (Figure 3). One micrometre was attached to the bottom of the aluminium plate in the centre of the simulated jaw segment. At that location, a hole had been drilled so the micrometre could read the distance between the aluminium plate and the palate of the acrylic base. This hole was located in exactly the same position in relation to the simulated ridges regardless of the ridge shapes. The other micrometre was attached at the edge of the aluminium plate touching the widest part of the acrylic base representing the posterior edge of the denture. This micrometre was used to displace the acrylic base anteriorly. Thus, by use of these two micrometres, it was possible to record the vertical distance between the palate part of the aluminium plate and the acrylic record base as it was displaced in horizontal direction.

Before any recordings were made, all edges around the periphery of the acrylic record bases were smoothed to facilitate the seating of the acrylic record bases on the aluminium ridges. The distal edges of the acrylic record bases were aligned along a straight line connecting the posterior edges of the aluminium ridges. That position represented the horizontal start position and was assigned the value 0.000 mm. From that position the acrylic record base was displaced in an anterior direction. The vertical micrometre, on the other hand, was set in its zero position when its measuring rod was flush with the simulated palate of the aluminium plate. The distance from the zero position to the point when the measuring rod touched the intaglio surface of the denture base was then recorded as the vertical discrepancy at the horizontal 0.000 mm position. The denture base was then displaced in anterior-horizontal direction steps of 1.000 mm with the horizontal micrometre rod. At each such step the distance between the palate and the intaglio of the denture base was recorded with the vertical micrometre. These recordings continued until no further displacement could be read because of interference between the two micrometres. That interference occurred at an anterior displacement of 14.000 mm in all 54 cases.

The measured distances between the acrylic record bases and the aluminium plates at all intervals were entered into Microsoft Excel and plotted using the XY scatter chart type. After the graphs were completed, Microsoft Excel was used to formulate a trend-line of the plotted data represented by the thin lines in figures 4, 5 and 6.

The y-values at x=0 were also analysed using a two-way ANOVA to determine significant effects ($p<0.05$) of ridge slope and ridge convergence. The same analysis was conducted for the y-values determined at the 14.000 mm displacement location in sagittal direction.

RESULTS

Zero Displacement: The results are presented in Figures 4 - 6. Figure 4 shows ridge pair (OS85) with 5, 10 and 15 degrees anterior-sagittal convergence (AC5,10,15). At the zero mm displacement position, the average of the six samples yielded spacing between the palatal part of the acrylic base and the metal plate of 2.290 mm.). As seen from

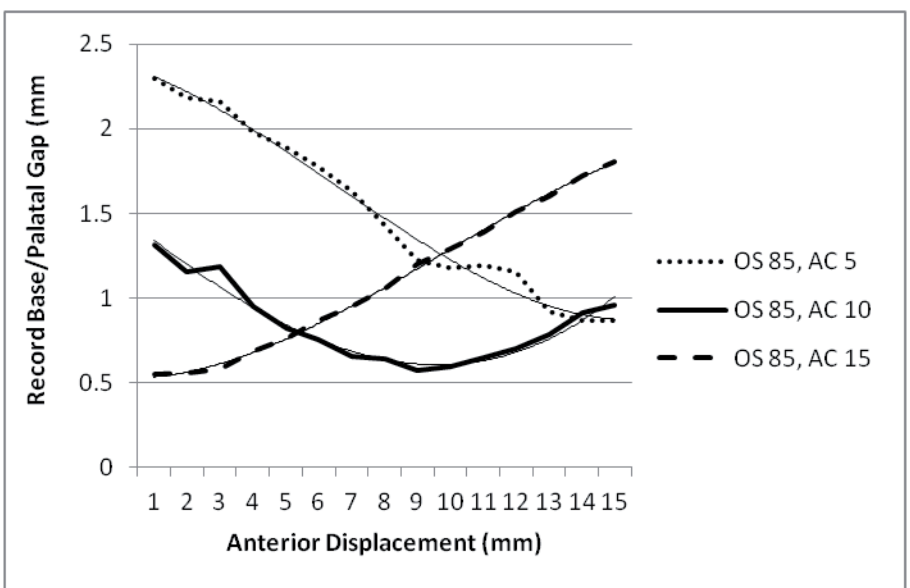

Figure 4. *Plot of ridge pair with outer slope of 85 degrees and anterior convergence (AC) of 5, 10, 15 degrees). Each data point represents the mean value (n=6) of the distance between acrylic record base and aluminium plate for a specific anterior displacement value. Thin lines represent polynomials.*

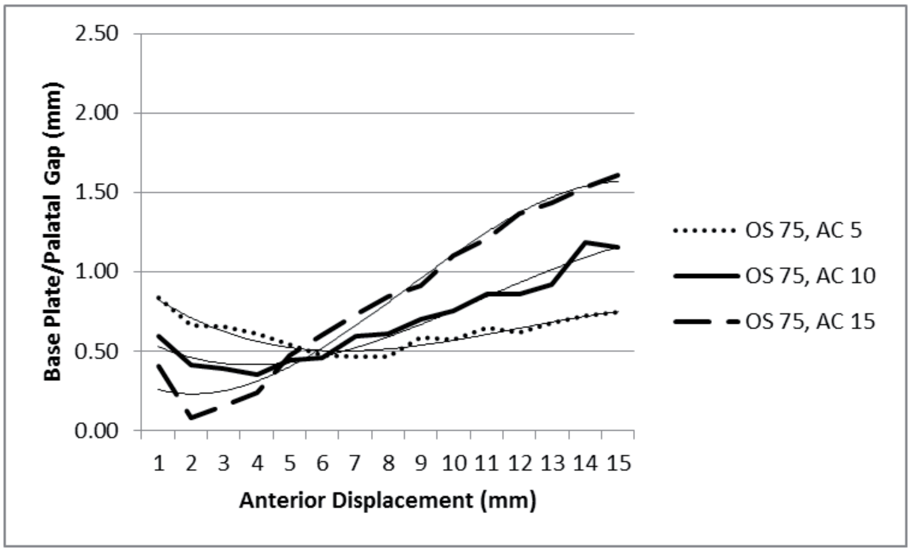

Figure 5. *Plot of ridge pair with outer slope of 75 degrees (OS 75) and anterior convergence (AC) of 5, 10, 15 degrees. Each data point represents the mean value (n=6) of the distance between acrylic record base and aluminium plate for a specific anterior displacement value. Thin lines represent polynomials.*

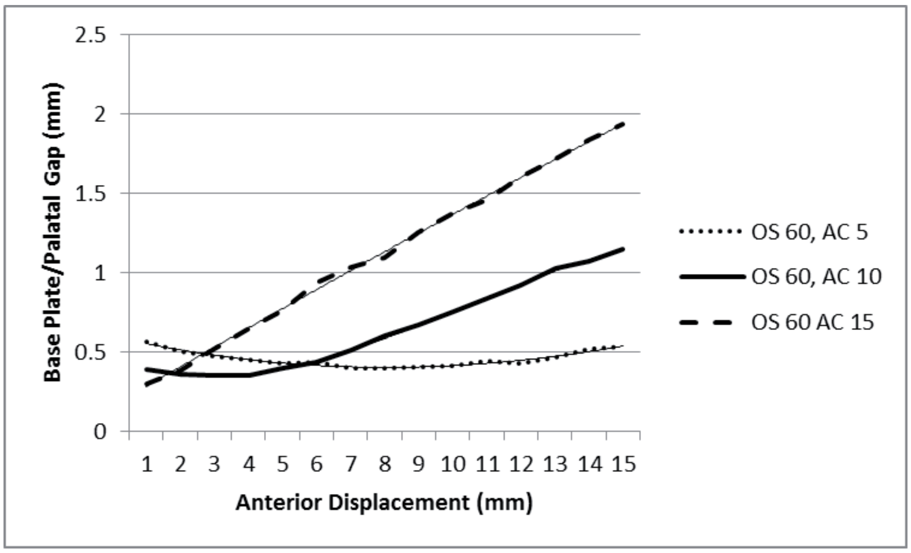

Figure 6. *Plot of ridge pair with outer slope of 60 degrees (OS 60) and anterior convergence (AC) of 5, 10, 15 degrees. Each data point represents the mean value (n=6) of the distance between acrylic record base and aluminium plate for a specific anterior displacement value. Thin lines represent polynomials.*

Figure 4, the ridge pair (OS85, AC10), at the horizontal zero position, the spacing between the acrylic record base had a mean value of 1.313 mm, while (OS85, AC15), the same average displacement was 0.564 mm. From these numbers it is clear that at the zero mm position, the acrylic plate to metal plate distance decreased as the sagittal conversion angle increased. A similar pattern was observed in the 10 degrees and 15 degrees anterior convergence of the aluminium ridge pairs with OS 75 degrees and OS 85 degrees at zero displacement.

Horizontal Displacement: After performing the measurements at zero horizontal displacement, the acrylic plates were displaced in an anterior direction by 1.000 mm increments. As the record base moved in anterior direction, the gap between the aluminium plate and the acrylic record base decreased. However, after the gap between the acrylic record bases and the aluminium plates reached a certain distance, that gap started to increase again. An exception for the above pattern was for the 15 degrees converging ridges (AC15), which had a tendency to start raising the acrylic plate gap earlier in the displacement (e.g. as soon as the displacement started). The inner slope of the aluminium ridges, which formed a 45 degrees angle with the metal plates, was found to be the contributing factors to the rise of the acrylic plates. Even though all inner slopes were constant at 45 degrees, they influenced the fit by interfering with the intaglio surface of the more converging ridges as the record base was displaced in an anterior direction (Figure 8).

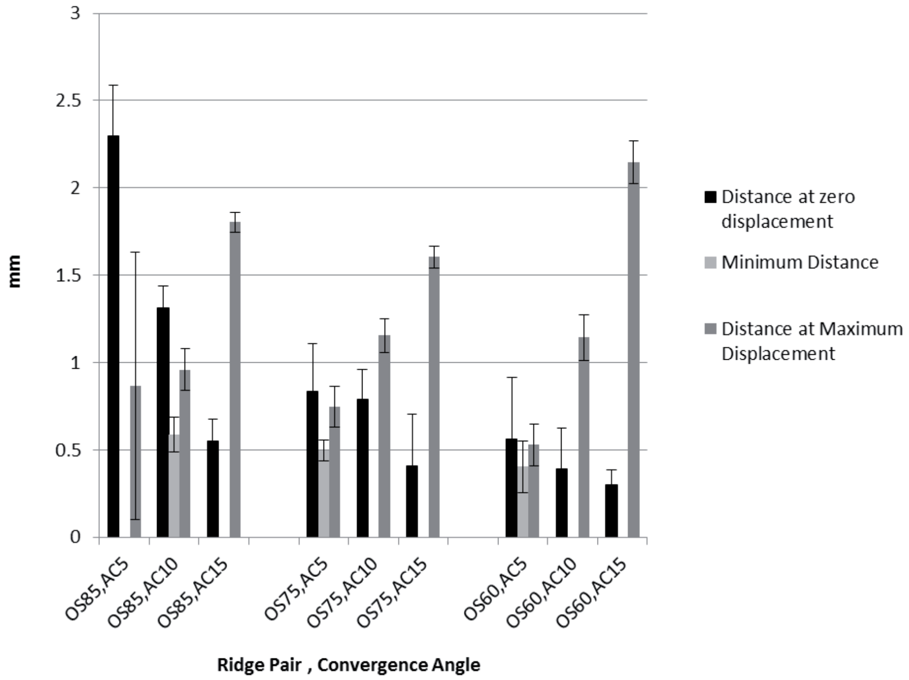

Figure 7. *Graph showing distance between the acrylic record bases and the metal palatal plate at zero displacement (black bars) and after 14 mm anterior displacement (dark grey bars). Minimum distances are shown as the light grey bars in the graph.*

Table 1. *Table showing polynomials for the three ridge pairs with different outer slope angles (OS) and anterior convergence angles (AC)*

	AC 5	AC 10	AC 15
OS 85	$y = -0.0004x^3 + 0.0124x^2 - 0.0053x + 0.5282$	$y = 0.0003x^3 + 0.004x^2 - 0.1579x + 1.495$	$y = -0.0004x^3 + 0.0124x^2 - 0.0053x + 0.5282$
OS 75	$y = -0.0005x^3 + 0.0172x^2 - 0.1644x + 0.9749$	$y = -0.0006x^3 + 0.0197x^2 - 0.1246x + 0.6353$	$y = -0.0012x^3 + 0.0306x^2 - 0.1103x + 0.3383$
OS 60	$y = -2E-05x^3 + 0.0034x^2 - 0.0508x + 0.6013$	$y = -0.0005x^3 + 0.0163x^2 - 0.0812x + 0.4577$	$y = -4E-06x^3 - 0.0003x^2 + 0.1242x + 0.1594$

OS= Outer surface angle for ridge pairs. AC=Anterior sagittal convergence of ridge pairs.

The trend-line generated by Microsoft Excel fit a third degree polynomial. By use of these third degree polynomials, it was also possible to determine maximum and mean values that were found for some cases within the 0.000 to 14.000 mm displacement. The x- and y-values of each ridge condition (Figures 4-6) followed third degree polynomials quite well (Table 1)

By use of a two-way ANOVA it was possible to demonstrate strong correlations between ridge slope and ridge convergence on fit ($p<0.001$). That analysis also revealed a weaker but still highly significant ($p<0.001$) interaction between ridge slope and ridge convergence.

DISCUSSION

Zero Displacement: As seen from Figure 7, the y-values at zero displacement (blue bars) revealed that the fit of the processed record base for (OS85) with 5, 10 or 15 degrees convergence (OS85,AC5), (OS85, AC10) and (OS85,AC15) is clearly worse than Groups (OS75) and (OS60) with 5, 10 and 15 degrees convergences (AC5,10,15). In other words, as the outer walls of the ridge pairs became steeper, the worse the fit of the acrylic plates became at 0.000 mm horizontal displacement. The poor fit can be attributed to polymerization shrinkage of the acrylic record bases, which results in a tighter contact on the outer wall of the steeper ridges (OS85) compared to the less steep outer wall groups (OS60).

At zero mm displacement, (OS 85,AC 5) exhibited worse fit than (AC 10,15) for that same group. When comparing all three ridge pairs with 5 degree convergence to matching ridge pairs with 10 and 15 degrees convergence, the fit of the acrylic record bases improved as the anterior-sagittal convergence increased.

Consequently, all ridge pairs with (AC 5) adapted worse than matching ridges that converged more. On the other hand, it was noticed that the poor fit of the acrylic base for (OS 85) improved when the same convergence angle (AC5) of ridge pairs (OS75) and (OS60) were compared at zero displacement (Figure 7). The same applied to all ridge pairs with (AC10) and (AC15) at zero displacement (Figure 7). Thus, ridges with more sagittal/anterior convergence had better adapting acrylic bases at x=0, which suggests that more tapered edentulous maxillae, when viewed occlusally, would have a better denture fit than an squared shaped edentulous maxillae. This result is in line with Körber's[24] clinical study. Also, dentures fabricated for edentulous maxillary ridges with more resorption on the buccal plate would fit better than dentures made for parallel ridges according to the above results.

Horizontal Displacement: At maximum displacement (x=14.00 mm, dark grey bar in Figure 7), the fit of the acrylic record base had an inversely related relationship with the fit of the acrylic record base at zero displacement. This is especially evident if the initial fit is poor or good. It was noticed while performing the measurements that the inner slopes of the ridge pairs had a significant influence on this phenomenon. When the initial fit of the acrylic base was mediocre, it seemed to be a competition between the outside ridge slope and the palatal ridge slope as the record base was displaced in the anterior direction. That interaction explains why a minimum (light grey bar in Figure 7) in y-values existed between the extreme displacement locations x = 0.000 mm and x = 14.000 mm. The reason is the degree of convergence of the ridge pairs. The more the ridge pairs converged anteriorly, the better the initial fit at zero displacement. However, the inner slope of the ridge pair influenced the record base sooner in the displacement and worsens the fit of the record base as the anterior displacement continues.

When evaluating the results presented in this study, they must be judged with some caution. The organically shaped human ridges covered with soft tissue will be different from the geometrically designed metallic ridges. Because of these differences, the presented results should be used to suggest how dentures may fit and might behave clinically rather than assume these results may be unequivocally transferred to the *in vivo* situation. For example, our results revealed rather large gaps under dentures, and that the periphery of the plates rests on the sloping ridge planes rather than reaching the metal surface on which the ridges are attached. Clinically, because of the compressibility of the soft tissue, such a tight peripheral fit caused by polymerization shrinkage of the base plate will most likely initially cause a peripheral snug fit causing the denture to act like a suction cup. However, after some time, the soft tissues have adapted and the overall fit of the denture has improved, causing the suction cup effect to disappear. That behaviour is often noticed when new dentures are delivered.

With the limitation of the study mentioned above, the results of this study can still be used to understand how dentures interact with edentulous arches when viewed transversely. The buccal plate of the edentulous maxillary arch resorbs medially as time passes. As suggested by the results of this investigation, the higher the degree of buccal resorption, the better the palatal adaptation will be. In cases where the edentulous arches are more parallel in sagittal direction, a clinician should expect more denture adjustments to be done on the buccal plate. Conversely, if the buccal plates of an edentulous arch seem highly resorbed, the clinician might predict a more intimate adaptation of the denture.

The shapes of the edentulous arches when viewed occlusaly is another factor that can help a clinician predict the fit of a denture. If the shape of the edentulous arch is tapered, one might argue that the patient will experience more sore spots around the inner slopes of the premaxillae area. This is suggested from the results presented above, because the higher the convergence seen between the edentulous arches, the sooner interference will be exhibited by the inner slope of the edentulous arches. If the shape of the edentulous arches is square on the other hand, the clinician might find less sore spots around the inner slopes of the premaxillae because the inner slopes wouldn't interfere with the seating of the denture as soon as a tapered shaped maxillary arch. In contrast, the sore spots might show more on the distal slope of the maxillary tuberosity close to the hamulus. Early adjustment of occlusion should be performed with caution on day of delivery of the dentures if the denture bases are not fitted correctly. The swelling of the denture and the adaptation of the tissue are two factors that could render the early adjustment of the denture occlusion problematic. This emphasizes the importance of checking and adjusting the tissue-fitting surface of the denture with disclosing paste before adjustment of occlusion.

SUMMARY AND CONCLUSION

Three configurations of simulated edentulous arch regions with three options of anterior-sagittal convergences were evaluated regarding the fit of heat polymerized acrylic record bases. The results revealed that the steeper the outer angles of the ridges, the worse the fit of the acrylic base at zero displacement. If the initial fit of the record base is poor (parallel outer slopes or parallel convergence), anterior displacement causes it to improve. On the other hand, if the initial fit of the record base is good (converged outer slopes or converged ridges), the anterior displacement causes the fit to become poor because of the influence of the inner slopes of the simulated ridges.

MANUFACTURERS DETAILS

- Vinylpolysiloxane (VPS) duplicating material (Poly-Pour, batch #060321, GC Lab Technologies, Alsip, IL, USA)
- Dental stone (Microstone, batch# 027040705, Whip Mix, Louisville, KY, USA).
- Heat polymerized resin (Lucitone, batch# 061113, Dentsply Int., York, PA)
- Two micrometers (Fowler 0-6" 0.00005", Fred V. Fowler Co., Inc, Newton, Massachusetts, USA)
- Microsoft Excel (Microsoft, Redmond, WA, USA)
- ANOVA (SAS, Raleigh, NC, USA)

ADDRESS FOR CORRESPONDENCE

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