A comparative study on the accuracies of resin denture bases and metal denture bases

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Since the late 1930s, acrylic resins have been the materials of choice for the fabrication of complete denture bases. It has excellent esthetic properties, adequate strength, low water sorption, and low solubility. But acrylic resin has disadvantage of processing shrinkage that reduces denture retention and accuracy of denture occlusion.

Metals also have been used in denture base material. Metals used in denture bases display excellent strength and dimensional stability. The major disadvantages associated with metal denture bases include increased cost, difficulty in fabrication, compromised esthetic qualities, and inability to rebase.

The purpose of this study is to compare the artificial tooth movements of complete dentures with resin bases and metal bases after curing, deflasking, polishing, immersion in water for 1 week and 4 weeks.

Twenty-four maxillary complete resin denture bases with artificial teeth were fabricated. Twelve of them were resin based and other twelve of them were metal based. Fine crosses were marked on the incisal edges of right central incisors and distobuccal cusps of both second molars. Measurements were done for the changes of distances of reference points at the time of wax denture, after deflasking, after decasting, after polishing, after immersion in water for 1 week and 4 weeks Meaurements were done to the accuracy of 0.001mm with a measuring microscope.

The results were as follows :

1. Metal base showed significantly less tooth movement than resin base after curing and decasting ($p<0.01$).
2. Metal base showed significantly less tooth movement than resin base after polishing ($p<0.01$).
3. After immersion in water for 1week and 4 weeks, metal base showed less movement than resin base.
   Difference was significant for anterior-posterior distances ($p<0.01$), but not significant for molar-to-molar distance ($p>0.01$).
4. 1 week and 4 weeks of immersion failed to compensate the initial processing shrinkage of metal and resin bases ($p>0.01$).

Key Words :
Complete denture, metal base, resin base, accuracy, artificial tooth movement

Since the late 1930s, acrylic resins have been the materials of choice for the fabrication of complete denture bases. It has excellent esthetic properties, adequate strength, low water sorption, and low solubility.[1] But from the time that the denture wax-up is completed until the denture is delivered to the patient and properly seated, many changes occur in the positions of the artificial teeth. These changes, usually known as processing errors, have to be corrected before patients can successfully use their dentures.[2] Upon polymerizing, these poly(methyl methacrylate) resins exhibit a 0.2% to 0.5% linear polymerization shrinkage. Numerous articles reported concerning the physical and mechanical properties of PMMA. Woelfel[3] found that linear change from waxed to finished dentures, when measured molar to molar across the posterior section of the specimens, showed a shrinkage of 0.4mm(0.9%). A recovery of 0.1mm(0.2%) occurred after 3months of use. Several other investigators[4-7] used linear measurements to evaluate the dimensional stability of the denture base materials by placing pins at strategic points in dentures. Yun,[8] Chae[9] reported the dimensional stability of denture base resins and Kim[10] reported on occlusal and vertical changes after denture processing.

Anthony and Peyton[11] studied the dimensional stability of heat-activated resin bases, autopolymerized resin bases, and cast cobalt-chromium bases using a modified contour comparator. The results showed that the autopolymerizing resin denture showed the most accurate fit. This study was in agreement with that of Skinner and Cooper,[12] in which the temperature range of cooling required after the plastic reached a rigid state in the molds(transition temperature)was the principal factor in the observed shrinkage.

In the past few years, acrylic resin monomers and polymers have also been modified to improve not only physical and mechanical properties, but also the working properties that facilitate laboratory techniques of denture fabrication. These new laboratory techniques include microwave-and visible light-activated polymerization, and vacuum-plus-pressure adaptation during low-temperature polymerization of resin system.[13] In spite of all of these advances, no combination of resin material and processing technique has been able to reduce linear distortion to less than 0.2%.[14]

The movement of teeth during processing of complete dentures disturbs the harmonious occlusal scheme achieved at the final try-in stages. This movement can be in any direction and may occur as a result of processing procedures and dimensional changes of the acrylic resin denture base during curing, deflasking, finishing, and polishing.[15,16]

Several variables contribute to denture base distortion. For example, Woelfel and Paffenbarger[2] discovered that a thinner denture base will distort twice as much as a thicker denture base. Barco et al.[17] observed that dentures processed in heat-polymerized resin without teeth fit better than those with teeth.

Metal alloys also have been used in denture base material. Metal alloys used in denture bases display excellent strength-to-volume ratios[18] and may be cast in thin sheets maintaining rigidity and fracture resistance. Thinner metallic denture bases decrease interference with phonation.[19] Metal bases also display desirable dimensional characteristics and may be cast accurately.[20] They also exhibit the sorption-related dimensional changes characteristic of commonly used polymers.[21]

High thermal conductivity also has been thought to be a significant advantage and some practitioners feel that this characteristic is responsible for enhanced health of tissues in contact with metal bases. However, little objective information is available.

The major disadvantages associated with metal denture bases include increased cost, difficulty in fabrication, compromised esthetic qualities, and inability to rebase.

There were many studies on dimensional accuracy of resin denture base. But little research has been conducted on comparison of tooth movements in denture with resin base and metal base.

The purpose of this study was to compare the tooth movements of complete dentures with resin bases and metal bases after curing, deflasking, polishing, immersion in water for 1 week and 4 weeks.

MATERIAL AND METHODS

A rubber mold (Fig. 1) was made of a nonundercut edentulous maxillary cast (Fig. 2) using molding silicone (Shinetshu, Japan). This mold was used to prepare 24 identical stone casts. Type V dental stone (Die-Keen, Heraeus Kulzer Inc, USA) was measured and mixed with the recommended amount of water(W/P ratio=21ml/100g) using automatic mixer(MixQueen, Oscotec, Korea). A master complete maxillary denture (Fig. 3) with palatal thickness of 2mm was waxed up with acrylic resin denture teeth (Truebyte Bioform 264 and 32M, Dentsply). On 12 stone casts, metal denture base was fabricated (Ticonium Premium 100, Ticonium Co., Albany. NY). Metal bases covered all palate and were extended to residual alveolar ridge (Fig. 4). Retentive beads were formed for denture base resin to be attached to metal base. To ensure uniformity and permit comparisons, a mold from silicone rubber (Exaflex putty, GC America Inc., USA) was made from the master denture (Fig. 5). With the same mold of teeth the denture wax-up were duplicated by melting and pouring wax into the mold that

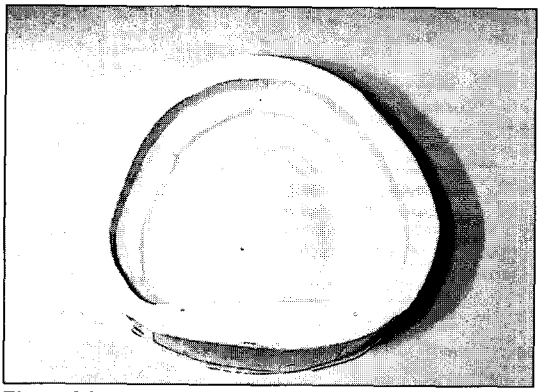

Fig. 1. Silicone mold for duplication of stone cast.

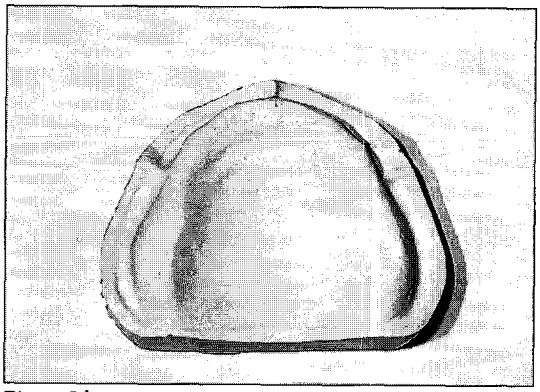

Fig. 2. The master stone cast.

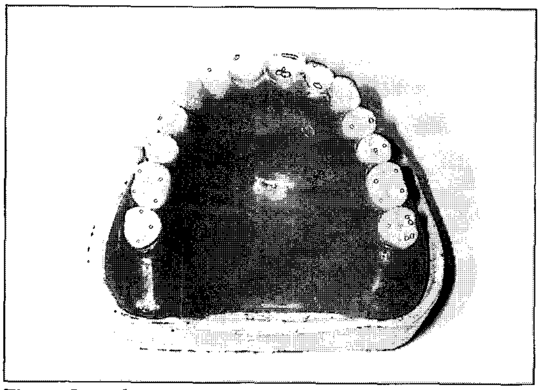

Fig. 3. Complete maxillary denture wax-up for resin base.

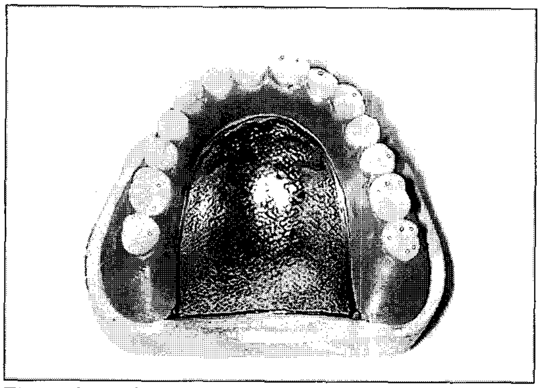

Fig. 4. Complete maxillary denture wax-up for metal base.

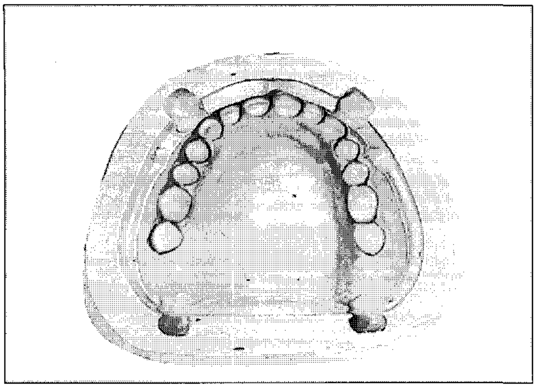

Fig. 5. Silicone mold for duplication of wax denture.

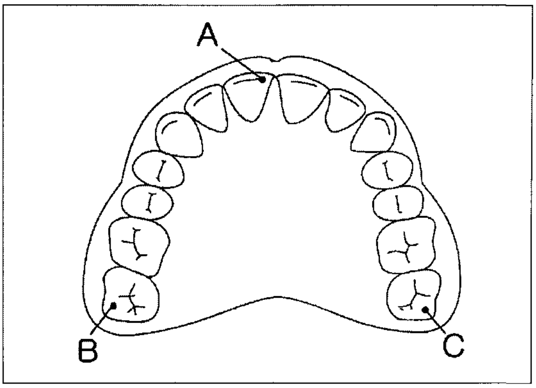

Fig. 6. Positions of reference points on maxillary denture.

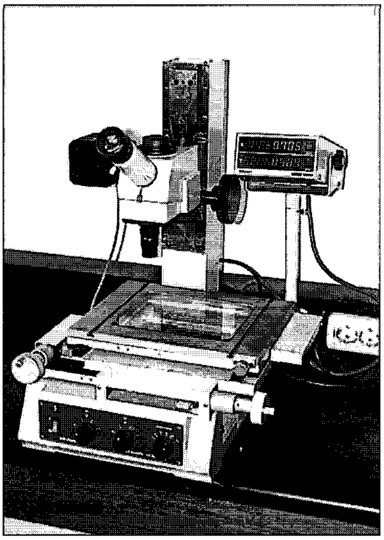

Fig. 7. Reference point seen with the microscope(× 50).

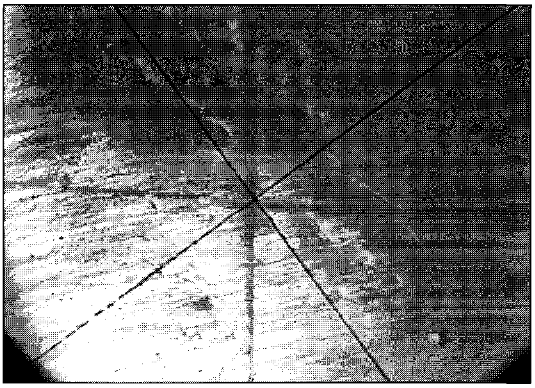

Fig. 8. Traveling microscope for measuring distances between reference points.

held the acrylic resin teeth and stone casts in correct relationship to each other.

Twenty-four denture wax-ups(twelve for metal denture base and twelve for resin denture base) including the reference points were made. The wax-ups were identical in thickness, height, and contour because they were prepared from the same mold. Fine crosses were marked with a surgical scalpel(Surgical Blade, Feather Safety Razor Co., LTD, Japan) on the incisal edges of right central incisors(point A) and distobuccal cusps of both second molars(point B and C) to be used as reference points for measuring distances(Fig. 6). The crosses were marked with indelible pencil to make them more visible(Fig. 7).

Distances(AB^{R}, BC^{R}, and CA^{R} for resin denture, AB^{M}, BC^{M} and CA^{M} for metal denture) on artificial teeth were measured at the wax-up stage before investing. These were used as the starting point, and all values were calculated with these measurements as the starting point. Subsequent measurements were made (1) after processing and before decasting, (2) after decasting, (3) after the dentures had been polished, (4) after the dentures had been stored in water at room temperature for 1week, and (5) for 4 weeks.

Heat curing acrylic resin (Vertex RS, Dentimex Zeist, Holland) was used for denture base material, and curing was performed in boiling water for 20 minutes with denture curing unit(Curing Unit, Teledyne Hanau, Buffalo, N.Y.).

All measurements were made with digital measuring microscope(Mitsutoyo, Japan) and recorded to the nearest 0.001mm(Fig. 8). Measurements were made by the same operator, and every measurement was made 3 times to establish a mean value.

The data were analyzed with Statistical Analysis System(SAS) Version 6.04 software(SAS Institute Inc., Cary, N.C.) using Wilcoxon rank sum test.

RESULTS

Table Ⅰ shows horizontal dimensional changes in AB, BC, and CA distances measured at the time of wax denture vs. measurements at various times and statistical results.

Table Ⅱ shows results of Wilcoxon rank sum test on the continuous dimensional changes in each group and each reference time. This shows whether each group had significant change compared to previous stage.

Figs. 9,10 and 11 show dimensional changes continuously and graphically. The shrinkage or expansion of measured distances are presented as negative or positive values in all tables and graphs.

Significant differences were found between the resin group and the metal group throughout the procedures. Metal group showed significantly smaller dimensional changes in processing, polishing, and storage of 1 week and 4 weeks for all the anterior-posterior measurements. But the molar-to-molar distances between metal base and resin base showed no significant difference after deflasking, immersion of 1 week and 4 weeks. So difference of tooth movement between metal base and resin base was small-

Table Ⅰ. Horizontal dimensional changes in AB, BC, and CA distances measured at the time of wax denture vs measurements at various times and results of Wilcoxon rank sum test

Location	Time of measurement	Dimensional change(mm) (Mean±S.D.)		Statistical significance
		Metal base	Resin base	
AB	Deflasked	-0.031±0.007	-0.191±0.007	*
	Decasted	-0.049±0.006	-0.287±0.010	*
	Polished	-0.045±0.040	-0.321±0.033	*
	1week	-0.050±0.007	-0.179±0.018	*
	4week	-0.045±0.008	-0.177±0.028	*
BC	Deflasked	+0.053±0.016	-0.234±0.007	n.s.
	Decasted	+0.076±0.016	-0.347±0.005	*
	Polished	+0.082±0.016	-0.406±0.005	*
	1week	+0.042±0.022	-0.219±0.029	n.s.
	4week	+0.046±0.016	-0.208±0.032	n.s.
CA	Deflasked	-0.032±0.007	-0.198±0.056	*
	Decasted	-0.052±0.005	-0.310±0.028	*
	Polished	-0.063±0.007	-0.362±0.025	*
	1week	-0.052±0.007	-0.197±0.033	*
	4weeks	-0.047±0.005	-0.207±0.078	*

* denotes significant difference at 0.01 level

Table Ⅱ. Wilcoxon rank sum tests on the continuous dimensional changes in each group and each reference time

Reference time	Time of Measurement	AB		BC		CA	
		Metal	Resin	Metal	Resin	Metal	Resin
Wax Denture	Deflasked	*	*	*	*	*	*
	Decasted	*	*	*	*	*	*
	Polished	*	*	*	*	*	*
	1week	*	*	*	*	*	*
	4weeks	*	*	*	*	*	*
Deflasked	Decasted	*	*	*	*	*	*
	Polished	*	*	*	*	*	*
	1week	*	*	*	*	*	n.s.
	4weeks	*	*	*	*	*	n.s.
Decasted	Polished	*	*	*	*	*	*
	1week	n.s.	*	*	*	n.s.	*
	4weeks	*	*	*	*	*	*
Polished	1week	*	*	*	*	*	*
	4weeks	*	*	*	*	*	*
1week	4weeks	*	*	n.s.	*	*	*

* denotes distance significantly different to that of reference time at 0.01 level.

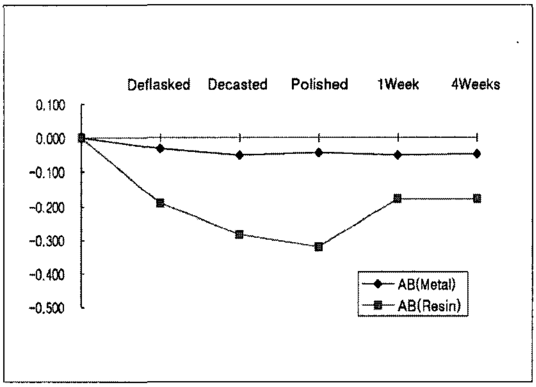

Fig. 9. Dimensional changes in AB distances of metal based denture and resin based denture.

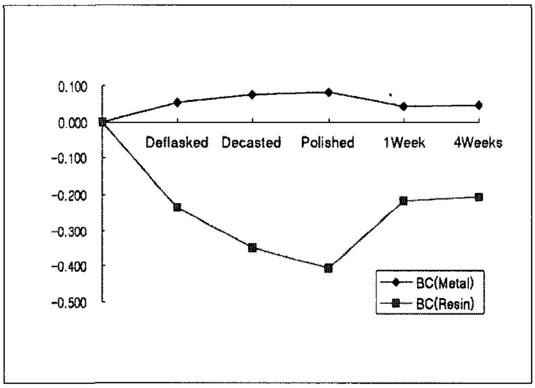

Fig. 10. Dimensional changes in BC distances of metal based denture and resin based denture.

er for molar-to-molar distance. Finally after storage of 4 weeks, the differences of changes in AB and CA distances showed significant differences between metal and resin base. But no significant differences were found for BC distances. All distances of resin base denture showed a shrinkage after processing. This finding confirms previous results.[22-29] Linear change increased continuously during deflasking, decasting, and polishing. After decasting, the decrease of distance of resin base was 0.287mm to 0.347mm. After polishing, it increased to 0.321mm to 0.406mm. After immersion in distilled water for 1 week and 4

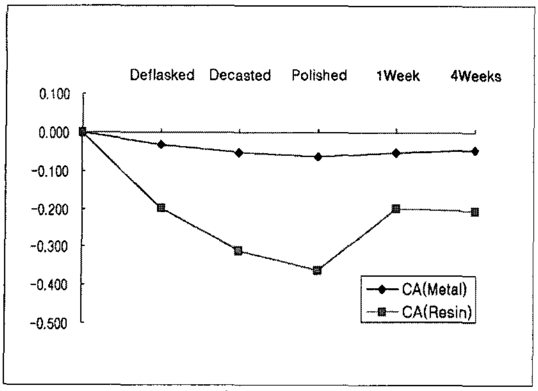

Fig. 11. Dimensional changes in CA distances of metal based denture and resin based denture.

weeks, some recovery of shrinkage was observed. Finally after storage in distilled water for 4 weeks, the decrease of distance was 0.177mm to 0.209mm.

As seen in the graphs, the amount of tooth movement in resin base increased continuously through the procedure of curing, decasting, polishing. The amount of tooth movement was greatest after polishing, and recovery occurred after immersion in water.

The changes of metal base were different from that of resin base. AB and CA distance of dentures of metal base decreased, but the BC distance of them showed a small increase. The distance of metal base denture showed a decrease of 0.049mm for AB and 0.052mm for CA after decasting. On the contrary, the BC distance increased to the amount of 0.076mm after decasting. After polishing they were 0.045mm for AB, 0.063mm for CA. And finally after storage of 4 weeks, they were 0.045mm and 0.047mm for each.

Also, analysis were done for continuous dimensional changes in each group and each reference time(Table II). Almost all measurements underwent significant changes after each step of denture fabrication.

DISCUSSION

The first unavoidable dimensional change in every acrylic resin prosthesis is shrinkage that occurs during processing and finishing. The second change, expansion, occurs when the dentures are either stored in a water bath or inserted in the mouth and then absorb oral fluids.[30-32]

In this experiment, dentures with metal bases showed greater dimensional stability after decasting. Traditionally, PMMA dentures are processed in brass denture flasks by compression molding of the acrylic resin with stone while it is in the doughy stage. The flasks are placed in a temperature-controlled water bath for a specified time to permit resin polymerization. There has always been a problem with shrinkage of the acrylic resin during the polymerization process. The resin' s coefficient of linear expansion is 81×10^{-6}. The gypsum products which form the mold have a coefficient of linear expansion one-eighth that of acrylic resin. This difference contributes to the dimensional change and induced strain.[33]

But it can be assumed that in a metal base denture, all the internal stress could not be released due to the reinforcing effect of the metal base. The metal frame had retentive beads and was extended beyond the residual alveolar ridge. Also a denture with metal base has smaller volume of PMMA resin than a denture without metal base. In this experiment, dentures with metal bases also showed significantly less tooth movement after decasting. The amount of movements were -0.052 to +0.076mm. They also showed significantly less tooth movement after polishing. They have less volume and less surface area of PMMA resin, and much less time and amount of resin to be reduced. So dimensional changes due to polishing and finishing is minimized. Woelfel[27] stated that during the finishing and polishing, minimize the reduction of bulk, avoid heating up the denture base as frequently occurs with the use of large arbor bands. He also stated that either gross bulk reduction or overheating may cause unnecessary denture base warpage. Other investigators[2,4,34,35] stated similar opinions.

The resin group showed decrease of distances for all direction, but in the metal group, molar-to-molar distance showed increase. This result can be thought to be due to the U-shaped portion of resin base. Resin contracts in a direction to the center, but in U-shaped base, contraction occurred to the outside direction. So expansion was observed in these measurements.

The changes of molar-to-molar distances for metal bases were smaller than that of resin bases, but no significant differences were found between metal bases and resin bases after 1 week and 4 weeks of immersion. The amount of processing shrinkage after decasting were -0.347 to -0.287mm in resin group. This amount is larger than those reported by other authors.[3,14,36] In this experiment, fast heat-cured resin(boilable resin) was used. Some articles reported about the dimensional stability of boilable acrylic resin. Some authors[29,33] reported that boilable acrylic resin produced significantly less distortion in a denture base than the conventional acrylic resin. Others[37,38] reported opposite opinion. These differences are thought be due to the different test specimen and conditions. In experimental studies on dimensional stability of complete denture, it is difficult to standardize test condition, e.g. palatal shape, arch shape, height of residual ridge, denture thickness. These factors would have led to different results.

Results of this study are comparable to the description of Woelfel and Paffenbarger.[39] They reported the dimensional changes in complete dentures upon drying, wetting, and heating in water. The average change of the molar-to-molar and the border-to-border distances for individual dentures during the 12 to 35 months of immersion in water raged from -0.017% to +0.70%; on drying for 3weeks in a desiccator the range was -0.03% to -0.92%. Also this results confirms the report of Antonopoulós[40] which described the dimensional and occlusal changes in processing denture.

All distances of resin base denture significantly expanded and showed recovery after 1-week compared to the measured distances after polishing. 4 week immersion in water failed to compensate processing shrinkage. Theoretically, water sorption can help compensate for processing shrinkage by expanding the denture.[41] Campbell[42] concluded that water sorption reflects increased retention of dentures. Skinner and Cooper[12] and other authors[43,44] stated that water sorption by the acrylic resin denture base generally compensates for the shrinkage that occurs during processing.

Woelfel and Paffenbarger[2] on the other hand, showed that linear shrinkage is actually greater than linear expansion. Polyzois et al.[29] reported that the expansion of dentures after storage in water at room temperature for 1 week failed to compensate for the initial processing shrinkage. Anthony and Peyton[11] stated that after storage in water for 8 months, the dentures remained dimensionally stable. Mowery et al.[45] concluded that the greatest dimensional recovery occurs during the first month of storage in water and that no significant expansion occurs afterward. Pickett and Appleby[46] concluded that maximum improvement in denture base adaptation occurs after 3 days storage in water when a tinfoil substitute is used as a separator during flasking and a 160°F, 15-hour curing cycle is used. These differences are thought to be the result of different test condition, test method, and material used.

All distances of metal base denture showed no significant recovery after immersion in water for 1 week and 1 month. Significant changes occurred after 4 weeks, but these changes failed to compensate initial processing shrinkage. It is difficult to evaluate this result because there are few articles reporting tooth movement of metal base denture.

But in this experiment after immersion in water for 4 weeks, metal base denture showed significantly less distortion than resin base denture.

Clinically, tooth movement during processing, polishing, and immersion in water affect the occlusion of the complete denture. Sykora et al.[47] emphasized that with the use of anatomical posterior teeth any induced change in the cusp angle relationship of the teeth to each other due to the wax and/or acrylic resin base dimensional change will be greatly magnified. This will substantially affect the incisal pin opening and the loss of centric occlusal contacts.

All of the errors and inaccuracies should be corrected before the patient is permitted to wear the prostheses.[48] The greater the errors, the more time consumed in the correction procedure. Accurate and dimensionally stable denture base is essential.

Metal denture bases have many advantages. It has better thermal conductivity and reduced bulk, increase tissue tolerance[49] and as seen in this study, has better dimensional stability during processing and storage. If these properties are understood, clinicians could have another treatment choice for complete denture patients.

CONCLUSION

This study measured the movement of artificial teeth in maxillary denture to evaluate the dimensional stability of two denture bases: heat-cured resin base and metal base.

The results were as follows:

1. Metal base showed significantly less tooth movement than resin base after curing and decasting ($p<0.01$).
2. Metal base showed significantly less tooth movement than resin base after polishing ($p<0.01$).
3. After immersion in water for 1 and 4 weeks, metal base showed less movement than resin base. Difference was significant for anterior-posterior distances ($p<0.01$), but not significant for molar-to-molar distance ($p>0.01$).
4. 1 week and 4 weeks of immersion failed to compensate the initial processing shrinkage of metal and resin bases ($p>0.01$).

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