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A COMPARATIVE STUDY ON THE DIMENSIONAL CHANGE OF THE DIFFERENT DENTURE BASES

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Statement of problem. Acrylic resin is most commonly used for denture bases. However, acrylic resin has week points of volumetric shrinkage during polymerization that reduces denture fit. The expandability of POSS (Polyhedral Oligomeric Silsesquioxane) containing polymer could be expected to reduce the polymerization shrinkage of denture bases and would increase the adaptability of the denture to the tissue.

Purpose. The purpose of this study was to compare the dimensional stability in the conventional acrylic resin base, POSS-containing acrylic resin base, and metal bases.

Materials and methods. Thirty six maxillary edentulous casts and dentures of different base were fabricated. Tooth movement and tissue contour change of denture after processing (resin curing, deflasking, decasting and finishing without polishing) and immersion in artificial saliva at 37℃ for 1 week and 4 weeks were measured using digital measuring microscope and three-dimensional laser scanner.

Results. The results were as follows:

1. The conventional resin group showed significant ($p<0.01$) dimensional change throughout the procedure (processing and immersion in artificial saliva).
2. After processing, the metal group and POSS resin group showed lower linear and 3-dimensional change than conventional resin group ($p<0.01$).
3. There was no statistically significant linear and 3-dimensional change after immersion for 1 week and 4 weeks in metal and POSS resin group.
4. In all groups, the midline and alveolar ridge crest area presented smaller 3-dimensional change compared with vestibule and posterior palatal seal area after processing and soaking in artificial saliva for 1 week and 4 weeks ($p<0.01$).

Conclusion. In this study, a reinforced acrylic-based resin with POSS showed good dimensional stability.

Key Words

Dimensional change, Acrylic denture base resin, Metal denture base, Polyhedraloligosilsesquioxane (POSS), Tooth movement, Laser scanning

Since the late 1930's, acrylic resin (PMMA, polymethylmethacrylate) 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. In addition, it is non-toxic, easy to repair, and can be used by simple molding and processing technique.[1] However, there are several problems with this material compared with ceramics and metal. One of those is dimensional shrinkage after curing at high temperature and high pressure. For example, dimensional shrinkage occurred in the range of 6~20% after curing (in various commercialized resins) as result of polymerization contraction, thermal contraction, internal stress release, water absorption, drying, and incomplete polymerization.[2] This shrinkage results in inaccurate adaptation of the denture to the tissue, reduction in denture stability and retention and changes in the positions of the artificial teeth.[3]

In the past few years, acrylic resin monomer and polymers have also been modified to improve not only physical and mechanical properties, but also the dimensional shrinkage and working properties that facilitate laboratory techniques of denture fabrication.[4] These new laboratory techniques of denture include microwave- and visible light activated polymerization and vacuum-plus pressure adaptation during low temperature polymerization of resin system.[5] 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 %.[6] Alternative materials such as polyamides, epoxy resin, polystyrene, vinyl acrylic, rubber graft polymers, polycarbonate and nylon have been attempted but no satisfactory material is available to date.[4,7] Glass fiber, metal inserts and ultra-high molecular weight polyethylene (UHMPE) fibers have been scrutinized in many ways to

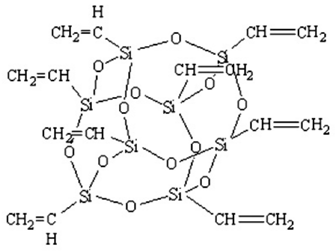

Fig. 1. The basic scheme of the POSS.

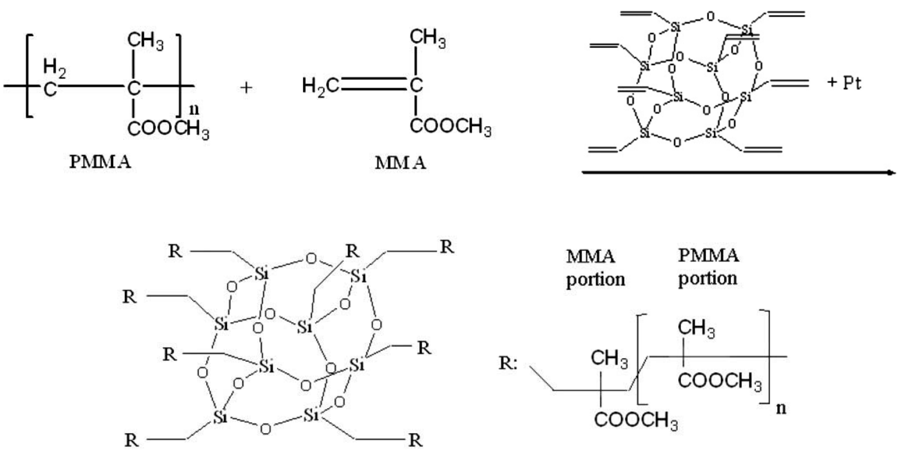

Fig. 2. The proposed chemical reactions in copolymerization of the PMMA / MMA with POSS and the structure of network obtained.

improve strength and increase the dimensional stability.[8-10] However, most of them are unacceptable to the dental technicians because of their poor processing characteristics.

While, Nam et al.[11] attempted to design and synthesized novel organic- inorganic hybrid denture materials based acrylic polymeric materials and monomeric vinyloligosilsesquoxane (Polyhedral Oligomeric Silsesquioxane, POSS). The hybrid composite obtained had all the advantage of polymeric materials. In addition it retained the superior characteristics of inorganic materials originated from silicone derivatives.[12] POSS (Fig. 1), which is one of the expandable monomers, has 8 vinyl functional groups in its own molecular structure, so in polymerization those double bonds in vinyl groups act as crosslinker to make network structure between PMMA and MMA matrices (Fig. 2).

As the results, expandability of POSS containing polymer could be expected to reduce the polymerization shrinkage of denture bases and would increase the adaptability of the denture to the tissue. While the formation of POSS-containing denture composite resin successfully resulted in improvements in the mechanical properties of the composites[13] and solved the good biocompatibility,[14] it is not clear whether the novel polymeric denture base resin is shrinkage reducible in comparison with metal denture base.

The purpose of this study was to compare the dimensional stability of the conventional acrylic resin base, prepared resin base of PMMA-POSS hybrid systems (POSS was explored as a partial substitute for MMA in the preparation of novel composites), and metal bases after processing (resin curing, deflasking, decasting and finishing without polishing) and immersion in artificial saliva at 37℃ for 1 week and 4 weeks. Three-dimensional laser scanning and digital measuring microscope were used as an evaluation method to determine and compare the dimensional change.

MATERIAL AND METHODS

1. Stone cast fabrication

A rubber mold (Fig. 3) was made of non-undercut edentulous maxillary cast (Fig. 4) using molding silicone (Shimetshu, Japan). This mold was used to prepare 36 identical stone casts. Type V dental stone (Die-Keen, Heraus Kulzer Inc, USA) was

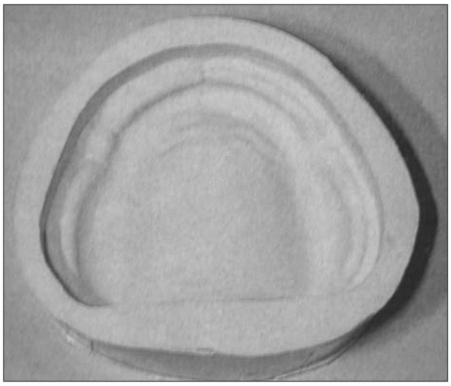

Fig. 3. Silicone mold for duplication of stone cast.

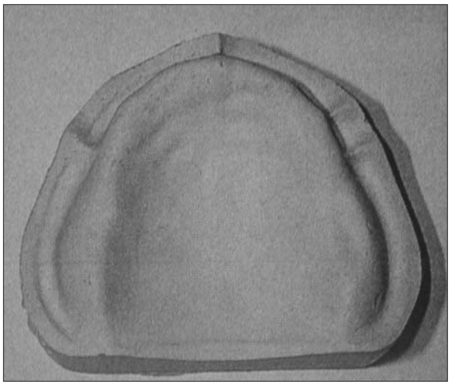

Fig. 4. The master cast stone.

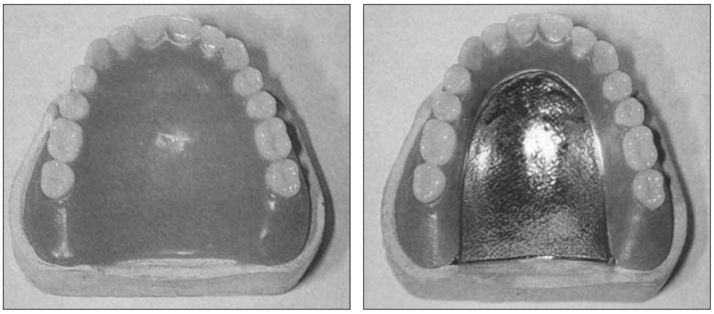

Fig. 5. Wax-up for resin base and metal base.

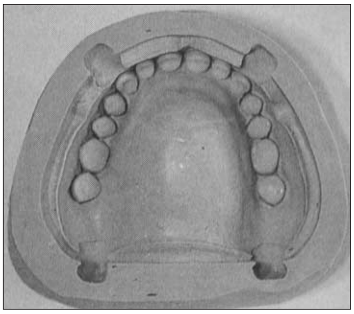

Fig. 6. Silicone mold for duplication of wax denture.

measured and mixed with the recommended amount of water (W/P ratio=21 ㎖ / 100 g) using automatic mixer (MixQueen, Oscotec, Korea).

2. Denture fabrication

A maxillary complete denture (Fig. 5) with palatal thickness of 2 ㎜ was waxed up with acrylic resin denture teeth (Trubyte Bioform 264 and 32M, Dentsply). On 12 stone casts, metal base was fabricated (Ticonium Premium 100, Ticonium Co, USA). Metal bases covered all palate and were extended to residual alveolar ridge with retentive mesh. To ensure uniformity and permit comparisons, a mold from silicone rubber was made from the master denture (Fig. 6). With the same mold of teeth the denture wax-up were duplicate by melting and pouring wax into the mold that held the acrylic resin teeth and stone casts in correct relationship to each other. Thirty-six denture wax-ups (12 for conventional resin base, 12 for POSS resin base, and 12 for metal base) were identical in thickness, height, and contour because they were prepared from the same mold. Each group processed into acrylic resin denture using the polymer (Vertex RS, Dentimex Zeist, Holland) and the monomer prepared as follows.

Group 1 ; Acrylic resin base (Control, conventional monomer)-PMMA:MMA system

Group 2 ; Acrylic resin base with POSS monomer-PMMA:MMA:POSS system POSS (Aldrich Chemical, USA) of 1% wt/vol was dissolved in monomer with 5 drops of Pt (Gelset, USA) and stirred for 10 min under vacuum

Group 3 ; Metal base (conventional monomer)

A mix of resin was made using 8㎖ of the monomer and 20g of the polymer. A conventional heat curing cycle of 70℃ for 30 min and 100 ℃ for 2hr was performed with denture curing unit (Curing Unit, Teledyne Hanau, USA).

3. The methods of measurement of dimensional change

In this study, laser scanner (Surveyor, Laser design, USA) and microscope (Mitsutoyo, Japan) as the measurement tool of dimensional accuracy were used. We attempted to evaluate and compare the surface contour change and linear change between the cast and denture base.

(1) linear dimensional changes in the prepared denture base

The movement of teeth after processing of complete denture can be in any direction and may occur as a result of dimensional changes of acrylic resin.[15,16] Fine crosses were marked

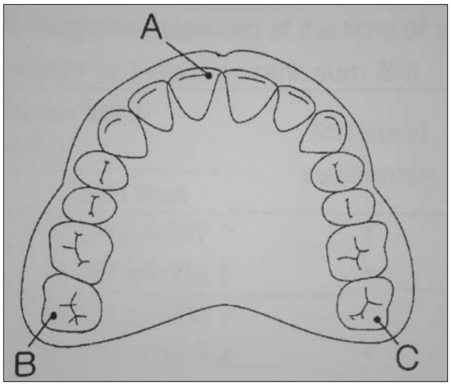

Fig. 7. Positions of reference points.

Table Ⅰ. Composition and ratio of artificial saliva (g/l)

NaCl	0.4
KCl	0.4
$CaCl_2 \cdot H_2O$	0.8
$Na_2S \cdot 5H_2O$	0.01
$CO(NH_2)_2$Urea	1.0

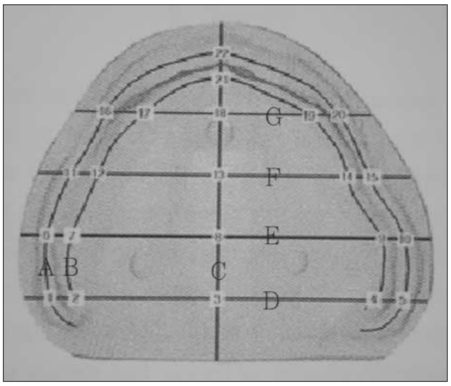

Fig. 8. Sectioning of the cast and denture on the computer screen (22 points).
Line A: middle of vestibule
Line B: alveolar ridge crest
Line C: midpalatal line
Line D: posterior palatal seal
Line E, F, G: equally sectioned line between point 22 & 3
Vestibule area: point 1,5,6,10,11,15,16,20,22
Ridge crest area: point 2,4,7,9,12,14,17,19,21
Midline area: point 3,8,13,18
PPS area: point 1,2,3,4,5

with a surgical scalpel on incisal edges of right central incisor (point A) and distobuccal cusps of both second molars (point B and C) to be used as reference points of tooth movement measurement (Fig. 7). Distances (AB and BC) on artificial teeth were measured at the wax-up stage (starting point), after processing, after the dentures had been stored in artificial saliva prepared using magnetic stirrer according to the composition suggested by Indiana University as shown in table Ⅰ - in at 37 ℃ water bath for 1 week and 4 weeks using digital measuring microscope to the nearest 0.001 ㎜. Measurements were made by the same operator and repeated 3 times to yield comparable results.

(2) three dimensional changes in the prepared denture base

Thirty-six stone casts were laser-scanned with scanning distance of 0.1㎜, accordingly scanning was repeated over 700 times for each cast. The 3-dimensional tissue surface data were processed through SURFACER 9.0 software program. After the dentures were processed, they were laser scanned within 24 hrs and the 3-dimensional tissue surface data were filed and overlapped onto those of the stone cast to evaluate the absolute average dimensional shrinkage. And then, the dentures were soaked in artificial saliva for 1week and 4weeks at room temperature, they were again laser scanned. The tissue surface data were again filed and overlapped onto those of the stone cast to compare the dimensional change.

To evaluate the local dimensional accuracy after denture processing, 7 lines were drawn on the overlapped images of the stone cast and dentures on the computer screen (Fig. 8). The distance between the cast and denture was measured at 22 points.

4. Statistical analysis

The statistical evaluation of the data was performed using the software package SPSS/PC+ Statistics™ 10.1 (SPSS Inc., Chicago, IL, USA). Data are reported as mean ± standard deviations (SD) at a significance level of $P < 0.01$. Statistics were performed by analysis of variance (ANOVA), followed by Tukey's test for a post hoc comparison.

RESULTS

1. Linear dimensional changes in the experimental group and procedure

Figure 9 shows linear dimensional changes as difference of AB and BC distances measured after the processing and immersion of wax denture. The shrinkage and expansion are presented as negative and positive values. The metal group showed slight expansion (increase of AB distance) result in comparison with wax denture step specially. Significant dimensional changes were found ($p<0.01$) among the experimental groups. The POSS resin and metal group showed significantly smaller linear dimensional changes in all 3 procedures (after processing and immersion for 1week or 4 weeks). The conventional resin group showed significant difference throughout the procedure, while the POSS resin and metal group presented no significant difference. In other words, some recovery of shrinkage after immersion in artificial saliva was observed in only conventional resin group. There was no statistical difference between immersion for 1 week and 4 weeks.

2. Three dimensional changes in the experimental group and procedure

After overlapping the data of stone cast with those of denture, 3 types of value were made.

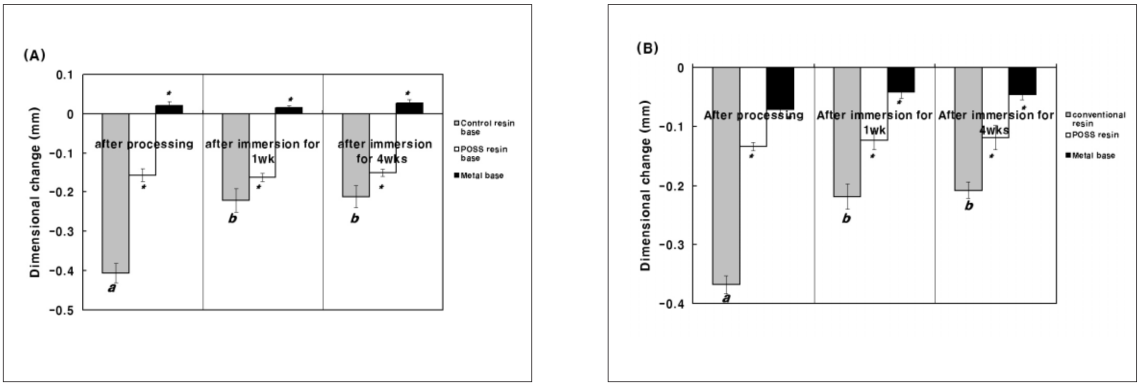

Fig. 9. Linear dimensional changes in AB distance (A) and BC distance (B) measured at the each group and procedure. Data were expressed as mean values and standard deviations (n=36). Data were analyzed by ANOVA. * denotes a significant difference from the control (conventional resin) group ($p<0.01$). The different matching letters indicates the significant difference ($p< 0.01$) between procedures (after processing and immersion) in each group based on Tukey's multiple comparison test.

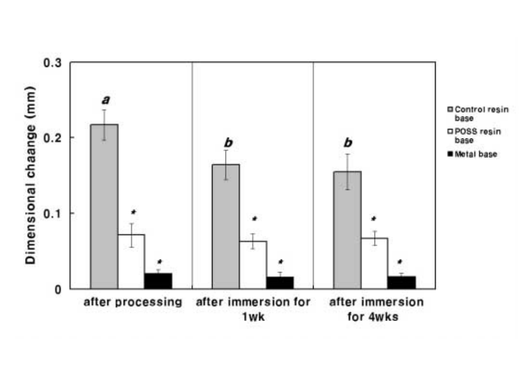

Fig. 10. The absolute mean three dimensional shrinkages after procedure were measured. Data were analyzed by ANOVA. * denotes a significant difference from the control (conventional resin) group (p<0.01). The different matching letters indicates the significant difference (p<0.01) between procedures (after processing and immersion) in each group based on Tukey' s multiple comparison test.

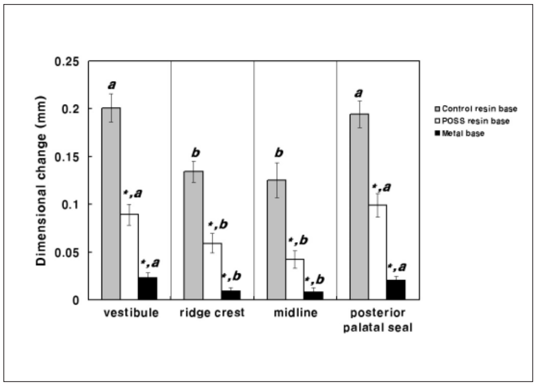

Fig. 11. The local dimensional shrinkage after denture processing was measured. Data were analyzed by ANOVA. The different matching letters indicates the significant difference (p<0.01) between denture areas in each group based on Tukey' s multiple comparison test.

The positive and negative value of the distance between the stone cast and the tissue surface of denture were caused by shrinkage, expansion and deformation. The absolute mean values were measured and used as comparison factor.

The metal group showed the lowest 3-dimensional shrinkage and POSS resin group presented significantly lower (p<0.01) 3-dimensional change than control (conventional resin) group in all procedures (Fig. 10) in the same manner with linear dimensional change. POSS group and metal group showed non-significant (p>0.01) volumetric change after immersion (Fig. 10).

After sectioning the overlapped image of a stone cast and a denture to evaluate the local dimensional shrinkage, the distances were measured 3 times at vestibular area 9 points, ridge crest area 9 points, midline area 4 points, and the posterior palatal seal area 5 points. In all groups, the midline and alveolar ridge crest area showed significantly lower dimensional change than the vestibular and posterior palatal seal area (Fig. 11).

DISCUSSION

In this study, digital microscopic measuring and 3-dimensional laser scanning were used to determine the dimensional change. Zissis et al[16] reported that 60% of articles which had been published about dimensional accuracy of denture bases during the past 30 years used microscopy, and 25 % used simple hand-held caliper instruments. These methods could not evaluate the surface contour changes between the cast and denture than simple linear contraction measurement. Recently, a 3- dimensional digitization and computer graphic system has been developed to study and reproduce anatomic surfaces. The laser scanner reads an object and obtains numerous point data. These point data are converted into surface data through the computer program and reproduction of the original object can be possible on the screen. We attempted to evaluate and compare the linear and three dimensional changes according to denture base materials. Our results showed similar trends in linear volumetric change and tissue surface contour change. In other words, 3-dimensional volumetric shrinkage reflected the linear dimensional change. Therefore, simple linear dimensional change is regarded as a comparable tool in the measurement of dimensional accuracy or stability as well as three-dimensional change.

The first unavoidable dimensional change in all acrylic resin prosthesis is shrinkage that occurs during processing and finishing. The second change, expansion, occurs when the dentures are either stored in water bath or inserted in the mouth and then absorb oral fluids.[17-19] 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 polymerization process. The resin's coefficient of linear expansion is 8.1×10^{-7}. The gypsum products which form the mold have a coefficient of linear expansion of 1/8 that of acrylic resin. This difference contributes to the dimensional change and induced strain.[20] PMMA resin monomer can shrink up to 21 %vol during the polymerization process. In this study, the amount of processing shrinkage is larger than those reported by other authors.[3,6,15] The fast heat-cured resin(boilable resin) was used in this experiment reported produce significantly less distortion in a denture base than conventional acrylic resin by some author[20,21] Others suggested opposite results. These differences are thought to be the different test specimen and conditions. In experimental studies on dimensional stability of maxillary complete denture, it is difficult to standardize test condition, for example, palatal shape, arch shape, height of residual ridge, denture thickness. These factors would have led to different results. Theoretically, water sorption can help compensate for processing shrinkage by expanding the dentures. A dimensional shrinkage of conventional resin base group showed recovery after 1week immersion but, no more compensated in 4 weeks immersion. We confirmed that the greatest dimensional recovery occurs during the first week storage in water and that no significant expansion occurs afterward. The dimensional shrinkage by processing is actually greater than dimensional expansion by water sorption. Campbell suggested that water sorption reflects increased retention of dentures.[22]

In this experiment, metal base group showed greater dimensional stability after processing and immersion. It can be assumed that all internal stress could not be released due to the reinforcing effect of metal base - the metal frame had retentive beads and was extended beyond residual ridge- and metal base group has less volume and less surface area of PMMA resin than resin denture groups. The metal base group showed increase (expansion) for distance of anterior-posterior direction (AB distance), especially. This result thought to be due to the U-shaped portion of PMMA resin. The contraction of U-shaped portion might occur to the outside direction in contrast to total resin base contract in a direction to the center.

POSS-containing acrylic resin group showed good dimensional stability (lower dimensional shrinkage) than the conventional heat cured resin after processing immersion for 1week and 4 weeks in the current study. POSS is one of non-shrinkable monomers containing a cage structure consisting of Si-O bonds. POSS can be hybridized with copolymerization of various monomers, such as stryl, acrylics, polyamides and light curing polymers.[23] It is assumed that pt catalyst act as a trigger for opening the vinyl groups in POSS, subsequently all of the 8 vinyl participated in connection reaction with the MMA vinyl groups. Finally a 3-dimensionally cross-linked network structure, which is volumetric stable, was made. As a result, it is thought be the dimensional change after processing and soaking in artificial saliva is relatively small in POSS resin group.

The adaptation of a denture base depends of many factors which include the method and the material used for its construction. It is self-evident that the more dimensionally accurate and stable a material is the more retentive and adaptive will be the denture. Therefore, the properties of the denture base material used are considerable importance in denture fabrication. Additionally, high thermal stability and anti-abrasion ability are also expectable in an anti-shrinkable POSS composite because of its network structure. It has been reported that this new resin has better properties in terms of mechanical intensity and stability against heat.[11,24,25] We hope that these results might help to develop a reinforced acrylic-based denture resin.

CONCLUSION

The movement of artificial teeth and the difference between laser scanned data of cast and denture in maxillary complete denture to evaluate the dimensional change of three denture bases: heat-cured conventional acrylic resin base, POSS-containing acrylic resin base, and metal base: were measured in this study.

The results were as follows:

1. The conventional resin group showed significant difference ($p<0.01$) throughout the procedure (after processing and immersion in artificial saliva).
2. After processing, the metal group and POSS resin group showed lower linear and 3-dimensional change than conventional resin group ($p<0.01$).
3. There was no stastistically significant linear and 3-dimensional change after immersion for 1 week and 4 weeks in metal and POSS resin group.
4. In all groups, the midline and alveolar ridge crest area presented smaller 3-dimensional change compared with vestibule and posterior palatal seal area after processing and soaking in artificial saliva for 1 week and 4 weeks ($p<0.01$).

REFERENCES

1. Winkler S. Denture base resins. Dent Clin North Am 1984;28:287-297.
2. de Gee AJ, ten Hakel EC, Davison CL. Measuring procedure for the determination of the three-dimensional shape of dentures. J Prosth Dent 1979;4:149-153.
3. Woefel JB. Processing complete dentures. Dent Clin North Am 1977,21:329-338.
4. Jagger DC, Harrison A, Jandt KD. Review -The reinforcement of dentures. J Oral Rehabil 1999;26:185-94.
5. Takamata T, Setocos JC. Resin denture bases: Review of accuracy and methods of polymerization. Int J Prosthodont 1989;2:555-562.
6. Baemmert RJ, Lang BR, BarconMT, Billy EJ. The effects of denture teeth on the dimensional accuracy of acrylic resin denture bases. Int J Prosthodont 1990;3:528-537.
7. Chow TW. A study of reinforcement of dental polymers with ultral high molecular polyethylene fibers. PhD thesis, Univ of London. 1996.
8. Vallitu PK. Effect of some properties of metal strengtheners on the fracture resistance of acrylic denture base material. J Oral Rehab 1993;20:241-248.
9. Vallitu PK, Lassila VP, LAppalainen R. Acrylic resin fiber composite. Part 1: The effect of fiber concentration on fracture resistance. J Prosthet Dent 1994;71:607-612.
10. Kaine T, Fujii K, Arikawa H, Inoue K. Flexural properties and impact strength of denture base polymer reinforced with woven glass fibers. Dent Mater 2000;16:150-8.
11. Nam KW, Chang MW, Chang BS, Han DH, Shim JS, Chang IK, Heo SJ, An JH, Chung DJ. Development of the reinforced acrylic-based hybrid denture composite resin with vinyloligosilsesquioxane(POSS). J Kor Acad Prosthodont

2000;38:782-790.
12. Schwab JJ, Lichtenhan JD. Polyhedral oligomeric silsesquioxane (POSS)-based polymers. Appl Organometal Chem 1998;12:707-713.
13. Lichtenhan JD. Polyhedral oligomeric silsesquioxanes: building blocks for silsesquioxane-based polymers and hybrid materials. Comment Inorg Chem 1995:17:115-30.
14. Kim SK. Cytotoxicity of denture base resins. PhD thesis, Seoul National Univ. 2001.
15. Philips RW. Skinners science of dental materials. 9TH ed. Philadelphia: WB saunders, 1991:177-213.
16. Zissis A, Huggett R, Harrison A. Measurement methods used for the determination of dimensional accuracy and stability of denture base material. J Den 1991;19:199-206.
17. Sykora O, Sutow EJ. Improved fit of maxillary complete dentures processed on high expansion stone casts. J Prosthet Dent 1997;77:205-208.
18. Johnson DL, Duncanson JM Jr. The plastic postpalatal denture seal / Quentessence Int 1987;18:457-462.
19. Jow J. Mechanical undercuts as a means of decreasing shrinkage un the postpalatal seal region of the maxillary denture. J Prosthet Dent 1989;62:110-115.
20. Firtell DN, Green AJ, Elahi JM. Posterior peripheral seal distortion related to processing temperature. J Prosthet Dent 1981;45:598-601.
21. Polyzois GL,Karkazis HC, Zissis AJ, Demetriou PP. Dimensional stability of dentures processed in boilable acrylic resins: A comparative study. J Prosthet Dent 1989;57:639-647.
22. Haddad TS, Lichtehan JD. Hybrid organic-inorganic thermoplastic styryl base polyhedral oligomeric sidseqioane (POSS)molecules. Macromolecules. 1996;7302-7305.
23. Campell RL. Effects of water sorption on retention of acrylic resin denture bases. J Am Dent Assoc 1956;13:269-282.
24. Gao F, Tong Y, Schricker SR, Culbertson BM. Evaluation of neat resins based on methacrylates modified with methacryl-POSS, as potential organic-inorganic hybrids for formulating dental restoratives. Polym Adv Technol 2001;12:355-60.
25. Fong H, Dickens SH, Flaim GM. Evaluation of dental restorative composites containing polyhedral oligomeric silsesquioxane methacrylate. Dent Mater 2005;21:520-9.

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