# Three dimensional deformation of dry-stored complete denture base at room temperature

**Seo-Ryeon Lim, Joon-Seok Lee***

Department of Prosthodontics, College of Dentistry, Dankook University, Cheonan, Republic of Korea

**PURPOSE.** The aim of this study was to evaluate whether there is any typical deformation pattern existing in complete denture when it was dried by using the 3D scanner and surface matching program. **MATERIALS AND METHODS.** A total of 28 denture bases were fabricated with heat curing acrylic resin (each 14 upper and lower denture bases), and 14 denture bases (each 7 upper and lower denture bases) were stored in the water bottle (water stored), and another 14 denture bases were stored in the air (dry stored). Each specimen was scanned at 1st day after deflasking, 14th day after deflasking, and 28th day after deflasking, and digitalized. Three dimensional deformation patterns were acquired by comparison of the data within storage group using surface matching program. For evaluating differences between groups, these data were compared statisticallyusing Kruskal Wallis and Mann Whitney-U test ($\alpha$=.05). **RESULTS.** When evaluating 3D deformation of denture base, obvious deformations were not found in maxillary and mandibular water storage group. However, in dry stored group, typical deformation pattern was detected as storage time passes. It occurred mostly in first two weeks. Major deformations were found in the bilateral posterior area in both maxillary and mandibular group. In maxillary dry stored group, a statistical significance was found. **CONCLUSION.** It was proved that in both upper and lower denture bases, dry storage caused more dimensional deformation than water storage with typical pattern. ***[J Adv Prosthodont 2016;8:296-303]***

**KEYWORDS:** Dimensional deformation; Denture base; 3D surface matching software; Dry storage; Denture storage method

## INTRODUCTION

Polymethyl methacrylate (PMMA) as denture base material has many advantages including adequate mechanical strength, esthetics, low toxicity, easiness of repair, and can be cured by simple procedures, therefore, PMMA has been the most commonly used for fabricating denture base since it was developed in the mid-1945.[1,2]

Corresponding author:
Joon-Seok Lee
Department of Prosthodontics, College of Dentistry, Dankook University, Cheonan, 119 Dandae-ro Dongnam-gu, Cheonan 31116, Republic of Korea
Tel. +82415501865: e-mail, joon322@dankook.ac.kr
Received January 28, 2016 / Last Revision May 24, 2016 / Accepted May 30, 2016



This study was conducted by the research fund of Dankook University in 2013.

However, PMMA resin also has some disadvantages as denture base, and one of these is dimensional change after processing was completed. Dimensional change of denture base resin can be occurred by curing shrinkage and expansion through water absorption,[3] and other former studies stated that dimensional change would be a result of polymerization shrinkage,[4,5] thermal shrinkage,[4,6] internal stress release,[6] water absorption,[7,8] and dry shrinkage.[9] The denture base after curing may have shrunk linearly as much as approximately 0.5%.[10] It could lead distortion of the denture, and although this shrinkage may be compensated with expansion by water absorption, this change would result in poor adaptation of the denture to its tissue, and decrease of denture stability and retention.[6,11]

Concerning water absorption, some studies demonstrated that the greatest dimensional changes was occurred during the first month and no remarkable changes took place after two months.[12] Due to PMMA denture base should be influenced by water absorption, some authors insisted that occlusal adjustment of denture would be delayed until PMMA has become saturated with water.[7] However, Some


pISSN 2005-7806, eISSN 2005-7814

authors researched about changes in dentures during storage in water and in service for 18 months, and concluded a posterior linear expansion of heat curing resin was less than 1.0% and the dimensional changes did not affected the fit of denture,[8] and other studies also reported that there was no significant volumetric deformation in denture when denture was being stored in water.[13]

Most of previous studies tried to measure deformation and accuracy of the denture 2-dimensionally.[14-16] Nowadays, some authors tried to investigate the dimensional stability, and it is possible to compare two objects three-dimensionally by using surface matching program and scanning device.[17]

It is well known that denture should be stored in the water in order to minimize distortion and shrinkage, when they are once removed from the mouth.[7,14] However, it was not known shrinkage was occurred in certain pattern of form when denture was kept in dry condition, nor which portion of the denture should be watched carefully, if the patient who stores his denture in the air comes and want to relieve discomfort due to his denture.

The purpose of this study was to evaluate whether there is any typical deformation pattern of complete denture that was stored in the air, and if any, to find out what typical pattern would be by using the 3D scanner and surface matching program.

## MATERIALS AND METHODS

For fabricating upper and lower denture base, maxillary and mandibular edentulous models with little undercut were selected. Additional silicone material (Honigum, DMG, Hamburg, Germany) was used for duplicating edentulous model. The silicone molds were poured with improved stone (Fujirock EP pastel yellow; GC America Inc., Alsip, IL, USA) thus total 28 master casts, including 14 maxillary and 14 mandibular models, were fabricated. After trimming the master cast, recording base with 2.0 mm thickness was made with auto-polymerizing resin (Quicky, Nissin dental product, Inc., Kyoto, Japan) on each cast. After adjusting and confirming uniform thickness, each recording base was sit onto the corresponding cast and gap between recording base and master cast was sealed with molten baseplate wax.

Processing and curing procedure was performed by conventional compression method. After waxes were washed out with boiling water, heat polymerized acrylic resin (Lucitone 199, Dentsply International Inc, York, NY, USA) was packed into the mold and polymerized for 9 hours at 72°C and maintained for 30 minutes at 100°C. Flasks were cooled down to room temperature in the water for 12 hours. After denture base was removed from the cast, any nodule or fin edge on the denture base are carefully removed with acrylic bur. Total 28 denture bases were fabricated, and 14 denture bases (7 upper and 7 lower denture bases) were stored in the water bottle (water stored), and another 14 denture bases were stored in the air (dry stored).

Acrylic resin denture bases were scanned to construct digital 3D model. 3D laser scanner (MyScan Specification, RaphaBio, Seoul, Korea), which could detect 0.02 mm difference was used for digitizing the denture base. To confirm that denture specimen was mounted on the similar position of the scan table, silicone putty index was fabricated for each denture base specimen and each denture base was mounted with it. Scanned data was saved as stereolithography (STL) file using data compatible program (MyDesign, Raphabio, Seoul, Korea). Internal surface of each specimen was scanned at 1$^{st}$ day, 14$^{th}$ day and 28$^{th}$ day after deflasking. 3D scan data of internal surface of denture base were categorized depending on the storage method (W; water storage, D; dried storage), and subdivided into T1, T2, and T3 according to duration from deflasking to scanned time; 1$^{st}$ day after deflasking, 14$^{th}$ day after deflasking, and 28$^{th}$ day after deflasking, respectively.

Three dimensional deformation patterns were acquired by overlapping the scanned data between T1 and T2, T2 and T3, and T1 and T3 of each storage group by 3D surface matching program (Geomagic Qualify; Raindrop Geomagic, Research Triangle Park, NC, USA). Before performing best-fit alignment, unnecessary portion of the imported image except internal surface was eliminated. Best-fit alignment is the arranging process via matching repeatedly the closest points of corresponding images in the virtual space on the program, and permits to measure morphologic differences in form.[17] In this study, 300,000 to 600,000 random points were used for this alignment. After best-fit alignment procedure, the images of T1 and T2, T2

**Table 1.** Classification of maxillary (M) and mandibular (N) groups in this study

| Storage method | Groups | | Overlapping between | No. of specimen |
|---|---|---|---|---|
| | Maxilla | Mandible | | |
| Water storage (W) | MWa | NWa | T1 and T2 | 7 |
| | MWb | NWb | T2 and T3 | 7 |
| | MWc | NWc | T1 and T3 | 7 |
| Dried storage (D) | MDa | NDa | T1 and T2 | 7 |
| | MDb | NDb | T2 and T3 | 7 |
| | MDc | NDc | T1 and T3 | 7 |

and T3, and T1 and T3 within each storage group (W and D) were compared, and the results of surface matching in storage group W and D were named as group Wa, group Wb and group Wc, and group Da, group Db and group Dc, respectively, in each upper and lower denture bases. As a result, 7 color-coded maps were created in each image group (Table 1). When 3D compare was conducted, the maximum and minimum nominal values were set at ± 0.05 mm and the maximum and minimum critical values were set at ± 1.0 mm. On color-coded map, positive deformation that represent internal surface of the test model (the latter) was located above that of the reference model (the former) was expressed in the red to yellow color segments and negative deformation that represent internal surface of the test model was located lower than that of the reference model was expressed in color from cyan to deep blue.

For evaluating the deformation pattern in detail, cross-sectional 2-D comparison was also performed. Cross sectional view was created in med-palatal area (sagittally) and posterior molar area (frontally).

Statistical analyses were performed by IBM SPSS (SPSS v.22, IBM Corp., Armonk, NY, USA). The median, interquartile range, the maximum and minimum values of the positive and the negative deformation were measured. For evaluating differences between groups, these data were statistically compared at 95% significance level using Kruskal-Wallis test and Mann-Whitney U test for post hoc analysis.

## RESULTS

Generally, when evaluating 3D deformation of denture base in upper denture bases major deformation pattern could not be seen in group W according to the elapse of time. However, in group D, deformation pattern was detected as storage time passes. Also, in lower denture bases, major and repeating deformation could be seen in group D.

Figure 1, 2 represent the typical case of the color-coded map of groups and shows deformation pattern of both storage groups of upper denture bases, and Figure 3, 4 represent deformation pattern of both storage groups of lower denture bases. In the water storage group, although little deformation was observed at some area of all groups, area of deformation was very small and any repeated or specific pattern was not found (Fig. 1, Fig. 3).

In the dry-stored group of upper denture bases, when compared between first 2 weeks, deformation was found in the bilateral posterior buccal flange area (yellow) which means decrease in distance between posterior flanges, and also found in posterior palatal seal area (cyan) which means negative deformation was occurred in that area. However, when compared between second 2 weeks, significant deformation pattern was reduced. Therefore, results of color-coded map of subgroup MDa and MDc showed similar pattern (Fig. 2). These findings were repeatedly confirmed with results of 2 D compare procedure.

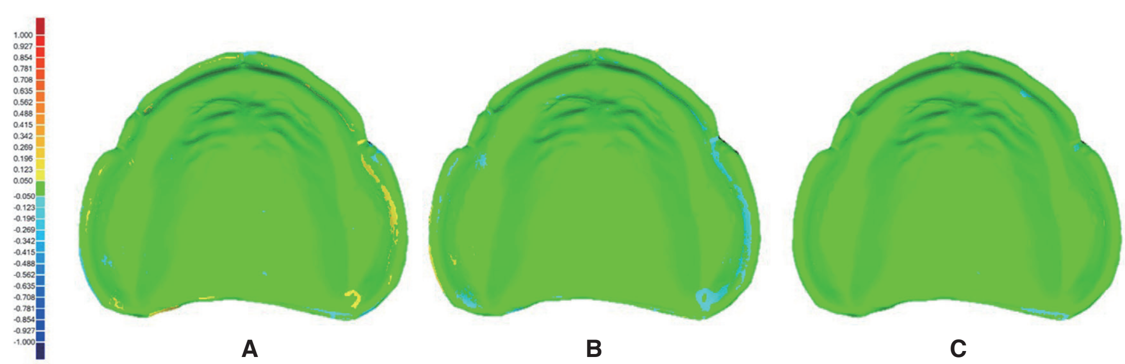


**Fig. 1.** Typical feature of color coded maps of water-stored upper denture base. (A) MWa, (B) MWb, (C) MWc.

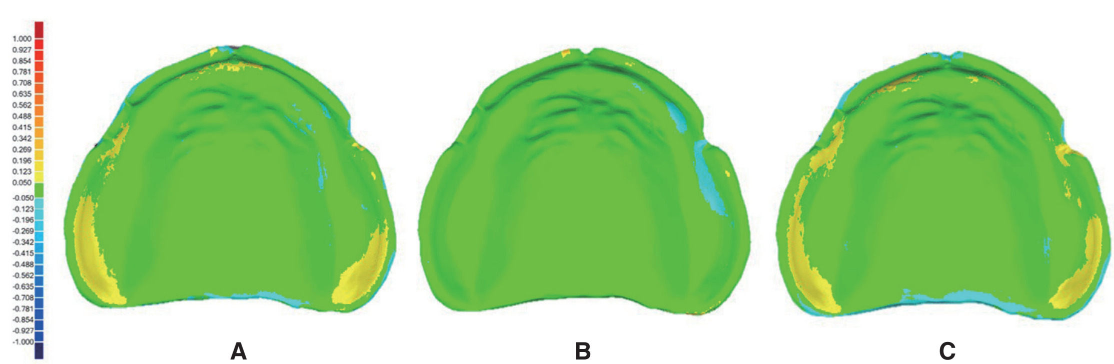


**Fig. 2.** Typical feature of color coded maps of dry-stored upper denture base. (A) MDa, (B) MDb, (C) MDc.

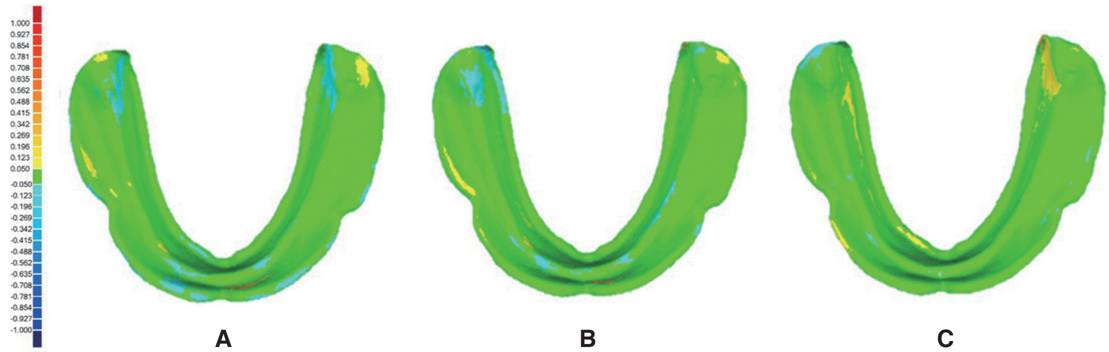


**Fig. 3.** Typical feature of color coded maps of water-stored lower denture base. (A) NWa, (B) NWb, (C) NWc.

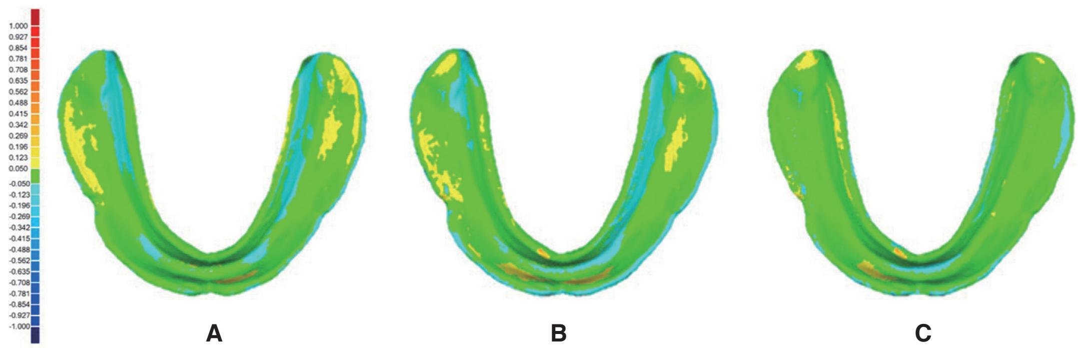


**Fig. 4.** Typical feature of color coded maps of dry-stored lower denture bases. (A) NDa, (B) NDb, (C) NDc.

In the dry-stored group of lower denture bases, more obvious deformation was observed at posterior buccal flange area (cyan) and buccal shelf and retromolar pad (yellow) than in water-stored group.

Result of Kruskal-Wallis test demonstrated that there are no significant differences in overall, positive, and negative deformation among subgroups in both maxillary and mandibular water storage group (Table 2 and Table 3).

**Table 2.** Result of Kruskal-Wallis test of deformations in maxillary group

| | | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|
| MW group | (+) deformaion | 0.495 | 2 | 0.795 |
| | (-) deformation | 0.778 | 2 | 0.678 |
| | Overall deformation | 0.518 | 2 | 0.772 |
| MD group | (+) deformaion | 8.182 | 2 | 0.017* |
| | (-) deformation | 0.653 | 2 | 0.721 |
| | Overall deformation | 7.258 | 2 | 0.027* |

* : statistically significant with 95% confident level.

**Table 3.** Result of Kruskal-Wallis test of deformations in mandibular group

| | | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|
| NW group | (+) deformaion | 0.851 | 2 | 0.654 |
| | (-) deformation | 3.517 | 2 | 0.172 |
| | Overall deformation | 3.930 | 2 | 0.140 |
| ND group | (+) deformaion | 2.835 | 2 | 0.242 |
| | (-) deformation | 4.304 | 2 | 0.116 |
| | Overall deformation | 4.342 | 2 | 0.114 |

* : statistically significant with 95% confident level.

**Table 4.** Result of Mann whitney-U test in MD group

| Compare groups | Deformation | Asymp. Sig. (2-tailed) |
|---|---|---|
| MDa and MDb | (+) deformaion | 0.025* |
| | (-) deformation | 0.654 |
| | Overall deformation | 0.012* |
| MDb and MDc | (+) deformaion | 0.009* |
| | (-) deformation | 0.609 |
| | Overall deformation | 0.034* |
| MDa and MDc | (+) deformaion | 0.749 |
| | (-) deformation | 0.406 |
| | Overall deformation | 0.797 |

* : statistically significant with 95% confident level.

In the maxillary dried storage group, there were significant different between subgroups and Mann whitney U test was performed. (Table 4) When overall deformation between subgroups was compared, significant differences were found between MDa (median: 0.040 mm) and MDb (median: 0.000 mm), and also between MDb and MDc (median: 0.040 mm). When positive deformation was only concerned, statistical results were similar with that of overall deformation (median of MDa: 0.032 mm, median of MDb: 0.017 mm, median of MDc: 0.039 mm). However, when negative deformation was compared, there are no significant differences among subgroups. In the Mandibular dried storage group, likewise, no significant difference was found in positive, negative and overall deformation among subgroups (Table 3).

The median, interquartile range, maximum and minimum values, of overall, positive, and negative deformation of denture bases for all groups were presented in Figure 5, and Figure 6.

## DISCUSSION

It is obvious that the denture fabricated with a great care would be secured to patient's comfort, retention and stability of denture depending on the intimate contact between denture base and its basal tissue. However, to wear the denture longer and maintain good oral health, minimizing unexpected distortion of the denture is also an important factor as much as fabricating denture precisely. Thus, once the denture was fabricated precisely, maintaining of its accuracy would be a key factor for the longevity of denture.

PMMA is the most popularly used denture base material, and heat curing resin has some advantage such as less deformation after fabrication and better color stability compared to self-cured resin. However, among various molding methods, no method is free from dimensional deformation due to polymerization contraction, heat contraction, stress deformation, and water absorption, and compression molding is still frequently applied to fabricating denture. Therefore, heat-cured resin and compression molding method was utilized in this study.

Upon polymerization of resin, monomers contract as much as 21 vol%, so total contraction would be estimated about 5 to 7 vol% because monomers constitute 25% of the

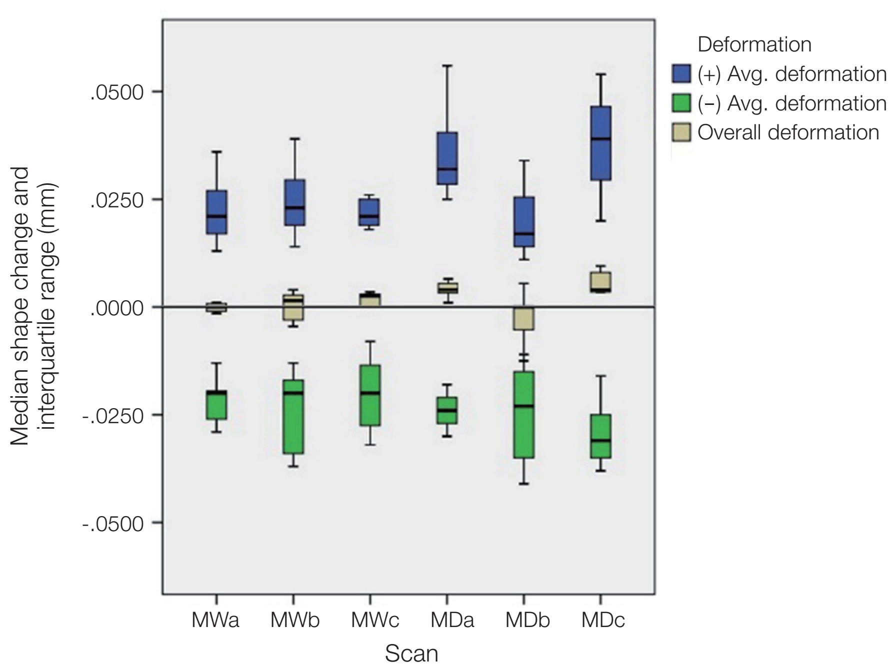


**Fig. 5.** Box and whisker plots of overall, positive, and negative deformation of maxillary group.

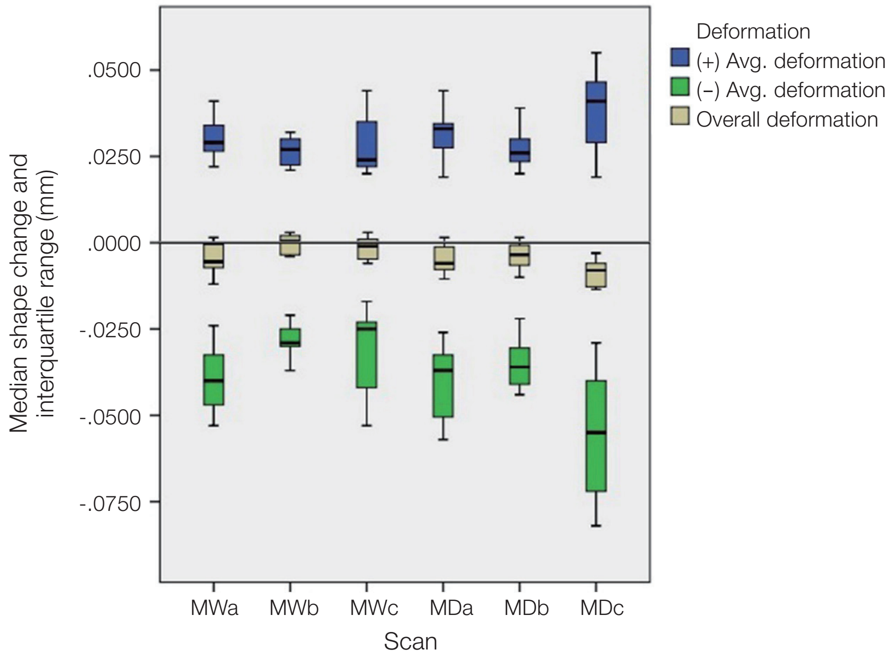


**Fig. 6.** Box and whisker plots of overall, positive, and negative deformation of mandibular group.

total volume.[4] In the previous study, regarding the influence of cooling time, more linear deformation was observed in fast cooling group compared to slow cooling group. The reported reasons were, inadequate time to compensate contraction by water absorption, and lack of emission of stress inside the denture base caused during curing.[18] Thus, this study was conducted after slowly cooling the denture bases for 24 hours in water.

Many previous studies were conducted for evaluating the deformation occurred in the denture base and its fitting accuracy. However, most of them were studied using linear or cross-sectional analysis. Majority of previous studies employed optical microscope for measuring distance between landmark points of dentures, and some of those were conducted by using simple calipers.[19,20] These methods were limited for the overall deformation because measuring the two points was merely linear analysis.

From the results and statistical analyses of this study, the fact that no significant deformation was observed during water storage resembles that of previous studies. Some previous studies reported expansion was occurred during water storage due to the water absorption. However, the meaning of contraction and expansion differs in this study. Expansion in the previous studies means increase in dimension, yet in this study, contraction was defined as the test surface being above the reference surface, and expansion was defined as being below the reference surface.

In the study concerning the water absorption of acrylic resin, it was observed that 0.42% of expansion was observed over 3 weeks, and it takes about 17 days to be completely saturated.[21] However, when water percentage was measured with digital scale and calculated with weight ratio, water percentage of 1.66 - 1.77 mass% was observed at deflasking, and water storage increased water percentage by only 0.46 - 0.50 mass%, indicating that high water percentage was already reached at deflasking.[6] In the group of upper denture bases in water storage, no significant difference according to the storage period was observed. As the result from color-coded maps of overlapping week 0, 2, and 4, no significant changes could be observed. This could suggest that after the procedure of flasking, curing, deflasking, cooling, denture bases were already saturated with water that water storage after deflasking had no big influence on dimensional deformation since movement of water molecules is ignorable.

In the group of upper denture bases in dry storage, week 0 and 2 showed significantly big difference in positive deformation ($P$ = .026) and overall deformation ($P$ = .011) compared to those of week 2 and 4, and week 0 and 4 also showed significant difference in positive deformation ($P$ = .007) and overall deformation ($P$ = .038) compared to those of week 2 and 4. This was the result of evaporation of water diffused into resin molecules, and more deformation took place during the first two weeks, indicating that most of the contraction occurred at that time. In addition, although insignificant, deformation was occurred during 4 weeks. It can be said that deformation increases by time. Upon observing deformation patterns with color-coded map, most contraction occurred at bilateral posterior buccal flange area somewhere between the week 0 - 2 and week 0 - 4, and as a result, the distance between the flanges decreased. Posterior palatal seal region tended to expand.

The reasonthat significant deformation could not be seen in lower denture bases is thought that lower denture bases have broader surface than upper denture base, therefore enough water sorption could occur until deflasking.

Deformation patterns could be observed more clearly with two-dimensional analysis. In upper denture bases, at the sagittal section of the image, no repeating deformation patterns were observed except for expansion at posterior palatal seal, but more clear and repeated bilateral contraction was seen at the frontal section. In this way, deformation of upper denture bases develops more frontally than sagittal.

Nowadays, it is possible to analyze denture bases at a virtual space using digital scanner and computer software.[16] To measure an object 3-dimensionally, contact and non-contact types are present, and basically, contact type has excellent accuracy, but is more appropriate to measure narrow area such as teeth, than to measure broad area such as denture bases. Optical laser scanner used in this study is 2-axis type with Z axis on rotating plate and Y axis at swing arm, and the scanned data was saved as STL file to digitalize. Digitalized data were analyzed by surface matching program. In other studies of analyzing discrepancies 3-dimensionally, performed surface overlap alignment after placing reference points at specific places, such as palatal portion of denture, alveolar ridge crest or cusp tip.[16,20] However, these techniques need assumption that no deformation occurs at the reference points during curing or storage, but there is no proof of it. Therefore, best-fit alignment can be utilized to minimize the errors of comparing and analyzing two denture bases, because this method uses scanned data of the whole surface.[17]

Through this study, the overall deformation and its pattern in cured upper and lower denture bases in dry and water storage was compared 3-dimensionally and analyzed in timely manner. To further evaluate the clinical effect, experiment protocol and program development is required to evaluate the adaptation of oral tissue and denture base. In addition, long-term and intensified studies are required to evaluate dimensional deformation during curing, deflasking and storage as they can be evaluated in 3-dimensional manner.

## CONCLUSION

Following conclusions were attained from this study.

During dry storage of upper denture bases, significant deformation was observed as time passed from week 0, 2, to 4. It occurred mostly in first two weeks, contraction was observed at bilateral posterior flange, and expansion at posterior palatal seal region. Although no significant differences were found in both storage of lower denture bases, obvious 3D deformation pattern were observed in dry storage denture bases, contraction at posterior buccal flange area and expansion at buccal shelf and retromolar pad. Most dimensional deformation presented within the first 2 weeks in all groups.

## ORCID

Seo-Ryeon Lim *http://orcid.org/0000-0002-5817-9299*
Joon-Seok Lee *http://orcid.org/0000-0003-2962-1380*

## REFERENCES

1. Winkler S. Denture base resins. Dent Clin North Am 1984;28:287-97.
2. Peyton FA. History of resins in dentistry. Dent Clin North Am 1975;19:211-22.
3. Skinner EW, Cooper EN. Physical properties of denture resins: part I. Curing shrinkage and water sorption. J Am Dent Assoc 1943;30:1845-52.
4. Taylor PB. Acrylic resins: Their manipulation. J Am Dent Assoc 1941;28:373-87.
5. de Gee AJ, ten Harkel EC, Davidson CL. Measuring procedure for the determination of the three-dimensional shape of dentures. J Prosthet Dent 1979;42:149-53.
6. Wong DM, Cheng LY, Chow TW, Clark RK. Effect of processing method on the dimensional accuracy and water sorption of acrylic resin dentures. J Prosthet Dent 1999;81:300-4.
7. Sweeney WT, Paffenbarger GC, Beall JR. Acrylic resins for dentures. J Am Dent Assoc 1942;29:7-33.
8. Woelfel JB, Paffenbarger GC, Sweeney WT. Changes in dentures during storage in water and in service. J Am Dent Assoc 1961;62:643-57.
9. Peyton FA, Mann WR. Acrylic and acrylic-styrene resins: Their procedures in relation to their uses as restorative materials. J Am Dent Assoc 1942;29:1852-64.
10. Yeung KC, Chow TW, Clark RK. Temperature and dimensional changes in the two-stage processing technique for complete dentures. J Dent 1995;23:245-53.
11. Darvell BW, Clark RK. The physical mechanisms of complete denture retention. Br Dent J 2000;189:248-52.
12. Mowery WE, Burns CL, Dickson G, Sweeney WT. Dimensional stability of denture base resins. J Am Dent Assoc 1958;57:345-53.
13. Consani RL, Monteiro VL, Mesquita MF, Consani S. The influence of storage on dimensional changes in maxillary acrylic denture bases and the effect on tooth displacement. Eur J Prosthodont Restor Dent 2011;19:105-10.
14. Zarb GA, Bolender CL, Carlsson GE. Boucher's prosthodontic treatment for edentulous patients. 11th ed. St. Louis; CV Mosby; 1997. p. 380.
15. Lee SH, Chang IT, Yim SH. Dimensional accuracy of denture base using laser scanner of reverse engineering technic. J Korean Acad Prosthodont 1999;37:167-84.
16. Kim MJ, Kim CW. A comparative study on the dimensional change of the different denture bases. J Korean Acad Prosthodont 2006;44:712-21.
17. Artopoulos A, Juszczyk AS, Rodriguez JM, Clark RK, Radford DR. Three-dimensional processing deformation of three denture base materials. J Prosthet Dent 2013;110:481-7.
18. Kimoto S, Kobayashi N, Kobayashi K, Kawara M. Effect of bench cooling on the dimensional accuracy of heat-cured acrylic denture base material. J Dent 2005;33:57-63.

19. Consani RL, Mesquita MF, Consani S, Correr Sobrinho L, Sousa-Neto MD. Effect of water storage on tooth displacement in maxillary complete dentures. Braz Dent J 2006;17:53-7.
20. Frejlich S, Dirckx JJ, Goodacre CJ, Swartz ML, Andres CJ. Moire topography for measuring the dimensional accuracy of resin complete denture bases. Int J Prosthodont 1989;2:272-9.
21. Ristic B, Carr L. Water sorption by denture acrylic resin and consequent changes in vertical dimension. J Prosthet Dent 1987;58:689-93.