The Fit Consideration of the Denture Manufactured by 3D Printing and Sintering

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***Abstract*—In previous study, the shrinkage rate of denture was investigated, and the denture was fixed on the standard mold successfully. However, the shrinkage at the bottom of denture is most important to fit the tooth properly. If the fitness isn't close enough, the bacterial will get into aperture easily to make the teeth being decayed again. It will make the teeth to be removed completely. In this paper, the cross section of the denture is measured and compared through the 3D printing and sintered to study the fit on the standard mold. The shrinkage rates are then obtained along different directions. The results can be applied to amplify the model of denture for the 3D printing to make the denture more close to the mold.**

***Index Terms*—3D printing, tooth, CAE analysis**

I. Introduction

The analysis and experimental processes proposed by Chang *et al*. [1] are applied to predict the shrinkage of different dentures shape. Then the model of dentures shape for 3D printing can be reverse amplified. The product manufactured by 3D printing and sintering needs to be close to the patient fitness requirement. The proposed method can avoid the complicated procedure of CNC machining and reduce dentists finishing time. Ji *et al*. [2] described a level-set method to extract tooth shape from cone beam computed tomography (CBCT) images of the head. This method improves the variation level set framework with novel energy terms which is a robust shape prior to impose a shape constraint on the contour evolution. The purpose in Ref. [3] was to develop a methodology to measure the mesiodistal angulation and the faciolingual inclination of each whole tooth by using 3-dimensional volumetric images generated from CBCT scans. In Ref. [4] and Ref. [5], a system was developed for fabricating complete dentures applying CAD/CAM technology. In the system, artificial teeth were bonded to the recesses of a milled denture base. However, the offset values needed for the recesses are not known. The purpose of the study was to evaluate the accuracy of bonded artificial teeth positions in 0.00 (control), 0.10, 0.15, 0.20, and 0.25 mm offset recess groups. After bonding artificial teeth on the milled denture base model, a CBCT scan was performed to obtain scanned data. Deviations between the master data and the scanned data were calculated. In Ref. [6], the methods of measurement of dimensional accuracy and stability of denture base materials are reviewed. Most authors utilized optical measuring apparatus, with the use of calipers being the second most popular method. In Ref. [7], the Michigan Computer-Graphics Coordinate Measurement System (MCGCMS) was used to determine the dimensional accuracy of dentures processed by three different techniques: conventional heat compression, microwave, and visible-light activation. At specific sites, the visible-light-activated technique produced significantly more flange distortion than either the conventional or microwave techniques did. Nawafleh *et al*. [8] investigated marginal adaptation of crowns and fixed dental prostheses (FDPs), and discussed the testing variables employed and their influences. In [9], the marginal and internal fit of three-unit fixed partial dentures (FDPs) that measured by using the micro-CT technique, and each FDP was seated on the original model and scanned. In Ref. [10], the contours are reproduced in graph form, and the fit accuracy of the denture for any point which has been recorded may be determined by measuring the shortest distance between the contour lines. A series of heat-cured dentures were processed under nearly identical conditions, and from their contours, a representative median contour line was drawn.

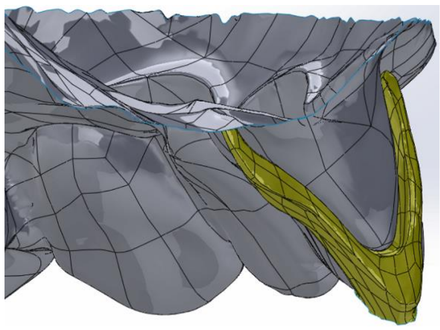

Figure 1. The denture was fit with standard mold by one side.

II. Theoretical Gap Predicated through CAE

To study the fitness of the denture, the inside profile of the denture is the most important consideration in the manufacture. However, the inside profile of whole denture is difficult to measure, so in this paper, the

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denture is printed out in a half separately. They are specimens 1 and 2. After printing and sintering, the denture and standard mold are put into 3 Shape to reverse scan, and the STL files were got and composed. At first, the theoretical denture predicated by the method proposed by the authors [1] was fit with standard mold by one side as shown in Fig. 1. The gap between the denture and standard mold can be measured. The maximum and minimum of the gaps are shown in Table I.

TABLE I. THE GAP OF SPECIMEN 1 AND 2 MEASURED IN SOLIDWORKS.

	Specimen 1 left side	Specimen 1 right side	Specimen 2 left side	Specimen 2 right side
Max gap (mm)	0.5331	0.3878	0.4836	0.5215
Min gap (mm)	0.1693	0.2385	0.0688	0.1937

Normally, the gap between the denture and standard mold can be only in 100 microns, because the gap is needed to be filled by the adhesive. The results obtained in the CAE simulation show that the gaps of dentures are over than 100 microns. It might be happened due to the inaccuracy reversed scan of the denture. In the next section, the actual denture is measured.

Figure 2. 2.5D image measurement device.

III. IMAGE MEASURED BY 2.5D OPTICAL DEVICE

In order to study the shrinkage of the denture, in this paper, the actual workpiece of half denture was put on standard mold, and measured by 2.5D image measurement device as shown in Fig. 2. In the measurement, the denture was fit one side with standard mold as shown in Fig. 3, and the gaps between the denture and standard mold were measured. The maximum and minimum gaps are shown in Table II.

After the measurement, the gaps of maximum and minimize are more than 100 microns. When the denture is put on the standard mold, the big gap will cause further damage, although the adhesive is glued. It also causes the germs to grown up easily. In the next step, the section of denture will be compared for the user to magnify the model for 3D printing.

Figure 3. The denture was fit with standard mold by one side.

TABLE II. THE GAPS OF SPECIMENS 1 AND 2 MEASURED BY 2.5D IMAGE MEASUREMENT DEVICE

	Specimen 1 left side	Specimen 1 right side	Specimen 2 left side	Specimen 2 right side
Max gap (mm)	0.44	0.2375	0.5745	0.2025
Min gap (mm)	0.0975	0.042	0.134	0.0695

IV. SECTION COMPARISONS OF SINTERED AND UN-SINTERED

Because the measured area can't be confirmed easily in 2.5 image measurement, the half denture was marked the measuring point as shown in Fig. 4. And the work pieces are measured by 2.5D image measurement and shown in Fig. 5 to Fig. 11. In reference [1], the shrinkage of dentures is assumed to be constant in all the directions. However, the results in this paper show that there is a small difference along the irregular curve comparing the thickness at the marked positions. The results shown here are helpful to understand the shrinkage rate in 3D printing and sintering. It is useful for the designer to magnify the model for 3D printing according to the shrinkage obtained in this paper.

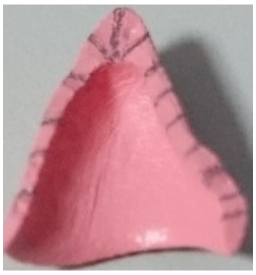

Figure 4. The measuring point of the specimen 1 was marked.

V. CONCLUSION

In previous study [1], the shrinkage rates are considered to be the same in every direction of the standard specimen. In order to make the dentures profile more closely to the mold, the section profile is investigated in this paper. From the obtained results, the shrinkage rates can be found that they are a little different in the irregular surface. The factors can thus be considered in the future research to correct the shrinkage rate in the irregular surface. The model for the 3D printing can thus be amplified according to the shrinkage rate.

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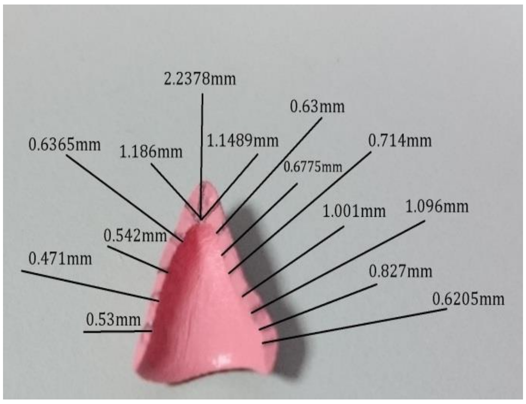

Figure 5. The thickness of specimen.

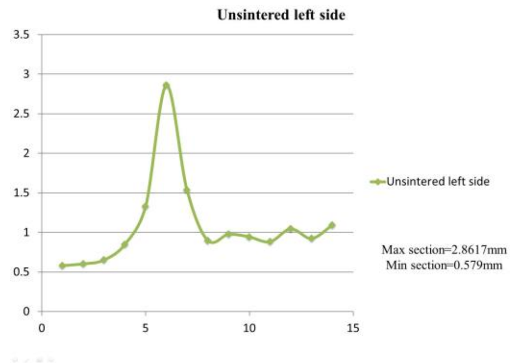

Figure 6. The measured thickness of the left side of un-sintered denture.

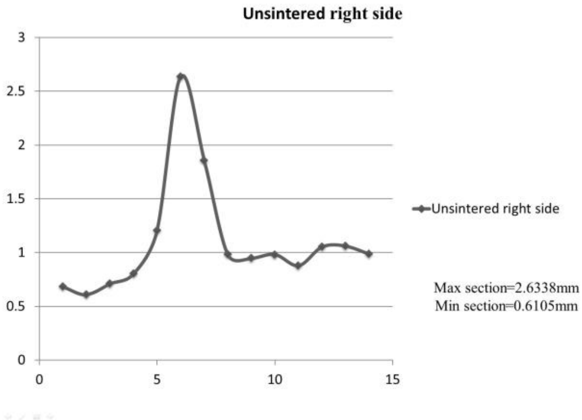

Figure 7. The measured thickness of the right side of un-sintered denture.

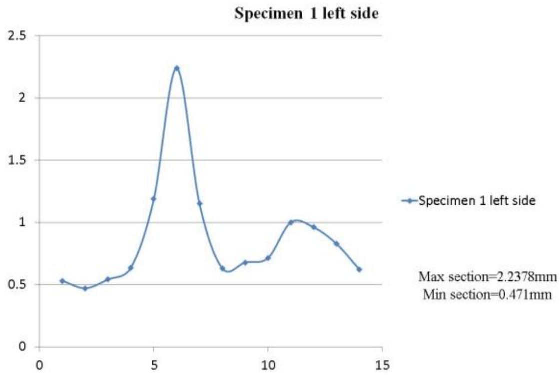

Figure 8. The measured thickness of the left side of specimen 1.

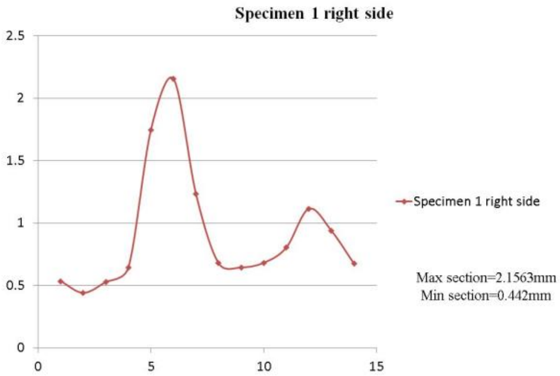

Figure 9. The measured thickness of the right side of specimen 1.

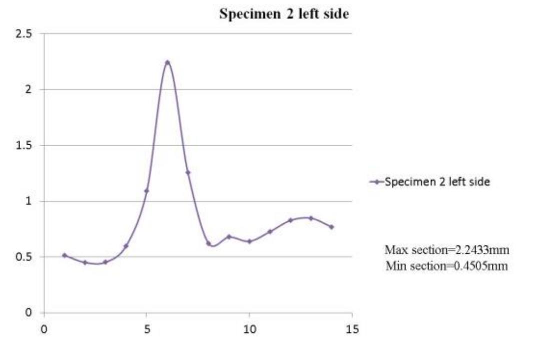

Figure 10. The measured thickness of the left side of specimen 2.

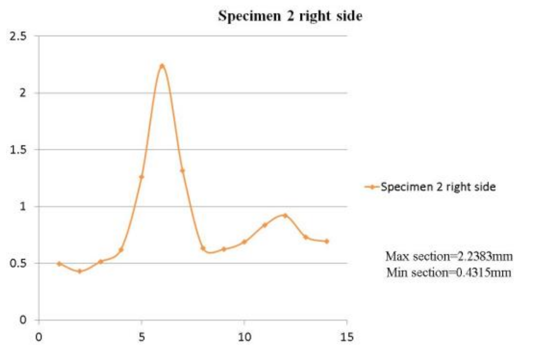

Figure 11. The measured thickness of the right side of specimen 2.

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