Effect of Complete Dentures on Facial Soft Tissue Volume: 
A 3D Comparative Study

Emilia López Hernández, DDS
Department of Prosthodontics, School of Dentistry, Medical Center - University of Freiburg, Freiburg, Germany.
Private Practice López Niñoles. Alicante, Spain.

Alberto Alvarez, MSc
Technical School of Industrial Engineering, Polytechnic University, Madrid, Spain.

Samir Abou-Ayash, Dr. med. dent.
Senior Lecturer and Head of the Section for Digital Implant- and Reconstructive Dentistry [DIREcD], Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, Switzerland.

Wael Att, DDS, Dr. med. dent, PhD.
Professor and Chair of the Department of Prosthodontics, Tufts University School of Dental Medicine, Boston, MA, USA.

Correspondence to: Emilia López Hernández
emilopezhernandez@gmail.com

Submitted April 10, 2020; accepted November 16, 2020

Purpose: To investigate the volumetric facial soft tissue changes associated with wearing complete dentures using 3D face scans. Materials and Methods: Forty volunteers, 20 men and 20 women, were recruited for the study and treated with maxillary and mandibular complete dentures. Six facial scans were taken of each subject. Three scans were wearing a complete denture, and three without them. The 3D face scans were captured with the volunteers in three mouth positions: closed, relaxed, and smiling. Each scan was superimposed in order to analyze and quantify the linear measurements of 14 soft tissue landmarks and the total volume that the subject gained with the prosthesis. Results: Three variables were evaluated in each analysis: gender, mouth attitude, and age category. In the analysis of the soft tissue
landmarks, there was a significant effect of age, with patients older than 75 years showing the greatest changes ($P < .05$). The landmarks that showed the most changes were those located around the mouth. In the volume analysis, the variable with the highest influence was gender, with men gaining more volume than women ($P < .05$). **Conclusion:** Complete dentures have a significant effect on volumetric change in perioral tissues. These changes are marked in patients older than 75 years. Compared to women, men depicted greater volumetric changes with complete dentures. These results open a new avenue for clinicians and developers using face scans to design future restorations for edentulous patients. *Int J Prosthodont 2021.* doi: 10.11607/ijp.7057

**Introduction**

Tooth loss affects the esthetics, face appearance and physiology, which leads to changes in the height of the face, reduction in alveolar ridges and a great loss of lip support. 1-5

After adolescence development, all parts of the face continue to change in adulthood. The face is decreasing in volume due to the atrophy of the soft tissue together with the loss of bone support. 2 Facial ageing is a dynamic process causing skin atrophy, with a loss of elasticity, muscle tone and volume. These changes are due to the less production of collagen and elastin, fat cells initiate to disappear, the skin loses the ability to absorb moisture, the dead skin cells do not fall off so quickly and there is a slower creation of new skin cells. 6

Over the years, different changes appear in facial hard and soft tissues: the area of the orbits increases in size, the nose grows in a downward and forward direction, the
maxilla decreases causing an accentuation of the nasolabial fold, the lips become more retrusive, thicker and longer, and it appears a protrusion of the chin.\textsuperscript{4, 5, 7, 8}

The loss of the teeth has always been a commonplace. In most of the population the cause of tooth loss is largely due to diseases such as periodontitis or caries.\textsuperscript{9, 10}

Edentulous patients show different changes in their facial morphology related to anatomic changes. The degrees and variations of the facial changes produced in an edentulous patient are influenced by the patient’s age, sex, health, race and the time of tooth loss. The appearance of an edentulous subject caused by the loss of the teeth and support structures is characterized by external evidences of collapse and the decrease of the lower third of the face. The lips and cheeks tend to perform a horizontal movement inward by the removal of the support of teeth structures. The loss of the teeth and alveolar processes produce a change in the vertical dimension, resulting in a shortening of facial length, causing an approach of the nose and chin.\textsuperscript{11}

To restore the esthetic, chewing function and phonetic, one of the conventional solutions is the complete denture, which also helps to give the patient a younger and more natural appearance. For decades, the complete dentures have been the only option to treat edentulous patients. Today, it is still considered one of the treatment option for many developing countries due to the cost, aesthetics and easy maintenance.\textsuperscript{12} One of the greatest effects that occurs in the soft tissues of an edentulous patient following tooth extractions is the loss of lip support. After treating the patient with denture construction, the morphologic changes that occur on the patient’s facial appearance are considered; the change was more noticeable in the maxillary than in the mandible, being the most appreciated one in the philtrum and lips.\textsuperscript{13, 14}
Until today, quantitative volumetric changes in the soft tissue of the face as a result of wearing complete dentures have not been reported. Previous studies have always been based on the analysis of the linear facial parameters. Nowadays, in order to enhance a good diagnosis and treatment planning for the patient, three-dimensional image (3D) has been created to provide a realistic and accurate virtual model of the patient head. The use of digital 3D photogrammetry in the clinical and research field is increasing. This technique allows, in addition, linear measurements, calculations such as angles, arcs and areas of the surface and volumes from the face. This method is composed of a series of synchronized cameras which take a few seconds when capturing the image. The cameras capture the facial image from different angles and the software reconstructs a digital 3D image, which gives the physician and patient a realistic perception of the effects of the treatment plan.

The present study was conducted in patients with at least one year of tooth loss. According to Tallgren in a 7 years longitudinal study of positional changes of complete dentures, demonstrated that a reduction of the residual alveolar ridges was most rapid during the first year of denture wear. This was in accordance with findings by other authors for various categories of denture wearers. The aim of the present study was to investigate the volumetric facial soft tissue changes associated with wearing complete dentures using 3D face scans. The null hypothesis was that complete dentures do not alter 3D volume of facial soft tissues.

(737 words)

Materials and Methods

Participants
Forty study subjects (white European Caucasians) were selected, 20 males and 20 females, aged between 50 to 80, who were treated with upper and lower complete dentures at the Freiburg University Dental Hospital in the Prosthesis Department. The volunteers were called for a follow up of the prosthesis. Provided with the informed consent of all volunteers. The study design was approved by the ethical committee (no. 509/15).

All of the patients already had the complete denture for at least one year. Whether the patients had complete denture or were edentulous before that was not possible to verify. The participants in the study had to have the dentures worn for at least one year in order to allow for proper adaptation and function.

All protheses were made in the student clinic by forty practitioners at the University of Freiburg following the traditional method. The tooth set-up and the manufacture of the dentures was carried out according to the Gerber principles, including a lingualized, and bilaterally balanced occlusion of the posterior teeth. The maxillary middle incisors were positioned to overlap the occlusal plane by 1mm, the lateral incisors were positioned 0.5mm apical of the occlusal plane, and the canines were positioned with its’ cuspids on the occlusal plane. The lower anterior teeth were positioned to result in a horizontal overjet of 2mm and vertical overbite of 1mm.

The prostheses were manufactured by various dental laboratories collaborating with the school. In short, the technique followed for the manufacture included the following clinical stages: Anatomic and functional impressions using custom-made impression trays, followed by registration of patient-relevant references using face bow and wax rims. After mounting in a semi-adjustable articulator, full tooth set-up was performed and tried in. After verification of esthetics, phonetics and function, the dentures were finalized and delivered to the patients. Ten days after delivery, all
dentures were remounted for adjustments and to improve adaptation and facilitate better comfort and function. All patients were regularly visiting the school for follow-up appointments twice a year.

The selection of study subjects was based on the inclusions and exclusions criteria:

**Inclusions**
- Edentulous patients.
- Facial harmony (no scaring or anomalies).
- At least one year of edentulous arch.
- Treated with complete dentures in both arches.

**Exclusions**
- Dentate or partially edentulous patients.
- Facial or lips anomalies.
- Edentulism less than one year.
- Patients untreated or treated with implants.

The included participants did not have any major life such as weight loss, weight gain, major surgery, etc. These points were already checked during the evaluation of the medical history.

**3D Data Acquisition**

Six face scans were taken for each patient using a non-contact 3D scan (Face Hunter, Zirkonzahn, Gais, Italy). Three of them were made with the complete denture and the other three without them. Each scan was acquired with the mouth in three different positions: closed, relaxed and smiling (Fig.1: a, b, c; Fig. 2: a, b, c). 3D facial data were exported and saved as wavefront 3D object (OBJ) files for data analysis.

**Data Analysis**
For the data analysis, each patient was scanned with and without prosthesis. These scans were superposed using the best-fit algorithm of the 3D evaluation software (Geomagic QualifyTM 2012, Moirisville, USA) in order to analyze and quantify the soft tissue total volume the patient gains with prosthesis and the lineal analysis of the soft tissue landmarks.

To evaluate the precision and accuracy, a 3D comparison between two different poses was used. For this purpose, the immobile areas of the face such as the forehead, nose and cheekbones were selected, provided that, as immobile parts, the 3D difference between the two poses should be zero. It was analyzed the statistical distribution of the 3D distances, presenting a total of N = 8,527 points. The statistical distribution for 3D differences (3D distances) showed a mean of 0.2300 mm and standard deviation of 0.3364 mm. It was obtained a precision of +/- 1.009 mm calculated as an interval of 6 sigma (+/- 3 sigma), and it showed an accuracy of +/- 0.23 mm calculated as mean of deviation (Table.1).

The maximum signal (3D distance increment) was in the range of 10 mm. With a precision of 1.09 mm it supposes a consistent ratio signal to noise of 10 (signal is 10 times higher than the noise). Any signal level below 1 mm should be considered as potential noise. The Figure 4 shows all the areas in green within the precision level (+/- 1mm), and graphically how the signal is clearly concentrated in the interest area (mouth and lips).

**Analysis of the soft tissue landmarks**

Firstly, a selection of the soft tissue landmarks for the linear analysis was carried out. Fourteen were chosen, almost all of the lower third of the face, which are the ones that have the greatest change when inserting the complete denture (Fig. 5; Table. 2).
Prior to conducting the study, it was necessary to calibrate the facial soft tissue landmarks. Three examiners were calibrated by reviewing and assessing and annotating landmarks of 20 facial scans of random patients not relevant to the study. After calibration, two examiners annotated the scan of each participant in the study independently. The annotated landmarks from each examiner were cross matched to verify for accuracy and reach an inter-examiner agreement. In case of disagreement, the third examiner was requested to annotate the landmarks and then a consensus was reached among all the examiners.

One the calibration of the anatomical facial landmarks was achieved, was carried out the linear analysis of them. For this, it was necessary to superimpose the face scans with and without complete denture for calculating the lineal distance of each of the soft tissue landmarks (Fig. 6).

**3D Volumetric Analysis**

The second part of the study consisted of the calculation of the total volume gained by the patient with the complete denture. In both facial scans (with and without prosthesis), the lower facial third was evaluated, composed by cheeks, perioral region and lips (Fig. 7). To be able to analyze each area separately, the two face scans were superimposed (Fig. 8; Fig. 9: a, b, c).

**Statistical Analysis**

The statistical analysis was performed to investigate the changes of the soft tissues landmarks and the volume gained in an edentulous patient after having been rehabilitated with a complete denture. The data were compared between gender (males and females), mouth attitude (closed, relaxed and smiling) and age category (up to 60 years, from 60 to 75 and more than 75 years).
Means and standard deviations (SD) were computed for a descriptive statistical analysis. One-way ANOVA was used to compare the differences of the group means.

All calculations were performed with the statistical software Minitab® 16.1.1. The threshold of statistical significance was set to p<0.05.

**Results**

There were defined 14 landmarks, which were identified for each patient in 3 different mouth positions (for each facial scan). For every patient were registered the closed mouth attitude (without prothesis vs with prothesis), the smiling attitude (without prothesis vs with prothesis) and relaxed attitude (without prothesis vs with prothesis), and it was measured the 3D distance between every landmark in the three registered mouth positions (without prothesis vs with prothesis). This measured distance represents the change of position of every landmark due to wearing the prothesis or not. The table 3 represents the mean and standard deviation (SD) of every landmark distribution among all the patients. The landmarks that showed most changes after inserting the complete denture were those located around the perioral region, and specially, those of the upper lip (Fig. 10).

The fourteen soft tissue landmarks were analyzed statistically according to age category, gender and mouth attitude, to see which one was the most influential factor when performing a complete denture. The only variable that showed some significant difference was the age category, being the patients older than 75 years having the greatest changes (p<0.05). The Table 4 shows the gender with their respective ages.

The statistical analysis of the 3D volumetric analysis was conducted in the same way as the soft tissue landmarks. The overall mean values of each volume (volume
gained, volume of the perioral region, volume of the left and right cheek and volume of the lips) and the standard deviation (SD), are shown in Table 5.

The data were analyzed in cubic millimeters (mm³), but for better understanding they were also calculated in cubic centimeters (cm³) (Table 6).

The overall mean values performed for each volume showed that the greatest change of volume was in volume gained (24.9 ± 12.9 cm³), which was normal because it was the whole area chosen to perform the analysis. This area covers the two cheeks, perioral region and lips. The second area where there was more change when inserting the complete denture was the perioral region (18.0 ± 9.9 cm³), then the lips area (10.5 ± 5.8 cm³) and finally the cheeks area (left 3.5 ± 2.1 cm³, right 3.9 ± 2.1 cm³).

Unlike the other analysis, the variable that showed significant differences was the gender (p<0.05), where men gained more volume than women (Table 7; Figure 11).

**Discussion**

This clinical 3D comparative study investigated the effect of complete dentures on facial soft tissue volume. The 14 soft tissue landmarks and the volume of the lower third of the face were analyzed. The results showed in the analysis of the soft tissue landmarks some statistically significant differences in the variable of age. The landmarks that increased more when introducing complete denture were labiale superius (ls), sublabiale (sl), crista philtra (cph), labiale inferius (li) and subspinale (ss), in particular all the landmarks around the perioral region. On the other hand, in the 3D volumetric analysis of the lower facial third, some statistically differences were found in the variable of gender: men gained more volume than woman when the denture was inserted.
The selection of the materials and methods used to carry out this study were the key to perform a different and novel research that has not been developed until today. In the literature, if we look for more current studies on the use of 3D scans, we will find some, although these studies did not focus on volumetric changes.\textsuperscript{27-29} Unlike 2D imaging such as cephalometry, stereophotogrammetry is a new non-invasive method that allows capturing facial soft tissue without radiation exposure. This new 3D method has the advantage of being non-invasive, thus allowing the possibility of collecting more information than the traditional method, such as volume calculation, surface areas, linear measurements, as well as the ability to archive an exact copy of the face subject.\textsuperscript{30} A study compared traditional cephalometric measurements 2D with three-dimensional (3D) photogrammetry measurements, using photographs, study models, cephalometric radiographs and facial and intraoral scan with the teeth together. It was performed on each patient using the Vectra M3 imaging system (Canfield Imaging Systems, Fairfield, NJ). It was concluded that 3D photogrammetry measurements had a positive correlation with traditional cephalometric measurements and could serve as substitutes.\textsuperscript{31} Another study that compared the 3D scanning versus 2D photography concluded that 3D scanning could be a useful and reliable tool for the realization of linear and angular measurements of the face, as well as for orthognathic surgical diagnoses and treatment plans.\textsuperscript{32} Therefore, the 3D image is a new non-invasive method, which can be used as substitute for the traditional method in the clinical and medical field according to the authors mentioned above and others like.\textsuperscript{20-22} So far, research have focused on making linear measurements in different parts of the lower facial third to assess changes between sex, age, etc., but only based in toothed patients, not in edentulous patients treated with complete dentures. This
means that by making a comparison with other investigations, the bone loss and the soft tissue decrease is greater due to the loss of all the teeth.

In this research patients older than 75 years had significant effect in the changes produced by the complete denture throughout the perioral tissue.

Over the years the skin becomes less consistent and elastic, the epidermis becomes thinner, there is a loss of subcutaneous fat and changes in facial skeleton appear.33, 34 A study in which were analyzed the longitudinal changes in the adult facial profile concluded that from 18 to 42 years there was a decrease in the thickness of the upper lip, lower lip and soft tissue pogonion, and an increase in length of the upper lip with the age.35

The facial skeleton bone mineral density (BMD) in the maxilla and mandible that was changing with age was investigated in a study, making a comparison between sex. It was demonstrated that at greater age there was a decrease in BMD affecting the maxilla more than the mandible, and there was greater decrease in bone in men than in women.8

Other study was performed on dentate patients. It was measured the maxillary angle between different ages (from youthfulness to adulthood), and showed significant bone resorption with loss of prominence of the maxilla.36 Also it was confirmed by other study that the maxilla is retruded with aging, the maxillary angle decreased by about 10° between young and old persons.37 Farkas found in 2004 that the growth process does not tend to stop after 60 years of age. It was demonstrated that from maturation period (16-20 years) to late adulthood (81-90 years) there was a decrease in skin and bony surface of the maxilla and on the contrary, in the mandible there was an increase of the skin and bony surface.38
Another factor related to age is the decrease in the thickness of the soft tissues of the face, which leads to a decrease in volume. There is a research that studies the influence of sex, age and body mass index on facial soft tissue depths with an age range of 18 to 91 years,\textsuperscript{39} in which it was concluded that with the age of 50 years the mid mandibular angle increases about 2 mm, while the upper lip zone decreases approximately between 1 and 2 mm.

Comparing our observations with the previous ones, even though our study was conducted with edentulous patients wearing complete dentures, it seems to agree with the aforementioned study. We found that the soft tissue landmarks around the mandible showed no significant differences with the age variable (p>0.05), but nevertheless it was observed in the lower lip that, at an older age, the distance between the two superimposed scanners (without and with complete denture) was greater. The same happened with the upper lip, but here there was a significant difference with the variable of age (p<0.05). With this, as there was a decrease in the area of the lips, more lip support was needed when manufacturing a complete denture.

In the 3D volumetric analysis of the lower facial third, males depicted greater volumetric changes along with complete dentures. According to the literature, the men have thicker and longer lips than women. De Greef in 2009 found that the upper lip and the lower lip zone were between 1 and 1.5 mm thicker in males than in females.\textsuperscript{39} Another difference that occurs between sex is the mandible position: in men there is an anterior rotation of the mandible, causing an increase chin prominence, while in women there is a posterior rotation of the mandible.\textsuperscript{7, 35, 40-42}

In addition, there were also studies that found differences in the residual crest resorption between genders. This finding meant the decrease in the height of the
edentulous mandible was greater in women than in men.\textsuperscript{43-45} This is because in women in postmenopausal phase the creation of estrogen hormone accelerates skeletal bone loss, causing a rapid alveolar bone resorption.\textsuperscript{46}

There are more recent studies which also agreed to the results mentioned above, but they used digitally reproduced stone models and 3D volume of the lips were analyzed.\textsuperscript{47, 48}

(1116 words)

Conclusion

Within the limits of this study, it can be concluded that complete dentures have a significant effect on volumetric change in perioral tissues. These changes are marked in patients older than 75 years. Compared to females, males depict greater volumetric changes along with complete dentures. A volumetric evaluation of the impact of the entire prosthesis would provide valuable information about the changes of the face in 3D.

The design of this study opens a new avenue for research on relationship between prosthodontics and facial soft tissues. While we understand that the comparisons performed focused on with and without dentures, we measured other variables to explore possible factors that may yield an impact on the results. In this study, we did find a clear correlation between 3D volume and gender as well as age. While we cannot generalize the results, further studies with larger sample numbers are needed to draw clear conclusions.

References


Fig. 1: 3D face scans with complete denture: mouth closed (a), relaxed (b) and smiling (c).

Fig. 2: 3D face scans without complete denture: mouth closed (a), relaxed (b) and smiling (c).
Fig. 3: The area selected for the best alignment in both scans (with and without complete denture).

Fig. 4: Precision analysis: mouth closed (a), relaxed (b) and smiling (c).

Fig. 5: The facial soft tissue landmarks analyzed in the study.
Fig. 6: Superposition of the face scans with and without complete denture (a) and the linear analysis of the soft tissue landmarks (b).

Fig. 7: The area selected for the 3D volumetric analysis.

Fig. 8: Both scans superimposed (a) and joined (b).

Fig. 9: The areas evaluated separately: perioral region (a), right and left cheeks (b) and lips (c).
Fig. 10: The area of the greatest change of the soft tissue landmarks.

Fig. 11: Increment Volume Males vs Females.