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# The assessment of lower face morphology changes in edentulous patients after prosthodontic rehabilitation, using two methods of measurement

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**Abstract**

Using two measurement methods (a three-dimensional laser scanning system and a digital caliper), this study compares the lower face morphology of complete edentulous patients, before and after prosthodontic rehabilitation with bimaxillary complete dentures. Fourteen edentulous patients were randomly selected from the Department of Prosthodontics, at the Faculty of Dental Medicine, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania. The changes that occurred in the lower third of the face after prosthodontic treatment were assessed quantitatively by measuring the vertical projection of the distances between two sets of anthropometric landmarks: Subnasale – cutaneous Pogonion (D1) and Labiale superius – Labiale inferius (D2). A two-way repeated measures ANOVA model design was carried out to test for significant interactions, main effects and differences between the two types of measuring devices and between the initial and final rehabilitation time points. The main effect of the type of measuring device showed no statistically significant differences in the measured distances ($p=0.24$ for D1 and $p=0.39$ for D2), between the initial and the final rehabilitation time points. Regarding the main effect of time, there were statistically significant differences in both the measured distances D1 and D2 ($p=0.001$), between the initial and the final rehabilitation time points. The two methods of measurement were equally reliable in the assessment of lower face morphology changes in edentulous patients after prosthodontic rehabilitation with bimaxillary complete dentures. The differences between the measurements taken before and after prosthodontic rehabilitation proved to be statistically significant.

***Keywords***: laser scanning, edentulous, facial morphology.

## Introduction

In the last decade, medical imaging evolved from two-dimensional representations to more complex three-dimensional techniques. The laser scanner can be used as a soft tissue scanner and it is part of an array of imaging devices utilized for obtaining 3D images. Images using this particular technique have been created for assessing cross-sectional growth changes [1, 2] and clinical outcomes in surgical [3–10] and non-surgical treatments [11–13] in the head and neck region, and also for establishing clinical databases for normative populations [14].

According to Farkas [15], in order to define the size and shape of human craniofacial features, several anthropometric linear and angular measurements should be included in a basic craniofacial database. Traditionally, craniofacial measurements are taken using standard anthropometric instruments such as compasses, protractors, angle finders and calipers. In order to obtain correct measurements, Farkas [15] stresses that the examiner should have good knowledge of the areas where the measuring instrument only just comes in contact with the skin surface and the areas where the tip of the instrument must be pressed to the bony surfaces. Standard instruments could generate significant errors when measuring curved surfaces, because the position of measurement varies according to the interpretation of the examiner.

D'Apuzzo & Kochi [16] describe four basic common remote measuring techniques:

- "stereo disparity, commonly known as photogrammetry: the method simulates the two human eyes and the depth is measured in automated or in manual mode;
- "shape-from" techniques: they use a monocular approach to retrieve information related to contours, shading, texture or motion, generating surface orientations in a viewer-centered coordinate system;
- direct ranging or profiling: the laser rangefinder is a common device that measures depth by sending a laser pulse towards an object and measuring the time taken by the laser beam to be reflected and returned to the beam source;

▪ structured light: an artificial light source (usually a laser) illuminates a surface with a specific pattern; the image of the patterned surface is then used to determine the depth using triangulation algorithms.

The purpose of this study was to evaluate the lower face morphology changes in edentulous patients after prosthodontic rehabilitation with upper and lower complete dentures, using a conventional method (the digital caliper) and the 3D laser scanning method.

## Patients and Methods

Fourteen edentulous patients were randomly selected for prosthodontic rehabilitation with upper and lower complete dentures. The study was conducted in the Department of Prosthodontics, at the Faculty of Dental Medicine, "Victor Babeş" University of Medicine and Pharmacy, Timişoara, Romania, in accordance with ethical principles, including the code of ethics of the *World Medical Association Declaration of Helsinki* (2002) and additional requirements. The Ethical Board of the "Victor Babeş" University of Medicine and Pharmacy, Timişoara, approved the study protocol. In addition, positive written consent was obtained from each subject who participated in the study. The prosthodontic treatment was carried out by fifth year dental students, under the supervision of one of the faculty's prosthodontists (AJ).

For each patient, we measured the distances between two sets of anthropometric landmarks, with the complete dentures both removed from and inserted in the patients' mouth: D1 – the vertical projection of the distance between the Subnasale point (Sn) and the cutaneous Pogonion point (Pog') and D2 – the vertical projection of the distance between the Labiale superius point (Ls) and the Labiale inferius point (Li). The patients were examined in natural head position, while they were focusing on a distant point at eye level. This allowed for an extracranial vertical to be used as a reference line. All recorded measurements were projections on the vertical reference line of the distances between the aforementioned anthropometric points.

The dimensions of the lower third of the face, with and without complete dentures, were first assessed by one operator (AJ), using a digital caliper, which was maintained in a parallel position relative to a vertical reference line (Figure 1).

The same dimensions were assessed in the same day by a second operator (LT), under the direct supervision of the first operator (AJ), using a three-dimensional (3D) laser scanning system – NextEngine 3D Laser Scanner (NextEngine, Inc., Santa Monica, CA, USA). The system comprises a digital imaging system, a structured laser light source and a light projection system.

In the 3D laser scanning process, the surface of the face is illuminated with red laser beams generated by an array of lasers that scan in parallel, while the patterned surface is photographed by a CCD camera mounted close to the laser beam projector (Figure 2). At least three scans from different angles are required in order to render the 3D scanned surface. The patients were asked to stand still and to maintain the head in the natural head position during the scanning process of the facial profile. The accuracy of the 3D data acquisition was set to ±0.38 mm in Wide Mode (34.3×25.6 cm).

After processing the captured 3D data with the proprietary software ScanStudio HD PRO v. 1.3.2 (NextEngine, Inc., Santa Monica, CA), we obtained 3D images reflecting the changes that occurred in the lower face morphology after prosthodontic treatment (Figure 3).

Using the same software (ScanStudio HD PRO), the generated 3D data files were then exported to Autodesk 3ds Max 2010, where all the consecutive measurements were conducted, after superimposing the 3D images obtained for each patient (without and with complete dentures) (Figure 4).

The data were entered and analyzed using IBM SPSS Statistics version 21 for Windows (SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $p<0.05$. A two-way repeated measures (within-within-subjects) ANOVA model design was carried out, after the following assumptions were verified: there were no significant outliers in any group, the studentized residuals were approximately normally distributed (Shapiro–Wilk's test) and the sphericity has not been violated (Mauchly's test of sphericity).

## Results

The participants (nine women and five men) were, on average, about 67-year-old (Table 1).

**Table 1 – *Study sample descriptive statistics by age and gender***

| Gender | Mean age [years] | SD | Min. | Max. | *N* |
|---|---|---|---|---|---|
| *Men* | 69.2 | 10.7 | 52 | 78 | 5 |
| *Women* | 66.0 | 5.7 | 56 | 76 | 9 |
| Total | 67.1 | 7.6 | 52 | 78 | 14 |

SD: Standard deviation; *N*: Number of patients in the sample.

The descriptive statistics of the changes in lower face morphology assessed using the digital caliper and the 3D laser scanner, before and after the prosthodontic rehabilitation are presented in Table 2, Figures 5 and 6.

**Table 2 – *Descriptive statistics of the measurements taken with the digital caliper and the 3D laser scanner, before and after prosthodontic rehabilitation***

| Measuring device | Rehabilitation time point | Measured distance [mm] | Mean | SD | *N* |
|---|---|---|---|---|---|
| *Digital caliper [c]* | Initial [i] | D1c_i | 48.50 | 2.53 | 14 |
| | | D2c_i | 8.97 | 0.67 | 14 |
| | Final [f] | D1c_f | 50.24 | 2.49 | 14 |
| | | D2c_f | 12.17 | 1.12 | 14 |
| *3D laser scanner [s]* | Initial [i] | D1s_i | 48.66 | 2.54 | 14 |
| | | D2s_i | 9.10 | 0.80 | 14 |
| | Final [f] | D1s_f | 50.40 | 2.48 | 14 |
| | | D2s_f | 12.19 | 1.12 | 14 |

SD: Standard deviation; *N*: Number of measurements; D1: The vertical projection of the distance between Sn and Pog'; D2: The vertical projection of the distance between Ls and Li.

The two-way repeated measures ANOVA model design showed that there was no statistically significant interaction between the type of measuring device (digital caliper and 3D laser scanner) and time (the initial and final rehabilitation time points) neither on the D1 measured distance, $F(1,13)=0.02$, $p=0.88$, partial $\eta^2=0.01$, neither on the D2 measured distance, $F(1,13)=0.67$, $p=0.43$, partial $\eta^2=0.05$.

Because there was no statistically significant interaction, we proceeded with the assessment of the main effect for the type of measuring device and the main effect for time.

The main effect of the type of measuring device showed no statistically significant differences in the measured distances (*p*=0.24 for D1 and *p*=0.39 for D2), between the initial and the final rehabilitation time points (Table 3).

**Table 3 –** ***The main effect of the type of measuring device on the measured distances (D1 and D2)***

| Measured distance [mm] | Source (sphericity assumed) | Type III sum of squares | df | Mean square | *F* | Sig. | Partial $\eta^2$ |
|---|---|---|---|---|---|---|---|
| *D1* | Measuring device | 0.26 | 1 | 0.26 | 1.55 | 0.24 | 0.11 |
| | Error (measuring device) | 2.17 | 13 | 0.17 | | | |
| *D2* | Measuring device | 0.04 | 1 | 0.04 | 0.78 | 0.39 | 0.06 |
| | Error (measuring device) | 0.58 | 13 | 0.05 | | | |

D1: The vertical projection of the distance between Sn and Pog'; D2: The vertical projection of the distance between Ls and Li.

Regarding the main effect of time, there were statistically significant differences in both the measured distances D1 and D2 (*p*=0.001), between the initial and the final rehabilitation time points (Tables 4 and 5).

The results of this study showed that using the conventional method, the digital caliper, and the more advanced method, the 3D laser scanner, produced similar results in the measured distances D1 and D2. Both methods were reliable in measuring the changes that occurred in the lower face morphology after prosthodontic rehabilitation with bimaxillary complete dentures. The differences found between the initial and the final rehabilitation time points proved to be statistically significant (*p*=0.001), however, the magnitude of the differences noted for the D1 measurements might be clinically insignificant (<2 mm).

**Table 4 –** ***The main effect of time on the measured distances (D1 and D2)***

| Measured distance [mm] | Source (sphericity assumed) | Type III sum of squares | df | Mean square | *F* | Sig. | Partial $\eta^2$ |
|---|---|---|---|---|---|---|---|
| *D1* | Time | 41.14 | 1 | 41.14 | 66.18 | 0.001 | 0.84 |
| | Error (time) | 8.08 | 13 | 0.62 | | | |
| *D2* | Time | 140.18 | 1 | 140.18 | 158.23 | 0.001 | 0.92 |
| | Error (time) | 11.52 | 13 | 0.89 | | | |

D1: The vertical projection of the distance between Sn and Pog'; D2: The vertical projection of the distance between Ls and Li.

**Table 5 –** ***Mean differences of measured distances (D1 and D2), between the initial and the final rehabilitation time points, based on estimated marginal means***

| Measured distance [mm] | Mean difference (final-initial) | Std. error | Sig.[c] | 95% confidence interval for difference[c] | |
|---|---|---|---|---|---|
| | | | | *Lower bound* | *Upper bound* |
| *D1* | 1.71* | 0.21 | 0.001 | 1.26 | 2.17 |
| *D2* | 3.16* | 0.25 | 0.001 | 2.62 | 3.71 |

*The mean difference is significant at the 0.05 level; [c]Adjustment for multiple comparisons: Bonferroni.

**Figure 1 –** ***The measurement of the distance between two anthropometric landmarks (Labiale superius and Labiale inferius) using the digital caliper.***

**Figure 2 –** ***3D facial scanning of a patient before prosthodontic rehabilitation, utilizing the 3D NextEngine Laser Scanner (NextEngine, Inc., Santa Monica, California).***

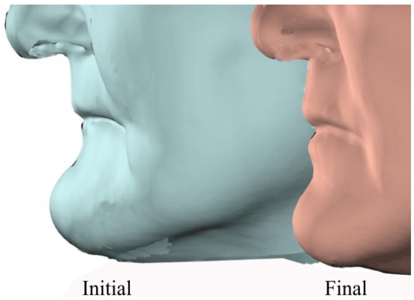


**Figure 3 –** ***The 3D generated face profile of a patient without and with complete dentures (the initial and final rehabilitation time points).***

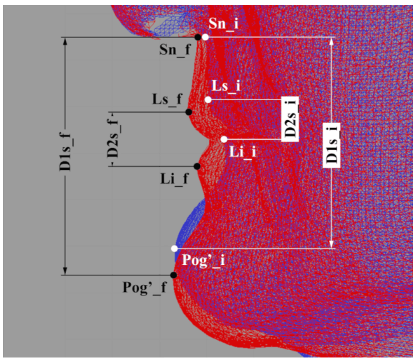


**Figure 4 –** ***The measurements conducted in Autodesk 3ds Max v.9, after superimposing the 3D images obtained for each patient, without dentures (the initial [i] time point) and with complete dentures (the final [f] time point).***

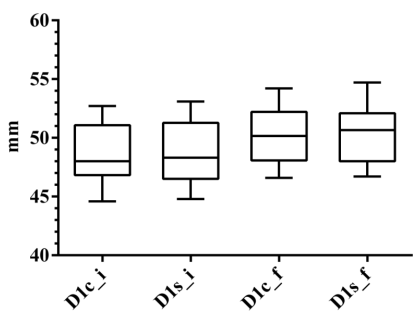


**Figure 5 –** ***Boxplots of the measurements taken with the digital caliper [c] and the 3D laser scanner [s] for D1, before [i] and after [f] prosthodontic rehabilitation.***

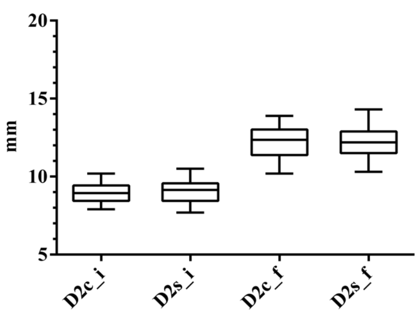


**Figure 6 –** ***Boxplots of the measurements taken with the digital caliper [c] and the 3D laser scanner [s] for D2, before [i] and after [f] prosthodontic rehabilitation.***

## Discussion

This study evaluates two methods of measurement (digital caliper and 3D laser scanner) for assessment the lower face morphology changes in edentulous patients, after prosthodontic rehabilitation with bimaxillary complete dentures.

Over the last decade, surface digitization technologies have become available for a large variety of medical applications [17].

Weinberg & Kolar [18] consider the importance of three-dimensional surface imaging in capturing reliable quantitative information from the region of the face and the head.

3D laser scanning offers several advantages over direct anthropometry: reduced invasiveness, increased data collection speed, and the possibility to create 3D databases, to document and store the facial morphology of each individual.

The reliability of measuring the three-dimensional morphology of soft tissue using a laser imaging system was evaluated by Kau *et al.* [19]. The authors demonstrated the potential of laser scanning in assessing the changes in facial morphology that occur because of facial growth, orthodontic treatment and maxillofacial surgery. In our study, we further exploited this potential, extending the use of 3D laser scanning technology in assessing the morphology of the lower face, before and after prosthodontic treatment.

Even though three-dimensional surface-based anthropometry has several advantages, it is also prone to a number of limitations and errors and should not be used without taking into account its potential strengths and weaknesses.

Gwilliam *et al.* [20] have researched the reproducebility of soft tissue landmarks on three-dimensional facial scans. It has been found that the accuracy of the soft tissue landmarks is dependent on the type of landmark, as well as on the examiner's expertise in placing it. The most reliable results had been obtained when a single examiner was included in the study and the landmarks were clearly defined and understood. In our study, all the measurements were recorded under the direct supervision of one operator (AJ).

Ayoub *et al.* [21] assessed in their study the accuracy of a three-dimensional imaging system in recording facial surface anatomy. The investigated imaging system offered several advantages over non-full field capturing techniques such as 3D laser scanning: fast image acquisition time of the face, facial landmark identification within an accuracy of 1 mm, cost-effectiveness, no harmful radiation, reliability for data storing and archiving.

Da Silveira *et al.* [22] demonstrated that three-dimensional laser surface scanning showed great potential as the technique facilitated the analysis, evaluation and documentation of treatment outcome in craniofacial anomalies.

The laser scanning technology is able to reproduce facial surfaces with high accuracy (<1 mm), in under 30 seconds. Gäbel & Kakoschke [23] reported, as a clinical requirement, that all facial measurements should have an accuracy of 0.1 mm. Other authors [4] reported that a relative accuracy of 0.5 mm is adequate for 3D data capturing, related to surgical planning. The NextEngine 3D Laser Scanner utilized in our study achieves a dimensional accuracy of ±0.12 mm in Macro Mode (12.9×9.6 cm) and ±0.38 mm in Wide Mode (34.3×25.6 cm).

In a prospective clinical study, Kau *et al.* [24] assessed the reliability of three-dimensional facial scanning regarding the measurement of facial morphology. The authors concluded that the captured data of the facial soft tissue morphology, recorded using this particular technique, was clinically consistent and could be reproduced both after three minutes and after three days from the baseline records. In our study, all the measurements, for each patient, were taken in the same day, in order to maintain the consistency and the reliability of the recorded data.

To our knowledge, no other published studies to date have compared the accuracy between the measurements taken with a digital caliper and a 3D laser scanner, while assessing the dimensions of the lower third of the face in edentulous patients, before and after prosthodontic rehabilitation.

## Conclusions

The two methods of measurement (the digital caliper and the three-dimensional laser scanner) were equally reliable in the assessment of lower face morphology changes in edentulous patients after prosthodontic rehabilitation with upper and lower complete dentures. The differences between the measurements taken before and after the prosthodontic treatment proved to be statistically significant.

**Conflict of interests**

The authors declare that they have no conflict of interests.

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