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Original article

The role of non-contact digitizer in geometrical evaluation of mandibular prostheses effect on facial asymmetry of mandibulectomy patients

Shataer Awuti[a], Yuka I. Sumita[a], Mahmoud Elbashti[b], Shajidan Kelimu[a], Amel Aswehlee[c], Mariko Hattori[a*]

[a]*Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan*
[b]*Laboratory for the Bioengineering of Tissues, INSERM U1026, University of Bordeaux, Bordeaux, France*
[c]*Department of Dental Technology, University of Tripoli, Tripoli, Libya*

Abstract

Purpose: This study sought to geometrically evaluate the effect of a mandibular prosthesis on facial asymmetry in patients with one of two different types of mandibulectomy defect.

Methods: Facial data from 20 participants (9 men and 11 women; mean age 68 years) with either a reconstructed segmental defect (segmental group, n = 10) or a marginal mandibulectomy defect (marginal group, n =10) were acquired with a non-contact three-dimensional (3D) digitizer. Facial asymmetry was evaluated by superimposing a facial scan onto its mirror scan using 3D evaluation software. Facial scans with and without the mandibular prosthesis in place were also superimposed to evaluate the effect of the mandibular prosthesis.

Results: Facial asymmetry differed significantly between subjects with and without the prosthesis in the segmental group (P = 0.005) but not in the marginal group (P = 0.16). There was no significant difference in the effect of the prosthesis on facial appearance between the two groups (P = 0.052). The ratio of 3D deviation of facial asymmetry without the prosthesis and in the mirror scan with the prosthesis differed significantly between the two groups (P = 0.01).

Conclusions: Placement of a mandibular prosthesis has a notable effect on facial asymmetry in patients with segmental mandibulectomy defects.

Keywords: *Facial asymmetry, Geometrical evaluation, 3D deviation, Mandibulectomy, Mandibular prostheses*

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1. Introduction

Patients who undergo mandibulectomy have numerous problems with oral function and esthetics due to anatomical compromise resulting from tumor resection [1-3]. One of the key functions of a prosthesis is to improve facial esthetics, which is directly linked to improvement in psychological disorders and social functioning [4]. Facial symmetry is one component of esthetics [5] that can be assessed objectively by three-dimensional (3D) evaluation of facial geometry. The objective evaluation of symmetry is considered superior to subjective evaluation because it has the advantage of repeatability and reliability, is widely accepted in the scientific community, and can be used to standardize evaluation [6]. This method has been reported in other fields of dentistry, including orthogenetic surgery [7], maxillofacial surgery [8], and orthodontics [9].

Recent advancements in digital technology have enabled changes in human soft tissue to be evaluated objectively using acquired 3D images. Digitized approaches that use 3D imaging technologies to capture facial morphologic structure are well documented in the literature [10-13]. In the field of maxillofacial prosthetics, Aswehlee et al. [14] evaluated the feasibility and accuracy of non-contact 3D digitization systems for capturing facial defects and concluded that 3D digitizers were effective for facial defects, with laser beam light-sectioning technology providing the most accurate digitization.

A number of Previous studies using 3D digitization techniques have focused on the effect of intraoral maxillofacial prosthesis placement on facial appearance and facial asymmetry in patients with maxillofacial defects. Hanawa et al. [15] used a 3D technique to examine the influence of a maxillary obturator prosthesis on facial soft tissue morphology and found that the prosthesis improved facial symmetry in individuals with unilateral maxillary defects. In a more systematic study, Aswehlee et al. [16] used a non-contact 3D digitizer to determine 3D deviation values to analyze the effects of maxillary defects and obturator prosthesis placement on facial appearance. They concluded that the effect of the prosthesis on facial appearance in maxillectomy patients depends on the size and shape of the defect.

Aswehlee et al. [6, 17] used a 3D digitizer to determine 3D deviation values and found that a mandibular prosthesis had a positive effect on recovery from facial deformity and facial asymmetry. In those studies, patients with various mandibulectomy defects were analyzed as one group. However, patients with different types of mandibular resection, such as marginal resection and segmental resection, would have different resulting effects in terms of facial asymmetry. Therefore, it is necessary to evaluate the effect of mandibular prosthesis on facial asymmetry in different patient groups. This study was designed to

* Corresponding author at: Tokyo Medical and Dental University, 1-5-45Yushima Bunkyo-ku Tokyo, Japan.
E-mail address: sasamfp@tmd.ac.jp (Mariko Hattori).

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evaluate the geometric effect of a mandibular prosthesis on facial appearance and facial symmetry in patients who had undergone marginal mandibulectomy or reconstructed segmental mandibulectomy. The null hypothesis of this study was that the mandibular prosthesis would have no effect on facial deformity or facial asymmetry in either mandibulectomy group, and that there would be no difference in the effect of the prosthesis on facial asymmetry between the two groups.

2. Materials and methods

2.1. Participants

We recruited 20 mandibulectomy patients (mean age 67.25 years) who had undergone either marginal or reconstructed segmental mandibulectomy for this study. All had undergone rehabilitation using a conventional partial denture or a conventional complete denture for the defect at our maxillofacial prosthetics clinic in a university dental hospital. All the prostheses were designed to have a heat-polymerized acrylic base with casted or wire clasp. Denture space measurements were taken to determine the position of artificial teeth and the outline of the polished surface of the prosthesis. Appearance was confirmed by the dentist and the patient at the trial and fitting stage, and adjustments were made as necessary. Participants were excluded if they had undergone total mandibulectomy, had a congenital mandibular deformity, had a facial defect, or had defects of both the maxilla and mandible.

Patients were divided into two groups based on type of surgical resection, the segmental mandibulectomy group and marginal mandibulectomy group. All patients in the segmental group underwent mandibular bone continuity reconstruction. From the medical records, intra-oral photographs and details of the clinical examination were gathered for age, sex, mandibulectomy characteristics, defect side, number of mandibular residual teeth, and prosthesis type (Tables 1 and 2).

The study protocol was approved by the ethics committee of our institution and was carried out in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to the study.

2.2. Data acquisition and evaluation

2.2.1. Face scanning and face model acquisition

Facial scans with and without the mandibular prosthesis placed were performed for all participants using a noncontact 3D digitizer (VIVID 910; Konica Sensing, Inc., Osaka, Japan). The scanner captures facial data in 2.5 s with 0.008-mm accuracy, according to the manufacturer. Three separate but overlapping scans (bilateral and frontal) in each condition were required to scan the entire face. Then the 3D images were produced and modeled with 3D scanning software (PET MFC; Konica Minolta Sensing, Inc., Ramsey, NJ) and saved as stereolithography files for data analysis. To ensure that the participants maintained the same facial expression during the facial scan with and without the prosthesis, they were instructed to relax, open their eyes, naturally close their lips, and sit motionless on the chair keeping their back straight. Their head was positioned with the Frankfurt plane parallel to the ground.

To improve the accuracy of 3D facial data entered into the facial models, all scanned data were trimmed using 3D modeling software to remove unwanted areas such as ears, shoulders, and hair (Artec 3D Studio; Artec, Palo Alto, CA). Next, the cropped data were imported into Mimics 11.11 3D modeling software (Materialise NV, Leuven, Belgium) to produce the mirrored data by reflecting the original scan along the sagittal plane for facial asymmetry evaluation (Fig. 1).

2.2.2. Three-dimensional evaluation

Facial asymmetry was quantified on each patient's 3D data with and without the mandibular prosthesis placed by superimposing the original facial scan onto its mirror scan. The original and mirror scans were aligned with respect to surface features using 3D evaluation software (GOM Inspect V8; Marubeni, Tokyo, Japan). Total differences in absolute 3D deviation of the entire face were calculated using the root mean square (RMS), which represents the approximate distance between the superimposed original scan and the mirrored scan. An RMS value of 0 indicates perfect symmetry; increasing values indicate increasing asymmetry. To compare changes in absolute 3D deviation of facial asymmetry before and after placement of a prosthesis in the two groups, we calculated the ratio of 3D deviation of facial asymmetry without the prosthesis to that with the prosthesis (3D deviation without the prosthesis / 3D deviation with the prosthesis).

Distances between the points on the superimposed scans were also color-coded for ease of visualization. The perpendicular of each polygon point on the original data to the corresponding polygon point on the mirrored data was computed and the deviation was displayed as a color plot on the original data using the software (Fig. 1). In the default legend templates of the GOM Inspect software, deviations are represented from blue to green to red. Blues at the negative end of the scale denote regions where the measured surfaces were beneath the reference surface, greens in the middle of the scale denote regions where there is no difference between the superimposed surfaces, and reds at the positive end of the scale denote regions where the measured data are above the reference surface.

2.3. Statistical analyses

All statistical analysis was performed using statistical software SPSS version 21.0 (IBM SPSS Japan, Inc., Tokyo, Japan). Normality was evaluated using histograms depicting variability. Nonparametric tests were used to analyze the data by comparing differences in absolute 3D deviation between the original facial scans and their mirror scans. The Wilcoxon signed-rank test was used to compare asymmetry between the two conditions, with and without the mandibular prosthesis in place in each group. The Mann-Whitney U test was used to compare asymmetry between segmental and marginal groups with the mandibular prosthesis placed. P-values less than 0.05 were considered statistically significant.

3. Results

The entire facial surface of each participant was successfully scanned, modeled as 3D data, and geometrically evaluated. The median of the absolute 3D deviation between the full facial scans with and without the prosthesis was 302.8 μm in the segmental group and 410.0 μm in the marginal group ($P = 0.052$; Fig. 2).

The median of the absolute 3D deviation between the original and mirrored faces was 765.0 μm with the prosthesis and 815.0 μm without it in the segmental group and 790.0 μm without the prosthesis and 915.0 μm with it in the marginal group. In the segmental group, there were significant differences in facial asymmetry between with and without the mandibular prosthesis ($P = 0.005$; Fig. 3). There were no significant differences in facial asymmetry between the original and mirrored faces with and without the prosthesis in the marginal group ($P = 0.160$; Fig. 4).

The median ratio of absolute 3D deviation of facial asymmetry without the prosthesis to that with the prosthesis was 1.06 in the segmental group and 0.96 in the marginal group. The ratio differed significantly between the two groups ($P = 0.01$; Fig. 5).

4. Discussion

The null hypothesis was rejected because the mandibular prosthesis had some effect on facial deformity or facial asymmetry in both mandibulectomy groups and the effect of mandibular prosthesis on

Table 1. Group 1: Profiles and characteristics of segmental mandibulectomy patients.

Patient	Age (years)	Sex (M/F)	Resection type	Defect side	Residual teeth (n)	Prosthesis type
1	69	M	Segmental	Left	8	Partial denture
2	59	M	Segmental	Right	7	Partial denture
3	74	M	Segmental	Left	8	Partial denture
4	51	M	Segmental	Right	4	Partial denture
5	66	F	Segmental	Left	3	Partial denture
6	75	F	Segmental	Right	Edentulous	Complete denture
7	82	F	Segmental	Right	2	Partial denture
8	74	M	Segmental	Right	9	Partial denture
9	43	F	Segmental	Right	7	Partial denture
10	76	F	Segmental	Left	5	Partial denture

M=Male; F=Female

Table 2. Group 2: Profiles and characteristics of marginal mandibulectomy patients.

Patients	Age (years)	Sex (M/F)	Resection type	Defect side	Residual teeth (n)	Prosthesis type
1	84	M	Marginal	Left	Edentulous	Complete denture
2	85	M	Marginal	Left	4	Partial denture
3	73	F	Marginal	Left	Edentulous	Complete denture
4	69	F	Marginal	Left	9	Partial denture
5	41	M	Marginal	Left	8	Partial denture
6	80	F	Marginal	Right	Edentulous	Complete denture
7	79	M	Marginal	Right	10	Partial denture
8	65	F	Marginal	Anterior	5	Partial denture
9	43	M	Marginal	Right	8	Partial denture
10	57	M	Marginal	Right	12	Partial denture

M=Male; F=Female

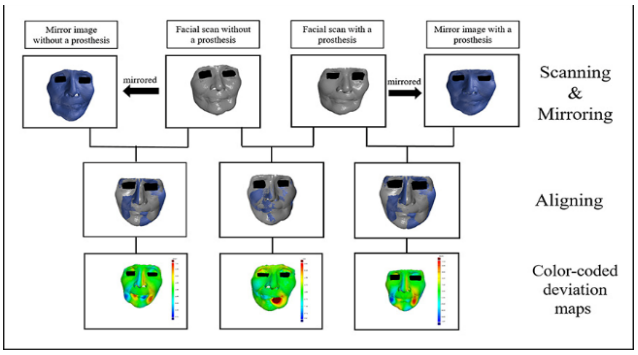

Fig. 1. Experimental procedure.

facial asymmetry differed between the two groups.

Instead of using conventional approaches, we digitized the faces in this study using a non-contact 3D digitizer to allow for facial surfaces to be captured without any direct contact with the face. This prevented any dimensional changes that may occur via direct contact with impression materials [12]. In addition, the 3D deviation method of evaluation that was used in this study enabled geometric facial asymmetry and changes in the asymmetry affected by placement of a mandibular prosthesis to be objectively evaluated. Previously, Kornreich et al. [18] compared global analysis and landmark analysis using 3D photogrammetry to establish a precise method for evaluating facial asymmetry. They found that facial asymmetry measurement was more accurate when using the RMS, and that the method was quick, reliable, and generated an RMS score and a corresponding color-coded facial map highlighting regions of higher and lower asymmetry. Zhao et al. [19] also reported the superiority of this method for 3D evaluation of facial asymmetry and deformity. Furthermore, the present method provided a higher level of accuracy for analyzing facial asymmetry than the conventional methods of evaluating direct clinical measurements [20] or two-dimensional photographs [21].

Previous studies showed that mandibular resection caused collapse of the facial surface and increased facial asymmetry [17]. The increase was caused mainly by the partial loss of mandible bone substance and surrounding structures, including the teeth that normally support the facial soft tissue. The median of the absolute 3D deviation between the original and mirrored faces in the subject groups in this study ranged from 765 μm to 915 μm and showed greater asymmetry compared with the reported range of 476.5 μm in normal subjects [16]. Our results were also comparable to the range obtained in the study with mandibulectomy patients [17]. Furthermore, we found that the median of facial asymmetry with a prosthesis was smaller than that without a prosthesis in the segmental group, and that facial asymmetry was significantly improved by the use of a mandibular prosthesis in all segmental mandibulectomy patients. This was because the prosthetic structure restores the position of the facial surface that had collapsed due to the loss of support caused by resected bone and teeth, thereby improving the facial contour and symmetry. In contrast, the marginal group showed no significant difference in the median of the absolute 3D deviation between the conditions with and without a prosthesis. This is likely because interpatient differences in defect size and depth as well as residual bone and teeth may yield different effects of the prosthesis on individual facial asymmetry. In this study, 3D deviation was used to evaluate facial asymmetry and geometric facial changes obtained with a mandibular prosthesis in mandibulectomy patients. Importantly, the obtained results provide clinicians with information about aesthetic rehabilitation, and assist them in effectively designing and adjusting prostheses.

In this study we compared the ratio of the absolute 3D deviation of facial asymmetry without a prosthesis to those with a prosthesis. The ratio is directly reflective of changes in facial symmetry as well as the direction of changes before and after wearing the mandibular prosthesis. Our results also revealed a significant difference in the effect of the mandibular prosthesis on facial asymmetry between the two groups. We believe that this difference might be caused by surgical intervention and the nature of the defects and, to some extent, by differences in residual bone and surrounding structures, as well as the

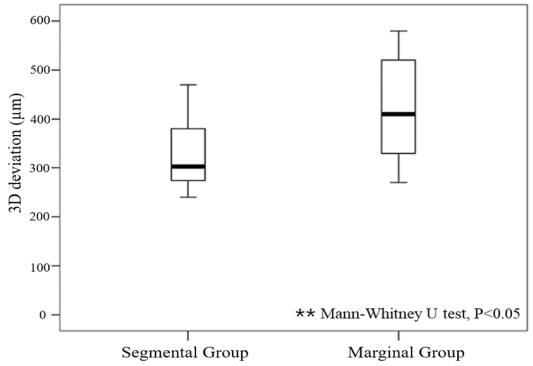

Fig. 2. Comparison of the effect of wearing a prosthesis on facial appearance between patients who underwent reconstructed segmental mandibulectomy (segmental group) and those who underwent marginal mandibulectomy (marginal group).

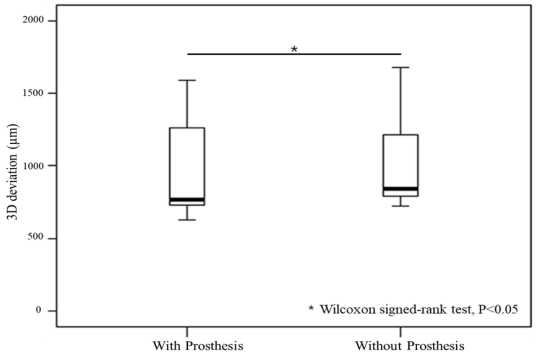

Fig. 3. Comparison of facial asymmetry between with and without a mandibular prosthesis placed in the reconstructed segmental mandibulectomy group.

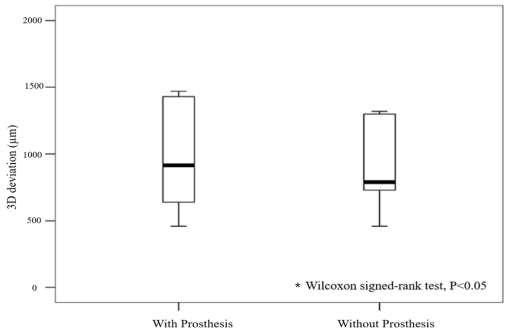

Fig. 4. Comparison of facial asymmetry between with and without a mandibular prosthesis in the marginal mandibulectomy group.

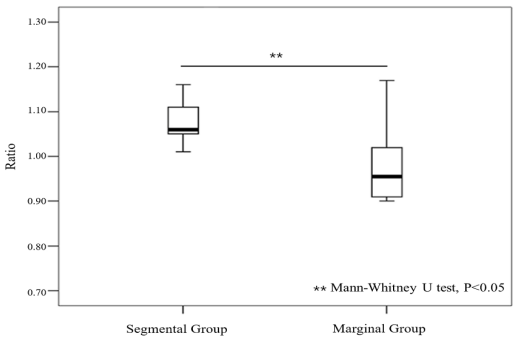

Fig. 5. Comparison of the ratio of 3D deviation without a prosthesis to with a prosthesis between the two groups.

size of the prosthesis used. Our results are comparable with the findings of previous studies [6, 17] where mandibular prostheses were found to improve facial appearance in patients with mandibulectomy defects.

As with any other clinical study in the literature, this study has some clinical limitations that cannot be ignored. Not only esthetics but also functional aspects such as mastication, swallowing, and speech must be considered in prosthesis design and in some cases, reasonable facial symmetry cannot be achieved due to limited available denture space. Other post-surgical problems, such as paresthesia from affectation of the inferior alveolar nerve that might affect the facial deformity, were not considered in this study. The influence of these factors should be discussed in a future study. The difficulty of scanning successfully for a few seconds without facial movement is also a limitation because movement of any facial muscle that affects function may also affect appearance. Future research using four-dimensional scanning may give more information on the appearance of patients with facial defects undergoing rehabilitation.

Conclusion

A non-contact 3D digitizer was used in geometric evaluation of the effect of prosthetic rehabilitation on facial asymmetry in patients with mandibulectomy defects. It was found that wearing a mandibular prosthesis has notable positive effects on facial asymmetry in segmental mandibulectomy patients.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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