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Evaluation Of Facial Soft Tissue Changes In Excessive Gingival Display Cases After Le Forte I Maxillary Impaction Surgery Using 3D Facial Surface Laser Scanner

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ABSTRACT

Introduction: Facial soft tissue changes in relation to hard tissue movements after orthognathic surgery cases is always of concern to patients , surgical and orthodontics teams. The aim of the present study was to assess facial soft tissue changes and stability using 3D facial laser scanner after orthognathic surgery Le Forte I maxillary impaction in excessive gingival display patients.

Methods: The subjects consisted of 12 patients with skeletal vertical maxillary excess (VME) causing an aesthetic concern to the patients in the form of "Gummy smile", who underwent LeFort I osteotomy with maxillary impaction, Three-dimensional images of the patients were acquired with a 3D laser scanner preoperatively and postoperatively. The changes in facial soft tissue were detected using a colour coded map for analysis.

Results: Significant change was recorded in the upper lip, alar base, nasolabial fold and nasal tip areas, without specification of this change in direction.

Conclusions: The 3D images captured using the laser scanner in this study can be a useful tool for communication with both patients and professionals but cannot be relied upon solely for accurate analysis of the facial soft tissue changes. The colour coded map analysis cannot be relied upon solely as a method of analysis as it lacks an important aspect of the change which is the direction.

1. INTRODUCTION

Maxillary movement during orthognathic surgery has a great effect on the mid facial soft tissues, these effects is the key for a successful outcome in the eyes of the patient and the surgical team. These changes were usually assessed using the conventional methods like (2D) images and cephalogram, which has its limitations,[(1)] which forced the clinicians to utilize different (3D) techniques either radiographically like CT scans [(2)], CBCT scans [(3)] or optic based like Stereophotogrammetry [(4)], structured light scanning [(5)] , and 3D laser scanning. The 3D laser scanning has the great advantages of not posing a risk from ionizing radiation, also immediately form the 3D image. Several studies have reported on the validity and high accuracy of the different laser scanning systems and the evaluated precision and reliability of data generated from the scans [,(6),(7),(8)] Colour coded map analysis, one of the most widely used type of analysis in the literature, as it gives a visual description of the face surface changes after orthognathic surgery, the entire face surface is involved in the analysis, it is presented visually which allow easier evaluation of the changes by the clinician, this allows general and local evaluation of areas of interest as well as the entire face. (9-13) The aim of the study was to Assess facial soft tissue changes and stability using 3D facial laser scanner after orthognathic surgery Le Forte I maxillary impaction in excessive gingival display patients.

2. SUBJECTS AND METHODS

Twelve patients suffering from vertical maxillary excess with excessive gingival display were recruited from outpatient clinic of Oral maxillofacial department, Faculty of Dentistry, Ain Shams University and Faculty of Oral and Dental Medicine, Future University in Egypt. Out of the 12 patients, 4 males and 8 females patients underwent a facial aesthetic evaluation, 2D photographic analysis, intraoral photographs, incisal show, gingival show, and models analysis, radiographic analysis of virtual cephalogram reconstructed from CBCT scans preoperatively (Figure 1). [(14)] All participants signed written consent form in which all treatment risks were explicitly reported before enrolling in the study. The study was conducted in accordance with the Helsinki Declaration of 2006 for medical studies, and the study has been independently reviewed from the Research Ethics Committee of Faculty of Dentistry in Ain Shams University. The study group was confined to VME skeletal deformity patients as a contributing factor to the excessive gingival display at smile complaint. [15] All patients were free from any systemic condition and of an adults group ranging from (21 – 40) years old. Patients with post traumatic dentofacial deformity, or other facial scarring, cleft lip and palate, syndromic craniofacial deformities were excluded from the study. All the patients underwent a Le Fort I Osteotomy maxillary impaction surgery where the surgical movement was ranging from 3 – 7 mm vertically, no alar cinch or V–Y closure was performed as it showed no significant difference in the effects on soft tissue change and incisal show.[16-20]

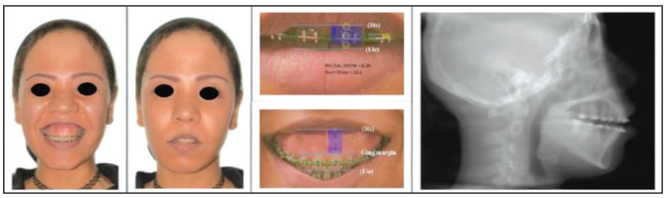

Figure (1) — Extra oral photographs captured for soft tissue analysis at rest and at maximum smile for incisal and gingival show, virtual cephalometric generation for its use at the preoperative assessment.

3D laser scanning data acquisition:

Three dimensional facial scans were acquired with a laser surface scanner of Planmeca ProMax® 1* and were recorded as the preoperative record (T0) & 6 months postoperatively (T1), The patient were scanned in a natural head position with no chin support or head straps to avoid any soft tissue distortion due to pressure,.3 dimensional models were generated by the computer as a mesh formed around a cloud of points and then the surface texture generated from the cameras is superimposed on the model surface as shown in (Figure2).Then the captured data of the 3D model was exported in (.OBJ) format for the analysis.

Figure (2) — Subject Top row pictures preoperative facial laser scan at (T0) . Bottom row pictures postoperative facial laser scan at (T1)

Data Processing: (Colour coded Distance mapping)

Cloud Compare an open source software was used to register the preoperative and postoperative scans were over each other using arbitrary points in the unchanged areas of the forehead and orbital region. (Figure 3) In addition the used software allows an automated surface fine registration based on surface topography. (Figures 4)

Cloud Compare uses an Iterative closest point algorithm (ICP) that measures the distance between the two mesh generated 3D models on each specific point on the cloud to reach the minimum distance between both of them and to be superimposed as accurate as possible. After accurate superimposition of the two generated mesh 3D models a comparison was done using a colour coded scale (in mm) to measure the distance between every point on the mesh 3D model.

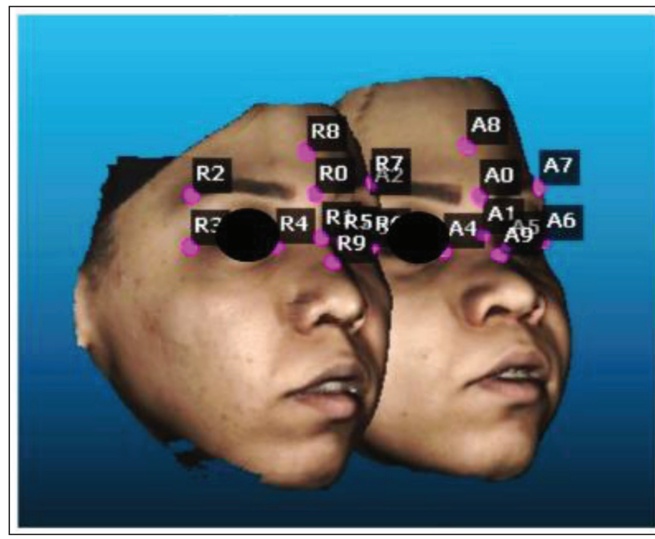

Figure (3) — Preoperative scan (T0) left, and the postoperative scan (T1) Right, registration automatically using arbitrary points.

Figure (4) — Pre-operative / post-operative facial laser scan on Cloud Compare with final fine surface registration

Soft tissue changes analysis postoperatively:

All 12 subjects had preoperative and 6 months postoperative laser surface scan of the facial tissues which were obtained according to the study protocol. All the laser facial scanned virtual models were superimposed using Cloud Compare software which is an open source software available for CAD comparison, where the comparative results were displayed as a colour coded map. All the changes were displayed in a range of colors ranging from Blue to Green and Red detailing the difference between the two superimposed models. (Figure 5) With the Green colour as the zero difference between the preoperative and postoperative models. The Green colour was evident in the nasal bridge, periorbital regions of zero difference postoperatively with no

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surgical movements allowing the confirmation of the registration of both models. While the Red, Orange and yellow colour represented the increase value in the nasal tip, alar base, nostrils, upper lip and the Blue represented the decreased value. All the readings were obtained accurately in mm using the map Different colour indices can be generated using the software as an added tool for better visualization of the changes occurred. (Figure 5).

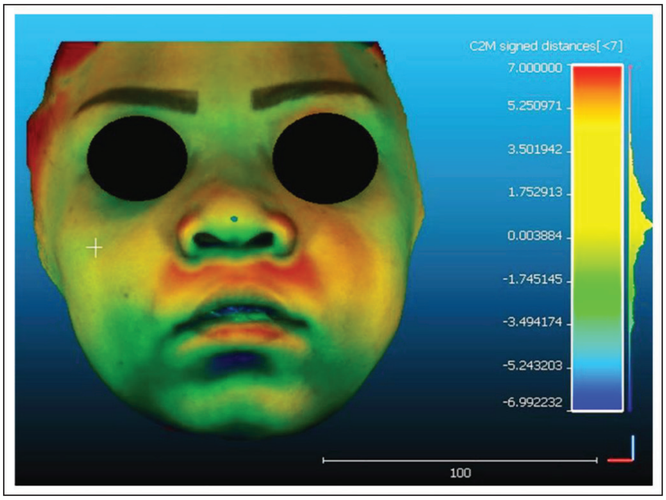

Figure (5) — The final comparison display in a colour map scale

Statistical analysis:

Recorded data were analyzed using the statistical package for social sciences, version 23.0 (SPSS Inc., Chicago, Illinois, USA). The quantitative data were presented as mean± standard deviation and ranges when their distribution was parametric (normal).

3. RESULTS

All the assessments of the detailed colour comprehensive descriptive maps for each patient's surgical change and its effect on the surrounding facial soft tissues in mm were tabulated, with a mean and standard of deviation calculated in relation to the surgical movement and presented in (Table 1).

Table 1:

Showing the values of soft tissue change in (mm) in relation to the maxillary impaction in (mm).

Maxillary impaction (mm)	Soft tissue Change (mm)				
	RightAlar Base	LeftAlar Base	Nasolabial fold	Nasal tip	Upper lip
3	1.37	1.62	1.75	0.62	1.75
7	3.5	4	2.37	-0.5	3.5
4	2.5	2.62	1.12	0.37	1.5
3	1.65	1.8	1.2	0.3	1.5
3	1.44	1.65	1.2	0.3	1.5
5	2.8	2.95	2	0.5	2.5
4	2.4	2.6	1.6	0.4	2
5	2.2	2.8	2	0.5	2.5
6	3	3.48	2.4	0.6	3
4	2.36	2.52	1.6	0.4	2
5	2	2.8	2	0.5	2.5
3	1.8	1.71	1.2	0.3	1.5
Mean (4.33)	2.2	2.5	1.7	0.3	2.1
SD (1.24)	**0.6**	**0.7**	**0.4**	**0.2**	**0.6**

The regions affected mostly to the Le Forte I Maxillary impaction were the upper lip with 49% a mean of (2 mm) SD (0.6), followed by Right alar base at 52% a mean of (2.25 mm) SD (0.7), Left alar base at 59% a mean of (2.5 mm) SD (0.7) also nasolabial fold with 39% a mean of (1.7 mm) SD (0.4) and nasal tip at 8.5% a mean of (0.35 mm) SD (0.2).

The following tests were done:

Paired sample t-test of significance was used when comparing between related readings. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as the following: Probability (P-value) P-value ≤0.05 was considered significant. P-value ≤0.001 was considered as highly significant. P-value >0.05 was considered insignificant. There was a statistically significant difference between Maxillary impaction "mm" compared to soft tissue change "mm" at "Right Alar Base, Left Alar Base, Nasolabial fold, Nasal tip and Upper lip", with p- value (p<0.001). (Table 2). (Figure 6)

Table 2:

Comparison between Maxillary impaction "mm" and soft tissue change "mm" "RT Alar Base, LFT Alar Base, Nasolabial fold, Nasal tip and Upper lip" among study group.

Range Mean±SD Paired Sample t-test

			Mean Diff.	t-test	p-value
Maxillary impaction (mm)	3-7	4.33±1.30			
Soft tissue Change (mm)					
Right Alar Base	1.37-3.5	2.25±0.65	2.08	9.183	<0.001**
Left Alar Base	1.62-4	2.55±0.75	1.79	10.567	<0.001**
Nasolabial fold	1.12-2.4	1.70±0.46	2.63	9.808	<0.001**
Nasal tip	-0.5-0.62	0.36±0.29	3.98	9.503	<0.001**
Upper lip	1.5-3.5	2.15±0.66	2.19	11.085	<0.001**

Using: Paired Sample t-test; **p-value <0.001 HS

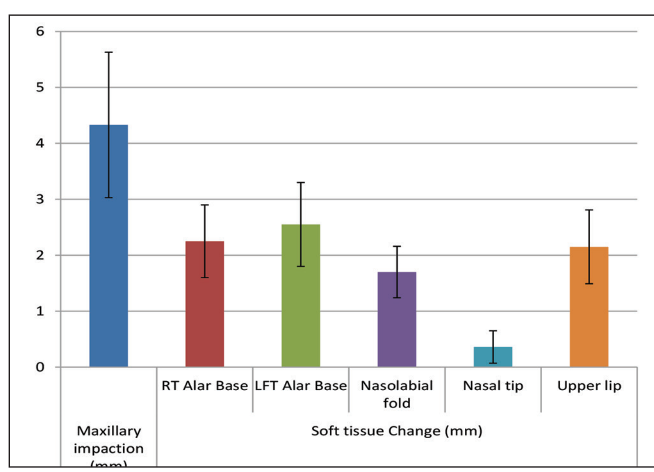

Figure (6) — Comparison between Maxillary impaction "mm" and soft tissue change "mm" "RT Alar Base, LFT Alar Base, Nasolabial fold, Nasal tip and Upper lip" among study group.

4. DISCUSSION

The current study was confined to Egyptian subjects to overcome the variables of soft tissue characters like thickness and features that may affect orthognathic surgery planning and results among different ethnic groups.

Any previous history of oral and maxillofacial surgical interventions in the subjects were excluded from the study to avoid the effect of previous facial scaring on tissue response after orthognathic surgery. To exclude any growth related changes during treatment planning and execution, the study was confined to an adult group.

The 3D soft tissue capture method that was used in this study was laser surface scanning, using Planmeca ProMax 3D®**, which facilitated the acquisition and superimposition of both bony and soft tissue scans simultaneously. The laser surface scanning was proved to be a simple and non-invasive method for 3D facial image capturing. Its validity and accuracy was demonstrated in several studies.[21,22] Some laser scanning devices reported in the literature to have some errors during acquisition and alignment of the facial scans. The margin of error in superimposition ranged from 0.13-0.18mm while the accuracy of facial morphology was within 0.85mm (Vivid 900***).[21,23]

The study in hand faced some acquisition problems for the three dimensional model some errors was shown in the form of chin cut, deformity of the mesh, blurring or closure of the eye which was contributed to the long scanning time. As it was previously reported in another study conducted on 15 patients using the Planmeca ProMax 3D®.[24]

The facial laser scanner proved to be superior to the CT scan and CBCT for imaging of the facial soft tissue as the acquired 3D model from a CT suffered from Distortion due to the effect of the gravity pull on the face while the patient is lying down on the gantry table, while the acquired 3D model from a CBCT showed distortion due to the effect of increased scattered radiation, head straps and chin support.[25] Some authors recommend capturing the CBCT scan without head straps, chin support and bite forks [26], but this might lead to lack of head stabilisation during obtaining the CBCT.

The laser scanning machine used in the current study bears some drawbacks. The long scanning time of up to 30 seconds shows some of the errors previously mentioned and has a moderate level of accuracy compared to industrial level scanners as reported by Amornvit P. & Sanohkan S. [22]

Comparing two 3D captured images within a virtual space with accurate coordinate system depends greatly on the superimposition accuracy. Surface based registration was used in this study for superimposing the 2 captured 3D images as it was reported to have equal results compared to voxel based method regarding the mean distance of the meshes.[27,28] For enhancing the accurate registration, the forehead and orbital regions w used as a stable reference. [29,27]

For the soft tissue analysis, a colour coded map was generated for the entire facial surface, where it was visually displayed, easily interpreted findings for the clinician, this method provided both general and specific surface measurements.

This method made it easier to overcome the limitation of landmarks for soft tissue analysis and made it easier for the clinician to compare the soft tissue change postoperatively in relation to the colour map, but cannot accurately determine the direction of the change in the virtual space. Other methods of analysis like landmark technique, showed some promising results but still without enough evidence of accuracy of three dimensional soft tissue analysis due to lack of standardization of the landmarks and statistical method for comparing the facial morphology.[30]

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*** Minolta, Tokyo, Japan

This study focuses on the static effect of orthognathic surgery on the soft tissue on the short term, excluding the long term stability or the dynamic changes that occurs postoperatively, as proven in the literature that a 6 months follow up doesn't demonstrate the long term stability of soft tissue changes postoperatively in relation to hard tissue movement. The comparison of the 12-month postoperative groups to the 5 year follow up show no significant differences as was shown in other studies. [31], so the long term stability can be assessed in a longer than 12 months periods.

It is worth to mention that the facial soft tissue envelope after orthognathic surgery follows the hard tissue movements with variable ratios. In the current study after only maxillary impaction several other regions of the face were affected, not only the upper lip and paranasal regions, this goes in accordance with other studies that reported the maximum soft tissue changes in maxillary orthognathic procedures to be in the nose, cheek, upper lip, lower lip and chin area. [31-33], these changes were high in the Alar base width, the upper lip (40% - 76%), nasal tip (10% -17%).

These similar results of previous studies and this study can give a general idea about the soft tissue affection by orthognathic surgery and the amount of changes seen where the greatest amount of change was in the Alar base width at a range of (52-58 %) with a ratio of (1.9-1.7:1), followed by the Upper lip (49 %) with a ratio of (2.1:1) then the nasolabial fold at (39%) with a ratio of (2.5:1) and finally at the nasal tip with only (8%) with a ratio of (12:1).

Laser scanning made acquisition and superimposition of facial soft tissue easier and better presented which allowed the simulation of soft tissue changes using different commercially available software. This raised the important issue of communication with both orthodontic and surgical teams and also allowed for better demonstration of the planned surgical results to the patient.

5. CONCLUSIONS

Laser surface scanner was a useful tool for 3D facial acquisition and superimposition with skin textured model which allowed the patient to understand the planned aesthetic results and helped the clinician to evaluate the postoperative soft tissue changes. Planmeca ProMax 3D ®****, proved to be dependable but have shown some errors regarding mesh deformation. Colour coded map analysis provides a good understanding of the three dimensional soft tissue changes secondary to bony movements but cannot be relied upon alone as it lacks evaluation of the movement direction. Le Forte I maxillary impaction surgery resulted in soft-tissue changes that were maximized in the central part of the face and included changes in other soft tissue regions like the lower lip and the chin.

6. RECOMMENDATIONS

The establishment of a multi-institute database for the Egyptian population is crucial for providing a proper base for the creation of a computational algorithms that can assist in predicting the surgical outcome for all dentofacial deformities and its treatment planning. Also developing a standardized 3D soft tissue analysis method that can produce a statistically feasible results.

Colour coded map analysis showed some potential that need to be augmented with demonstrating the direction of the soft tissue changes. Further studies are recommended to evaluate dynamic facial four-dimensional 4D surface imaging or 3D motion stereo photogrammetry through a methodological study paths as it shows a promising pathway for overcoming the limitations of static 3D imaging techniques to meet with the complex nature of the facial soft tissue changes. Other studies with similar results should be conducted on a longer term follow up that would help demonstrating and understanding the stability of the achieved results in relation to soft tissue changes.

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