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Frontal soft tissue analysis using a 3 dimensional camera following two-jaw rotational orthognathic surgery in skeletal class III patients☆

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ABSTRACT

Although two dimensional cephalometry is the standard method for analyzing the results of orthognathic surgery, it has potential limits in frontal soft tissue analysis. We have utilized a 3 dimensional camera to examine changes in soft tissue landmarks in patients with skeletal class III dentofacial deformity who underwent two-jaw rotational setback surgery.

We assessed 25 consecutive Asian patients (mean age, 22 years; range, 17–32 years) with skeletal class III dentofacial deformities who underwent two-jaw rotational surgery without maxillary advancement. Using a 3D camera, we analyzed changes in facial proportions, including vertical and horizontal dimensions, facial surface areas, nose profile, lip contour, and soft tissue cheek convexity, as well as landmarks related to facial symmetry.

The average mandibular setback was 10.7 mm (range: 5–17 mm). The average SNA changed from 77.4° to 77.8°, the average SNB from 89.2° to 81.1°, and the average occlusal plane from 8.7° to 11.4°. The mid third vertical dimension changed from 58.8 mm to 57.8 mm ($p = 0.059$), and the lower third vertical dimension changed from 70.4 mm to 68.2 mm ($p = 0.0006$). The average bigonial width decreased from 113.5 mm to 109.2 mm ($p = 0.0028$), the alar width increased from 34.7 mm to 36.1 mm (p-value $= 0.0002$), and lip length was unchanged. Mean mid and lower facial surface areas decreased significantly, from 171.8 cm^2 to 166.2 cm^2 ($p = 0.026$) and from 71.23 cm^2 to 61.9 cm^2 ($p < 0.0001$), respectively. Cheek convexity increased significantly, from 171.8° to 155.9° ($p = 0.0007$).

The 3D camera was effective in frontal soft tissue analysis for orthognathic surgery, and enabled quantitative analysis of changes in frontal soft tissue landmarks and facial proportions that were not possible with conventional 2D cephalometric analysis.

1. Introduction

Orthognathic surgery is used to correct dentofacial anomalies. The two key goals of surgery are correction of malocclusion and good postoperative facial aesthetics. Orthognathic surgery can alter facial soft tissue contours by changing skeletal tissue, and can therefore be used to create a more attractive face. However, the effect of skeletal surgery on soft tissue profiles is not easy to predict (Legan and Burstone, 1980). Although 2D cephalometry has been used for soft tissue analysis, it can only assess lateral profile, but cannot be used for anteroposterior frontal analysis, especially for facial soft tissue. Thus, 2D cephalometry emphasizes hard tissue landmarks because their reproducibility is better than for soft tissue landmarks (Enacar et al., 1999; Mommaerts and Marxer, 1987; Donatsky et al., 2009). Other methods of soft tissue analysis include anthropometry, photography, stereophotogrammetry, photocephalometry and Moire topography (Phillips et al., 1984; Tsuchiya et al., 1988; Shen and Shieh, 1995), but all of those approaches have

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major limitations such as time required, poor reproducibility or possible errors in translations (Phillips et al., 1984).

These shortcomings have caused an increase in the use of 3D imaging techniques. For example, visible volume changes of the facial soft tissue with an optical three-dimensional sensor had been tried after midface distraction or LeFort I maxillary advancement. (Soncul and Bamber, 1999; Nkenke et al., 2003; Nkenke et al., 2008). In addition, 3D CT with volume rendering has been used for soft tissue analysis following orthognathic surgery (Cavalcanti et al., 2002; Cavalcanti et al., 2004; Rodt et al., 2006; Marşan et al., 2009), but these techniques are limited for serial measurements by potential hazards from radiation and their poorer resolution than conventional photogrammetry (Park et al., 2012; Aboul-Hosn Centenero and Hernandez-Alfaro, 2012).

A 3D camera was introduced several years ago for analysis of soft tissue landmarks. Due to its high resolution, similar to that of photogrammetry, it has yielded accurate and reproducible data. The 3D camera allows for analysis of frontal views not possible by cephalometry. Moreover, 3D camera images can be rotated, translated and zoomed, providing realistic results of the effects of planned orthodontic and surgical treatment. In contrast, the results of conventional photogrammetry cannot be similarly manipulated, thus preventing serial anthropometric analysis despite multilateral pictures of natural head positions.

Although 3D camera systems have been shown to yield reliable and reproducible results (Baik et al., 2006; Calignano and Vezzetti, 2010; Marakhtanov and Zhulev, 2010), their usefulness after orthognathic surgery has not been assessed. We therefore tested the ability of a 3D camera system to analyze soft tissue landmarks in patients with skeletal class III dentofacial deformity who underwent two-jaw rotation with maxillary posterior impaction (MPI) but without maxillary advancement, a surgical approach that results in better aesthetic outcomes than conventional methods, including maxillary advancement and mandibular setback, in Asian skeletal class III patients (Baek et al., 2009). We utilized a new 3D camera system to quantitatively analyze soft tissue changes, with a particular focus on facial proportion including vertical and horizontal dimension, mid and lower facial surface areas and frontal soft tissue landmarks.

2. Materials and Methods

2.1. Subjects

The study involved 25 consecutive patients with skeletal class III dentofacial deformity who underwent two-jaw rotational setback surgery using posterior maxillary impaction without maxillary advancement between January 2008 and December 2009 at the Seoul Asan Medical Center. All 25 patients were of Asian ethnic background and had a mean age of 22 years (range 17–32 years). Patients who underwent conventional maxillary advancement and mandibular setback and those who underwent maxillary vertical reduction in the anterior part were excluded, as were patients with syndromic or disease-initiating dentofacial anomalies such as secondary cleft-related dentofacial deformities.

2.2. Imaging methods

A 3D camera system was used for frontal soft tissue analysis. 3D photographs of each face were captured with a 3D stereophotogrammetric camera setup and the software program modular system version 2.0 (Canfield, Vectra, USA, Fig. 1A). The camera setup consisted of 3 digital cameras, a flash and control bodies. Prior to its use, the camera was calibrated to define a 3D coordinate system for the 3D photographs. The 3D photographs were taken in a natural head position, with each patient looking into a mirror with a natural facial expression (Fig. 1B).The Vectra software program, Canfield Ltd, USA was used for the analysis. To test the reliability of our 3D photogrammetric tool, precision and accuracy testing was done. The test consisted of 10 normal adults, including 2 males and 8 females. Three observers were calibrated twice each time and six images were taken per object. Seven linear measurements and four angular measurements were completed for each 3D image. Precision testing revealed that the mean absolute difference (MAD) of linear measurement was within 1.2 mm, which is considered to be very precise compared to other measurement tools. The Kruskal–Wallis test demonstrated no statistically significant differences among observers and calibrations. Accuracy testing showed a 1.4 mm difference between measurements. Pearson's correlation coefficient was so high that the measured 3D values could be regarded as having very acceptable accuracy and precision. The 3D photogrammetry results were very similar to other reports using different measurement tools.

2.3. Identification of landmarks

Prior to placement of landmarks, axes were calibrated by yawing, rolling and pitching of the 3D images (Fig. 2A,B). Two observers indicated the landmarks on each facial soft tissue image twice each. The soft tissue landmarks were similar to those described, but were modified to fit 3D analysis based on the previous reports (Calignano

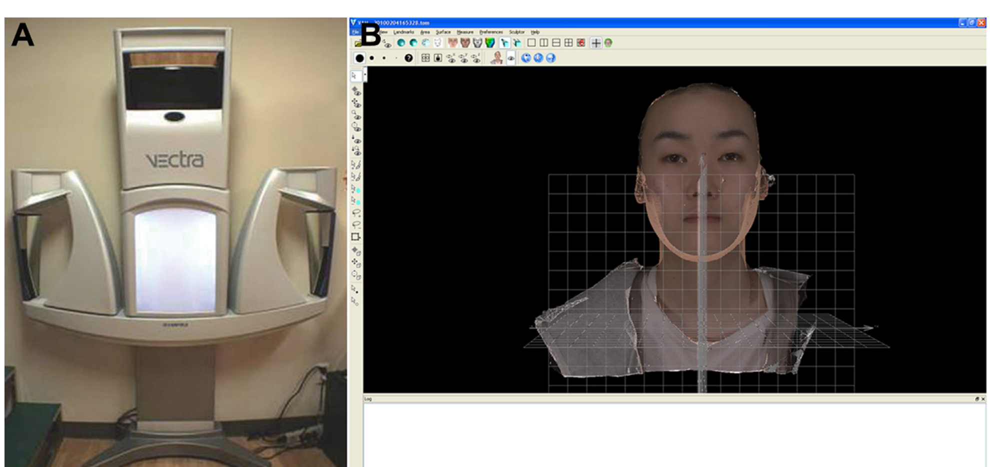

Fig. 1. A. 3 dimensional photogrammetric camera device system (2nd Generation, Vectra, Canfield, USA). B. The process of axis calibration. During this procedure, the correct frontal views can be obtained. Yaw, pitch and roll of the 3 dimensional images led to these calibrations.