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Clinical Paper
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Data-based prediction of soft tissue changes after orthognathic surgery: clinical assessment of new simulation software

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Abstract. The aim of the present study was to evaluate the accuracy of a novel simulation software package (OrthoForecast) for predicting the soft tissue profile after orthognathic surgery. The study included 15 patients with facial asymmetry (asymmetry group), 15 with a skeletal class II jaw relationship (class II group), and 15 with a skeletal class III jaw relationship (class III group). Twenty-four feature points were digitized, and the distances between points on the predicted and actual postoperative images were compared. Thirty-seven calibrated evaluators also graded the similarity of the predicted images compared to the actual postoperative photographs. Comparisons between the predicted and actual postoperative images revealed that the mean difference between feature points was 3.1 ± 1.4 mm for the frontal images and 2.9 ± 0.8 mm for the lateral images in the asymmetry group; 2.7 ± 0.9 and 2.1 ± 1.6 mm, respectively, in the class II group; and 1.8 ± 1.2 and 1.7 ± 1.0 mm, respectively, in the class III group. More than half of the evaluators assessed the predicted images as similar to the actual postoperative images in all groups. In conclusion, OrthoForecast can be regarded as useful, accurate, and reliable software to predict soft tissue changes after orthognathic surgery.

Keywords: feature point; orthognathic surgery; simulation system; prediction.

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The goals of orthognathic surgery are to correct the stomatognathic dysfunction associated with occlusal and skeletal discrepancies, as well as to improve facial aesthetics and harmony.[1–3] A desire for facial attractiveness is a strong motivator for patients seeking surgical correction of dentofacial deformities. However, in some cases, orthognathic surgery may not provide the patient's desired facial profile changes. Therefore, accurate prediction of the postsurgical facial appearance is of great importance for orthognathic treatment planning and successful patient management.

Early studies of changes in the soft tissue profile by orthognathic surgery concerned mandibular reduction procedures.

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Based on lateral cephalograms, these studies showed that for each 1-mm mandibular setback, the soft tissue chin moved posteriorly 0.9–1 mm, whereas the lip position moved only 0.6–0.75 mm (about two-thirds of the total skeletal change).[4,5] Many previous studies have reported the hard and soft tissue changes and their ratio after mandibular setback surgery. In some reports, formulations were used to predict the postsurgical results through cephalometric analysis.[6,7] Such predictions have been accepted in the field for more than 50 years.

Due to improvements in orthodontic and surgical techniques, a combined surgical approach is now available and is generally accepted as a superior method for correcting severe skeletal deformities compared to the simple one-jaw surgery. However, it is very difficult to predict the facial skeleton and soft tissue profiles resulting from combined surgery because the previous assumptions described above may not be applicable. Furthermore, details of the relationship between the hard and soft tissues, especially in the vertical and transverse directions, have not been fully clarified.

Recently, we developed a novel software program for predicting the postsurgical facial appearance – OrthoForecast (Miura Co., Hiroshima, Japan). The OrthoForecast database contains the actual facial displacements of patients who have undergone orthognathic surgery. We consider OrthoForecast to be useful software on the basis of reliable clinical evidence. However, the accuracy of prediction of this software has not been assessed objectively. The aim of this study was to evaluate whether this software is a useful tool for predicting postsurgical facial features.

Materials and methods

OrthoForecast

To predict the soft tissue profile after orthognathic surgery, OrthoForecast uses data provided by patients who have previously undergone orthognathic surgery. The OrthoForecast database contains information obtained from 400 patients, including 100 with facial asymmetry, 100 with a skeletal class II jaw relationship, and 200 with a skeletal class III jaw relationship. These patients underwent sagittal split ramus osteotomy (SSRO; 386 cases) or intraoral vertical ramus osteotomy (IVRO; 14 cases), with (352 cases) or without (48 cases) Le Fort I osteotomy. Table 1 shows a summary of the entire subject sample. Frontal and lateral cephalograms and facial photographs were taken routinely before and more than 1 year after surgery and stored in JPEG format. It was assumed that any postsurgical oedema in the soft tissue had resolved by the stated postoperative time point (>1 year after surgery). Lateral and frontal cephalograms and photographs were taken with the teeth in intercuspal position and the head in a position such that the Frankfort horizontal plane was parallel to the floor.

The data were standardized as follows. The orbitale–porion distance of all subjects was defined based on lateral cephalograms. Photographs were superimposed on each cephalogram by changing their size. The size of the frontal cephalogram was adjusted by the size of the lateral cephalogram. Then, according to the adjusted frontal cephalogram, the size of the frontal photograph was modified referring to the distance between the ear rod and soft tissue menton in lateral view. Finally, the modified photograph was superimposed on the frontal cephalogram.

A single examiner located 24 feature points on each photograph, including 11 points on the frontal photograph and 13 points on the lateral photograph, as shown in Figure 1 and described in detail in Table 2. Feature points were chosen on the basis of a facial recognition system, which has a reliability in identifying the arrangement of facial feature points of 97.6%.[8] Before taking the measurements, the accuracy of point plotting was investigated by three examiners. Three arbitrary points were marked on the computer display and plotted twice to obtain the x and y coordinates. Differences in these data were examined for the two plots by means of two-way analysis of variance (ANOVA). The x and y coordinates of all the points showed no significant differences between the first and second procedures for each of the three examiners and between the three examiners, confirming the accuracy of the point plotting. Displacements of the feature points between photographs taken before and after surgery were registered.

To predict a patient's postoperative profile, OrthoForecast applies a matching algorithm to the arrangement of the facial feature points on the patient's presurgical image. From the findings, five candidates are chosen from the stored data of 400 previous patients. The displacement of the feature points between images obtained before and after surgery is reflected in the patient's facial photograph. The presurgical feature points of the matched candidate are relocated onto the patient's facial photograph, and the patient's profile is morphed according to the displacement of the postsurgical feature points.

Table 1. Summary of variables for the entire sample.

Variables	Result
Sample size, *n* (%)	400 (100%)
Gender	
Male	146 (36%)
Female	254 (64%)
Deformity type	
Asymmetry	100 (25%)
Skeletal class II	100 (25%)
Skeletal class III	200 (50%)
Operation	
Two jaw	352 (88%)
LF I + SSRO	325 (81%)
LF I + SSRO + genioplasty	23 (6%)
LF I + IVRO	4 (1%)
One jaw	48 (12%)
SSRO	34 (9%)
SSRO + genioplasty	4 (1%)
IVRO	10 (2%)
Age, years, mean ± SD	26.5 ± 7.7

LF I, Le Fort I; SSRO, sagittal split ramus osteotomy; IVRO, intraoral vertical ramus osteotomy; SD, standard deviation.

Assessment of accuracy of the OrthoForecast prediction

The study was approved by the university hospital ethics committee. Fifteen patients with facial asymmetry (asymmetry group), 15 patients with a skeletal class II jaw relationship (class II group), and 15 patients with a skeletal class III jaw relationship (class III group) were enrolled. Frontal and lateral cephalograms and facial photographs were taken before orthognathic surgery and used in the