Prediction of Soft Tissue Profile Changes after Sagittal Splitting Ramus Osteotomy and Genioplasty

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Abstract

The purpose of this study is to improve the accuracy of predicting the soft tissue configuration from the change amounts of the hard tissue landmarks in the patients who underwent combined sagittal splitting ramus osteotomy (SSRO) and genioplasty for skeletal mandibular protraction. The samples for this study consisted of the lateral cephalograms records of 20 surgical orthodontics treated patients. The records of each subject were chosen on the basis of their having pre-treatment and post-treatment lateral cephalograms. Landmarks were traced from each film, and scaled to permit radiographic enlargement. The cartesian coordinates of these points were obtained with the use of calipers, where the coordinate set was first translated to bring the midpoint at sella turcica to the origin and then rotated to align the Frankfort horizontal plane with the X axis. Y axis was set perpendicular to the X axis. The means and standard deviations were estimated for each of the cephalometric variables in both the hard tissue and the soft tissue. There were significantly increased in the amount of change in Convexity, ANB, U1 to L1, on the contrary there were significant decreased in SNB, Facial angle, Gonial angle, IMFA. After SSRO and genioplasty there were significant decreased in the X-coordinates of the landmarks in the L1, Id, B, Pog and Me. Regarding the amount of those changes, in the soft tissue measurements, there were significant decreased in X-coordinates of Li, Sid, SB, SFog and SMe.

The results of the regression analysis suggested that the final positions of the points St (X) : 0.80, St (Y) : 0.77, Sid (Y) : 0.78, SB (Y) : 0.73, and SFog (Y) : 0.87, which showed R square greater than 0.70 (contribution%), could be predicted with confidence. On the contrary, in the measurement without corresponding hard tissue (Sn and Li), R square were more variable and could be predicted with less confidence.

The prediction of soft tissue profiles in combination with SSRO and genioplasty could be adequately predicted.

Keywords:
prediction, soft tissue profile, SSRO, genioplasty

Introduction

There is a strong necessity to improve functional problems such as jaw deformity, impaired mastication, and pronunciation etc., due to maxilla-mandibular imbalance, and also to improve aesthetics. Thus, many reports state that it is important to predict the soft tissue facial profile based on changes in hard tissue when planning treatment (1–10). However, the prediction accuracy is commonly based on the mean values of the general population, and it is common for the prediction prior to surgery and the results after the surgery to be inconsistent. The change in the soft tissue profile before and after the operation in the patients with jaw deformity are greatly affected by morphological changes of the jaws. However, the site and contact relation with the both lips and incisors, or the extent of backward rotation of the mandible, have been also reported to have an impact (11, 12).

Lower facial height in the patients with the jaw deformity especially mandibular prognathism is usually high. A long-
face maxillofacial configuration in not always improved post-
surgery, because tightness of the lips area needs to
accompany with the hard tissue improvement. Therefore,
geniplasty is generally performed (13-15). However, as
stated by Furuta et al. (16), in patients with an open bite and
an overly tight lower lip, the predicted postsurgical errors
are large, and the degree to which the soft tissue
morphology of the lips and chin improves post-surgically by
performing geniplasty to lower the height of the chin is
difficult to predict and commonly depends on the intuition of
the surgeon.

To determine the details of the procedure of the surgical
orthodontic treatment, paper surgery (PS) using a cephalo-
gram is commonly performed prior to surgery. Nunes et al.
(17) found a significant relationship between amount of
mandibular body changes and changes in PS comparing
sagittal splitting ramus osteotomy (SSRO) and Two jaws
surgery. On the contrary, Takeuma et al (18) reported that
it is difficult to analyze the need for geniplasty prior to
surgery based on the analysis of the skeleton and soft
tissues. Moreover, whether to perform it after re-diagnosing
the facial profile after surgery should be considered.

The purpose of this study is to improve the accuracy of
predicting the soft tissue configuration from the change
amounts of the hard tissue landmarks in the patients who
underwent combined SSRO and geniplasty for skeletal
mandibular protraction. For this purpose we analyzed
lateral cephalograms at the pre- and post-surgery.

Materials and Methods

The samples for this study consisted of the lateral
cephalograms records of 20 surgical orthodontics treated
Japanese selected from the files of the Department of
Orthodontics of the Nihon University School of Dentistry at
Matsudo. The records of each subject were chosen on the
basis of their having pre-treatment and post-treatment
lateral cephalograms with good definition of both hard and
soft tissues, molars in maximal occlusion with the lips closed,
and soft tissues that were subjectively judged to be
unstrained. The mean age of the pretreatment group was
28.2 ± 5.2 years (from 18 to 37 years). All subjects
exhibited Skeletal Class III. Excluding congenital abnor-
mality and syndromes including cleft lip and palate. The
overbite in pre-surgery was 1.0 mm or more, and the lateral
shift of mandible was 3.0 mm or less. This study was
approved by the Ethics Committee of Nihon University’s
School of Dentistry at Matsudo (approval no.: EC 12-11-041-
2).

Cephalograms were taken at the finishing of pre-surgical
orthodontic treatment and within 3 month after surgery.
The reference points (Figs. 1 and 2) and variables for the
multiple-regression analysis are defined in Fig. 3. Landmarks were traced from each film, and scaled to permit
radiographic enlargement. The rectangular Cartesian
coordinates of these points were obtained with the use of
calipers, where the coordinate set was first translated to
bring the midpoint at sella turcica to the origin and then
rotated to align the Frankfort horizontal plane with the X
axis. Y axis was set perpendicular to the X axis. The mean
and standard deviation (SD) were estimated for each of the
cephalometric variables in both the hard tissue and the soft
tissue.

Statistical analysis methods

Hard tissue morphology was measured at the end of the
pre-surgical orthodontics and at the end of the post-surgical
orthodontic procedure, and the amount of change before and
after treatment was determined. Subsequently, the means
and standard deviations of the various landmarks were
calculated, and a t-test was performed. Moreover, the
amount of change was determined from the difference
between the values of the X and Y-coordinates before and
after surgery of the various hard and soft tissue landmarks,
and a paired t-test performed.

Multiple-regression analysis

Multiple-regression analysis (19) was undertaken to pro-
vide equations for the estimation of each of the variables
describing the soft tissue profile of the post-surgery.
Multiple-regression analysis is a general statistical tech-
nique used to evaluate the relationship between a dependent
or criterion variable and a set of independent or predictor
variables. Multiple regression may be viewed as a descrip-
tive tool by which the linear dependence of one variable on
others is summarized and decomposed or as an inferential
tool by which the relationships in the population are
evaluated from the examination of sample data. Although
these two aspects of the statistical technique are closely
related, it is convenient to treat each separately, at least on a
conceptual level. The most important uses of the technique
as a descriptive tool are

(1) to find the best linear prediction equation and to
evaluate prediction accuracy, (2) to control for other con-
foundering factors in an attempt to evaluate the contribution
of a specific variable or set of variables, and (3) to find structural relations and to provide explanations for seemingly complex multivariate relationships, as is done in path analysis. In this study, multiple-regression analysis was performed in an attempt to evaluate the relationship between the hard tissue and soft tissue changes and to predict the soft tissue profile changes after SSRO and genioplasty.

**Measurement error**

In an attempt to assess the significance of the error involved in the radiographic measurement methods, a series of 20 subjects was reassessed 1 month after the initial measurements were taken. The mean difference between first and second measurements, the SE of a single measure, and the percentage of the total variance attributable to measurement error were calculated for each variable. The mean differences were less than 1.0 mm and 1.0 degree. The contributions of errors to the total variance were small, ranging from 1.0% to 6.7%. The errors involved in measuring both the hard and soft tissue variables were therefore regarded as nonsignificant.

**Results**

*The lateral cephalogram analysis*

Table 1 presents the results at the end of the pre-surgical orthodontics and those at the end of the post-surgical orthodontics. There were significantly increased in the amount of change in Convexity, ANB, U1 to L1, on the contrary there were significant decreased in SNB, Facial angle, Gonial angle, IMPA. After SSRO and genioplasty there were significant decreased in the X-coordinates of the landmarks in the L1, Id, B, Pog, and Me. Regarding the amount of those changes, in the soft tissue measurements,
there were significant decreased in X-coordinates of Li, Sid, SB, SPog and SMe.

Regression analysis
Regression analysis was performed to evaluate the relationship between hard and soft tissue changes and to predict the soft tissue-profile changes after SSRO and genioplasty. The relationship between the two sets of variables was estimated with the use of the R square (contribution), which also yields an estimate of the accuracy of the prediction equations. Table 4 shows the results of the regression analysis. The values indicate the coefficients of the prediction equations. For an individual, the predicted change for each of the soft tissue landmarks was calculated from an equation combining the changes in hard tissue landmarks multiplied by the corresponding regression coefficient. The significance of the coefficient was performed by F test.

The results of the regression analysis suggested that the final positions of the points St (X): 0.80, St (Y): 0.77, Sid (Y): 0.78, SB (Y): 0.73, and SPog (Y): 0.87, which showed R square greater than 0.70 (contribution%), could be predicted with confidence. On the contrary, in the measurement without corresponding hard tissue (Sn and Li), R square were more variable and could be predicted with less confidence.

Discussion
In studies on facial soft tissue before and after surgical orthodontic treatment of patients with jaw deformities, two-dimensional evaluations using lateral cephalograms as well as prediction etc., of treatment results are common. Recently, 3-dimensional (3D) analyses have been performed due to popularity of the non-contact optical surface scanner,
and 3-dimensional (3D) analysis of changes in facial soft tissue before and after surgical orthodontic treatment has been reported(20,21).

However, in surgical orthodontic treatment, a detailed treatment plan should include a surgical method where a close examination is performed at the initial examination. However, in genioplasty, regarding the evaluation of the height of the lower face, it is difficult to predict the postsurgical facial profile at the end of the pre-surgical orthodontics. PS where a cephalogram is traced and the prediction performed after the jaw bone and soft tissue are moved is commonly used as a prediction method(17, 22). By this method, the amount of movement of the maxilla-mandibular bone can be accurately judged. Furthermore,
### Table 2. Vertical and horizontal changes of hard tissue landmarks

| Landmark | Before SSRO | After SSRO | Differences | t-test |
|----------|-------------|------------|-------------|--------|
|          | Mean        | S.D.       | Mean        | S.D.   | Mean | S.D. |       |
| ANS(X)   | 71.6        | 2.8        | 71.3        | 2.5    | 0.3  | 0.2  |       |
| ANS(Y)   | -46.3       | 3.4        | -46.2       | 3.4    | 0.1  | 0.1  |       |
| A(X)     | 67.8        | 3.8        | 67.7        | 2.9    | 0.1  | 0.1  |       |
| A(Y)     | -50.8       | 4.1        | -51.6       | 4.3    | 0.8  | 0.4  |       |
| Pr(X)    | 72.6        | 5.0        | 71.8        | 4.7    | 0.8  | 0.4  |       |
| Pr(Y)    | -62.7       | 4.0        | -63.6       | 4.7    | 0.9  | 0.5  |       |
| U1(X)    | 78.0        | 5.9        | 77.6        | 5.2    | 0.4  | 0.2  |       |
| U1(Y)    | -78.1       | 4.4        | -77.7       | 5.2    | 0.4  | 0.2  |       |
| L1(X)    | 82.5        | 8.2        | 73.9        | 5.5    | 8.6  | 4.3  | **    |
| L1(Y)    | -77.6       | 5.6        | -75.8       | 4.9    | -1.8 | 0.9  |       |
| Id(X)    | 77.7        | 8.7        | 70.1        | 5.3    | 7.6  | 3.8  | **    |
| Id(Y)    | -95.9       | 6.1        | -94.5       | 5.4    | -1.4 | 0.7  |       |
| B(X)     | 78.4        | 9.5        | 70.3        | 5.3    | 8.1  | 4.0  |       |
| B(Y)     | -101.7      | 5.5        | -100.6      | 5.2    | -1.1 | 0.6  |       |
| Pog(X)   | 81.0        | 10.0       | 71.4        | 5.7    | 9.6  | 4.8  | **    |
| Pog(Y)   | -115.2      | 6.4        | -110.1      | 4.7    | -5.1 | 2.6  |       |
| Me(X)    | 75.5        | 11.4       | 67.0        | 4.4    | 8.5  | 4.3  |       |
| Me(Y)    | -124.8      | 5.9        | -119.1      | 6.0    | -5.7 | 2.8  |       |

* *p < 0.05, paired t-test.

** *p < 0.01, paired t-test.

### Table 3. Vertical and horizontal changes of soft tissue landmarks

| Landmark | Before SSRO | After SSRO | differences | t-test |
|----------|-------------|------------|-------------|--------|
|          | Mean        | S.D.       | Mean        | S.D.   | Mean | S.D. |       |
| Sn(X)    | 81.45       | 4.13       | 81.42       | 4.50   | 0.32 | 5.68 |       |
| Sn(Y)    | -50.45      | 3.75       | -50.45      | 3.47   | -0.03 | 5.57 |       |
| Ls(X)    | 89.08       | 5.78       | 88.76       | 5.24   | 0.32 | 3.54 |       |
| Ls(Y)    | -66.50      | 4.70       | -66.97      | 3.94   | 0.50 | 6.94 |       |
| St(X)    | 83.05       | 6.34       | 81.61       | 3.85   | 1.45 | 4.30 |       |
| St(Y)    | -75.28      | 4.87       | -77.29      | 4.60   | 2.26 | 6.03 |       |
| Li(X)    | 90.90       | 8.64       | 85.89       | 5.45   | 5.26 | 6.93 | **    |
| Li(Y)    | -81.03      | 5.62       | -82.26      | 5.76   | 1.50 | 6.99 |       |
| Sid(X)   | 88.50       | 8.79       | 83.68       | 5.12   | 5.11 | 5.87 | **    |
| Sid(Y)   | -96.35      | 5.78       | -97.29      | 5.98   | 0.87 | 6.44 |       |
| SB(X)    | 89.85       | 10.05      | 82.05       | 5.49   | 7.05 | 7.43 | **    |
| SB(Y)    | -102.00     | 5.70       | -102.58     | 4.03   | 0.58 | 8.07 |       |
| SPog(X)  | 89.10       | 10.44      | 84.61       | 5.25   | 4.92 | 7.17 | **    |
| SPog(Y)  | -115.38     | 5.57       | -114.15     | 5.91   | -0.97 | 8.64 |       |
| SMe(X)   | 73.3        | 10.52      | 64.00       | 5.76   | 9.47 | 7.31 | **    |
| SMe(Y)   | -129.50     | 5.42       | -128.32     | 9.07   | -1.16 | 7.05 |       |

* *p < 0.05, paired t-test.

** *p < 0.01, paired t-test.
recently various methods have been used such as one that incorporates 3D data obtained by CT, and the other where an oral cavity scanner is used in combination to reflect dental arch morphology. By these methods, evaluation can be performed where the results are scarcely different from those after surgery in 3D maxilla-mandibular changes. However, for genioplasty, considering that it is performed in combination with changes in the mandible position, presurgical simulation is difficult. For that reason, genioplasty is not performed at the same time as surgery for jaw bone fracture, and many reports recommend a method performed secondarily where re-evaluation of the facial profile is performed when the plate used to fix the bone fragments is being removed.23)

However, for cases where removal of the plate is not necessary, such as with absorbable materials, there is no need for a secondary surgery. As it is considered better to perform genioplasty at the same time when performing a primary is performed to reduce patient exposure and risks of general anesthesia, this study was performed.

Based on the analysis of the lateral cephalogram, the mandible was set backwards and even the soft tissue landmarks were set backwards. However, there was no significant difference in the amount of vertical change in the mandibular soft tissue landmarks, and a concomitant performance of genioplasty caused Pog, Me, SPog, and SME to set upwards compared to preoperatively, resulting in shrinkage of the chin area.

Kasai24), who performed lingual movement of the incisor by tooth extraction as well as Karakita et al.25) who attempted to predict SSRO alone, reported common results that the upper and lower lips as well as the lip junction descended. Even when there is a slack in the lip area, the upper and lower lips as well as the lip junction characteristic-ly descend if there is no change in facial height. Meanwhile, when genioplasty is combined with SSRO, the change in facial height caused no significant descent of the lower lip and lip junction; this change can be determined as characteristic of the SSRO and genioplasty combination.

When the results of the prediction of the soft tissue landmark sites are evaluated using R square, the horizontal positions of ST, Sid, SB, and SPog can be clinically predicted at ≥0.70. Meanwhile, it is difficult to predict the horizontal positions of SN, Li, and LS at ≤0.70, and so the level of tightness, stretch etc., of the soft tissue must be considered.

To predict soft tissue profiles in orthodontic treatment, Kasai24) described that the vertical and horizontal changes in St and in the lower lip were strongly associated with the vertical and horizontal changes in prosthion, infradental, lower incisors, point A, and point B. The other soft tissue landmarks appeared more variable. Several of the hard tissue changes were found to help significantly in prediction of soft tissue changes, because the hard tissue points significantly changed after surgery. The results indicated

| Table 4. Linear regression analysis of the hard tissue determinants of the soft tissue changes |
|-----------------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| S   | Sn |   X    | Y    | X    | Y    | X    | Y    | X    | Y    |
| U1(X) | 1.52 | 0.46 | 1.91 | 0.18 | 0.52 | 2.91 | 2.77 | 0.52 | -0.56 |
| U1(Y) | 1.53 | 0.52 | 1.83 | 0.59 | 0.03 | 1.89 | 0.73 | 3.52 | -0.16 |
| L1(X) | -0.13 | -0.89 | -0.63 | -0.92 | 0.31 | -2.57 | -3.14 | -1.99 |
| L1(Y) | -4.51 | 0.01 | -1.48 | 2.29 | -3.22* | 0.25 | -7.01 | -1.67 |
| Id(X) | -4.74 | 2.37 | 0.24 | 4.16 | -2.43 | 3.60 | 0.54 | -0.19 |
| Id(Y) | 1.41 | 0.60 | 0.23 | 0.10 | 0.74 | 0.85 | 2.65 | 1.92 |
| B(X) | 4.25 | 0.28 | 1.45 | -2.02 | 3.46* | 0.63 | 5.84 | 3.43 |
| B(Y) | 0.67 | -1.52 | 0.30 | -2.85* | 1.39* | -2.51* | 0.29 | -2.23 |
| Pog(X) | -2.42 | -1.54 | 2.06 | 0.66 | -2.86 | 0.29 | -5.17 | -2.54 |
| Pog(Y) | 1.56 | 0.01 | 0.40 | -0.80 | 0.86 | 0.61 | 1.41 | 0.16 |
| Me(X) | 2.66 | -0.41 | 0.97 | -1.72 | 1.95* | 0.23 | 2.35 | 0.95 |
| Me(Y) | -1.44 | 1.44 | -0.46 | 2.19 | -1.03 | 0.60 | -0.01 | 0.39 |
| Constant | -3.44 | 11.47 | 0.67 | 10.22 | -4.69 | 13.78 | 3.65 | 7.81 |
| R square | 0.56 | 0.58 | 0.60 | 0.75 | 0.80 | 0.77 | 0.64 | 0.61 | -0.78 | -0.73 | -0.86 | 0.56

* p < 0.05, F-test.
** p < 0.01, F-test.
— missing value because variable was indicated directly from diagram of each hard tissue point.

The values indicate the coefficients of the prediction equations. For an individual, the predicted change for each of the soft tissue landmarks was calculated from an equation combining the changes in hard tissue landmarks multiplied by the corresponding regression coefficient.
that the changes in St and reflected the changes in the hard tissue. On the contrary, the change in the upper lip showed a weaker association with the hard tissue changes.

These results suggest that useful clinical predictions of posttreatment soft tissue profiles can be made but that care must be applied in the interpretation of some of these predictions in cases where low R square suggest a high degree of variation not associated with the described hard tissue changes.

The prediction of soft tissue profiles in combination with SSRO and genioplasty is more difficult than in orthodontic treatment only. However, when determined based on R square, several landmarks can be adequately predicted. In the future, an investigation including more patients is necessary.

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