Evaluation of Chewing Movement in Skeletal Class III Patients with Orthognathic Treatment

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Abstract

The objective of this study was to clarify the influence of improvement in morphology on chewing movement in patients with skeletal reversed occlusion following orthognathic treatment. A total of 10 patients with skeletal class III reversed occlusion undergoing orthognathic treatment were included in the study. A number of parameters, including chewing rhythm, maximum opening and closing velocities, and opening distance during chewing of gum, were measured in a pre- (Pre) and post-treatment (Post) group. The laterality and stability of the measured items were then compared between the two groups and with those in another group of subjects with normal occlusion (Control). Laterality of chewing movement was greater in the Pre group than in the Control group, and significant differences were noted in all parameters, apart from closing Vmax and opening distance. No significant difference was noted in any parameter between the Post and Control groups. The coefficient of variation was significantly higher in the Pre group than in the Control group, apart from for opening phase. All parameters showed a significant decrease in the Post group compared with in the Pre group, yielding a stable chewing movement. Comparison of the Post and Control groups revealed no significant difference in any of the parameters, apart from in the occluding phase. These findings suggest that orthognathic treatment of skeletal class III malocclusion improves chewing movement to levels close to those in subjects with normal occlusion.

Key words: Chewing movement — Skeletal class III — Orthognathic treatment

Introduction

Three factors are closely involved in chewing movement: the teeth, the temporomandibular joint, and the masticatory muscles, while motor control of rhythmical movement is maintained by the central nervous system\textsuperscript{11,13}. Chewing involves integrating various elements of the stomatognathic system, and it is possible to evaluate such movement by objective analysis\textsuperscript{24}. Recent technological developments have allowed further quantita-
tive and objective evaluation of chewing movement. Many orthodontic studies have investigated chewing in patients with various types of malocclusion, particularly skeletal reversed. Fewer studies have been conducted on improvement in skeletal morphology by orthognathic treatment, however, or evaluation of chewing movement after such treatment, and no consistent view has been reached due to differences in study and analytical method.

Although a number of studies have compared post-operative chewing movement with that in subjects with normal occlusion, orthognathic treatment-induced changes in chewing movement remain to be elucidated.

The purpose of this study was to compare chewing movement in patients with skeletal class III reversed occlusion with that in the same patients on completion of orthognathic surgery. Changes in chewing movement were then compared with that in subjects with normal occlusion.

Methods

1. Subjects

Subjects comprised 10 patients with skeletal class III malocclusion and 10 adults with normal occlusion. The skeletal class III patients underwent orthognathic treatment involving sagittal splitting of the mandibular ramus (5 men and 5 women; age, 20 years and 3 months to 38 years; mean age, 26 years and 9 months) at the Orthodontics Department of Tokyo Dental College Chiba Hospital. These patients were designated as belonging to a pre- (Pre) or post-treatment (Post) group. The adults with normal occlusion (5 men and 5 women; age, 20 years and 8 months to 28 years and 9 months; mean age, 24 years and 11 months) were selected from students at Tokyo Dental College School of Dentistry and designated as the Control group. The study protocol was approved by the Ethics Committee of Tokyo Dental College (Ethical Clearance Number 149), and written informed consent was obtained from all subjects.

1) Pre group selection criteria

A diagnosis of skeletal class III malocclusion was reached according to the following criteria: an Angle Classification Class III for the occlusal relationship of the 1st molar; mean ANB and Wits values of $-3.0 \pm 3.5^\circ$ and $-15.3 \pm 3.3$ mm, respectively, according to cephalometric analysis; a protruding chin; overjet in the anterior teeth; and overbite of 0 mm or more with molar crossbite (mean overjet, $-2.7 \pm 2.1$ mm; mean overbite, $+1.6 \pm 1.0$ mm). Patients with a history of orthodontic treatment or with marked facial asymmetry were excluded. Patients with congenital abnormalities such as cleft lip or cleft palate, temporomandibular joint pain, or impaired jaw movement were excluded.

2) Post group selection criteria

The selection criteria for the Post group were as follows: a class I post-treatment occlusal relationship for the 1st molar (class II was accepted in one case, however, in which only the upper 1st premolar was extracted); an improvement in overjet and overbite; a stabilized intercuspal position; an esthetically balanced and morphologically improved frontal and lateral facial appearance.

3) Control group selection criteria

The selection criteria for inclusion in the Control group were as follows: a normal occlusal relationship between the upper and lower jaws (mean ANB: $+3.1^\circ$); normal vertical and horizontal overlaps (mean overjet, $+3.3$ mm; mean overbite, $+2.5$ mm); absence of morphological abnormality in the upper and lower dental arches; stable intercuspal position; and absence of subjective or objective functional abnormalities in the stomatognathic system. Subjects with no history of orthodontic treatment, loss of teeth other than the 3rd molar, or prosthetics other than onlay in the current teeth were considered eligible.

2. Recording method and equipment

Chewing movement was measured with an optical non-contact mandibular movement measurement system (Gnatho-hexagraph JM-1000, GC Co.). Each subject was required to
sit upright on a chair and look straight ahead. No mechanical fixation of the head was carried out. The subject was then required to chew gum. A crutch was placed on the labial surface of the mandibular incisor with resin and fixed with cyanoacrylate adhesive. After confirming adhesion, a mandibular face-bow equipped with a light-emitting diode-labeled point was attached to the crutch. The subject wore a head frame equipped with a light-emitting diode-labeled point, so that the head frame could be positioned parallel to the FH plane. Each subject was required to chew and soften a piece of gum (approximately 1.5 g XYLITOL Gum, Lotte Co., Ltd.) for approximately 3 min, after which, chewing movements were recorded for 20 sec each on the left and right sides. The subjects practiced lateral and opening movements, and intercuspal position was confirmed beforehand.

3. Analytical method

Movement was 3-dimensionally recorded, focusing on the chewing cycle in the frontal plane (Figs. 1, 2-a). Laterality and stability of chewing movement were compared between the Pre and Post groups, between the Pre and Control groups, and between the Post and Control groups.

For the analysis, 10 cycles were selected bilaterally, commencing from the 5th in each series, yielding a total of 20 cycles. Each group consisted of 10 subjects, and thus a total of 200 chewing cycles were analyzed. Each chewing cycle was divided into opening, closing, and occluding phases (Fig. 2-b) and 7 items measured: time required to complete chewing cycle, occlusion, opening, closing, maxi-
mum opening and closing velocities (Opening and Closing Vmax, respectively), and opening distance. The means and standard deviations of these parameters were calculated over 10 and 20 chewing cycles for laterality and stability, respectively.

To investigate laterality in chewing movement, the ratio of small to large values was calculated from the mean values on each side as a percentage. The coefficient of variation from each mean and standard deviation was also determined to obtain indices of stability of chewing movement (Tables 1 and 2). The normality of all parameters was determined by using the Shapiro-Wilk test. A paired t-test and the Wilcoxon signed rank test were used for comparisons between the Pre and Post groups, and the Student’s t-test and Mann-Whitney U-test for comparisons between the Pre and Control groups and between the Post and Control groups. The software package Stat View-5.0 (Abacus Concepts Inc., SAS) was used for the statistical analysis.

**Results**

1. Laterality of chewing movement

The mean laterality rate and its standard deviation were calculated from the bilaterally measured values in each item in the Pre, Post, and Control groups and significance determined (Table 1).

1) Comparison between Pre and Control
Fig. 3  Laterality rates were slightly lower in Post than in Pre group in all parameters, apart from closing Vmax, although differences were not significant.

Fig. 4  Coefficient of variation was smaller in Post than in Pre group in all parameters and significant differences observed in all parameters.
groups
The laterality rate was significantly higher ($p<0.05$) in the Pre group than in the Control group in all parameters, apart from closing Vmax and opening distance.

2) Comparison between Post and Control groups
The laterality rates for chewing cycle, occluding, opening, closing, and opening Vmax were slightly higher in the Post group, although the differences were not significant. The laterality rates for closing Vmax and opening distance were slightly lower in the Post group, although the differences were not significant.

3) Comparison between Pre and Post groups
The pre- and post-operative laterality rates in each subject are shown in Fig. 3A–D. The laterality rates were slightly lower in the Post group in all parameters, apart from closing Vmax, although the differences were not significant. The laterality rate for closing Vmax was significantly lower in the Post group ($p<0.05$).

2. Stability of chewing movement
The coefficients of variation of the parameters were calculated in the Pre, Post, and Control groups. Their means and standard deviations were calculated and compared among groups (Table 2).

1) Comparison between Pre and Control groups
The coefficient of variation was larger in the Pre group in all parameters. Significant differences were noted in opening and closing Vmax ($p<0.01$), chewing cycle, occluding and closing phases, and opening distance ($p<0.05$). No significant difference was noted in the coefficients of variation for opening phase.

2) Comparison between Post and Control groups
The coefficient of variation for the occluding phase was significantly smaller in the Post group ($p<0.05$). Those for chewing cycle, opening phase, opening Vmax, and opening distance were smaller, and those for closing phase and closing Vmax were larger in the Post group, although the differences were not significant.

3) Comparison between Pre and Post groups
The pre- and post-operative coefficients of variation in each subject are shown in Fig. 4A–D. The coefficient of variation was smaller in the Post than in the Pre group in all parameters, and the differences in those for the closing phase and opening distance were significant at $p<0.05$, while those in the other parameters were $p<0.01$.

Discussion

1. Recording method and equipment
Accurate measurement of chewing movement is necessary in the clinical examination of chewing function, here, a Gnatho-hexagraph, which collects accurate and reproducible data by a simple procedure, was used.

Chewing movement has been reported to be affected by the type, size, and hardness of the food involved. Therefore, chewing gum was selected as the test food, as this makes standardization of quality and quantity easier. To further eliminate the influences of taste and hardness on chewing movement, movement was measured after the chewing gum was sufficiently softened.

2. Analytical method
Functional analysis of chewing movement generally uses the pathway, rhythm, and velocity of movement as indices. Many reports have used time required for a single cycle, occluding, opening, and closing phases as indices, and individual variation in subjects with normal occlusion and in patients with malocclusion have been reported. Therefore, to eliminate individual variation in the present study, the proportion of the measured values on the left and right sides was calculated as the laterality rate ($\%$). Coefficients of variation in the parameters addressed were used to determine stability of chewing movement, as many reports have used this approach and its clinical utility has been confirmed. Here, opening and closing
Vmax and opening distance were employed, in addition to 4 time-related parameters, giving a total of 7 parameters.

It has been reported that the movement pathway and stability of movement rhythm are significantly more stable on the habitual chewing side than on the non-habitual chewing side in subjects with normal occlusion\(^1\). Significantly higher stability of chewing rhythm on the habitual chewing side than on the non-habitual chewing side, revealing functional laterality\(^2\), the absence of laterality\(^3\), and investigation of only the habitual chewing side\(^4,5\) have all been reported. The bilateral chewing side was analyzed in some reports, as the habitual chewing side could not be definitely identified in skeletal class III patients\(^6\). Skeletal class III patients and individuals with normal occlusion were selected as subjects in the present study and bilateral chewing sides investigated as analytical indices.

### 3. Laterality of chewing movement

The stomatognathic system exhibits functional laterality, although the structure itself is symmetric\(^7\), and individual variation may also be large. No significant bilateral difference in the pathway of chewing movement was reported by Yamamura \textit{et al.}\(^8\) or chewing rhythm by Ozaki\(^9\). Whether the habitual chewing side or bilateral sides are investigated, individual variation may manifest itself in the means of the parameters, making the results unclear. In the present study, therefore, chewing movement was investigated bilaterally in skeletal class III patients, calculating the laterality rates of the parameters and comparing them among the 3 groups. The results revealed that the laterality of the parameters was larger in the Pre group than in the Control group, and that the differences were significant, apart from for closing Vmax and opening distance. This suggests that functional laterality in chewing movement was larger, thus making movement unstable in the Pre group. The opening distances in the Pre and Control groups were similar, but further investigation using different test foods may be necessary. A comparison of laterality rates between the Pre and Post groups revealed no significant difference in any of the parameters, except for closing Vmax, although values decreased to a level close to that in the Control group after surgery. No significant differences were observed in laterality rates between the Post and Control groups, and pre-operative functional laterality in chewing movement showed a reduction to a level close to that in the Control group by orthognathic treatment.

These findings suggest that laterality in skeletal class III malocclusion is larger than that in normal occlusion, and that orthognathic treatment reduces laterality to levels found in normal occlusion. Given this relapse after orthognathic treatment and the negative effect of unilateral chewing, this suggests that training in bilateral homogeneous chewing may be necessary after surgery to avoid an increase in laterality.

### 4. Stability of chewing movement

Many studies on stability of chewing rhythm have used the coefficient of variation\(^10,11,12,13,14,15\), but few have compared stability between before and after orthognathic treatment, and data comparison with this study is further complicated by the different recording methods used.

Tsubura and Ishikawa\(^16\) performed a similar study, but the measuring equipment, subject selection criteria, and weight of the face-bow used were all different. Their study revealed that the parameters were reduced to levels close to those in the normal group after surgery, as in our study. The parameters were larger in our study, and this may have been due to the lighter face-bow (12g) attached to the mandibular incisor. This may have reduced stress during measurement, allowing accurate and detailed measurement of chewing movement.

Comparison of the Pre and Control groups revealed significant differences in many parameters, with greater irregularity and instability of movement in the Pre group than in the Control group. Comparison of the Pre
and Post groups showed significant differences in all parameters, suggesting that movement is stabilized after treatment. In an earlier study by Tsubura and Ishikawa\textsuperscript{23}, a comparison of the Post and Control groups revealed significant differences in the closing and occluding phases. In the present study, however, a significant difference was noted only in the occluding phase. These findings indicate that not all parameters are more unstable in skeletal class III patients than in normal occlusion, and that not all parameters improve with orthognathic treatment.

To determine how function is affected by orthognathic treatment-induced morphological change, it is necessary to standardize pre- and post-treatment morphological criteria. In this study, only the 1st upper premolar was extracted and, in one of the patients, treatment was considered complete on achieving a class II relationship between the upper and lower 1st molars. Local occlusal interference before treatment has been reported to affect chewing movement pattern, depending on the location of interference\textsuperscript{2}. Therefore, it may be necessary to develop a more precise system of classification that takes into account subject selection criteria, the presence or absence and degree of occlusal interference, and chewing side.

### Conclusions

Changes in chewing movement after treatment were investigated in 10 patients with skeletal class III malocclusion who underwent orthognathic surgery. Chewing movement was recorded bilaterally. Laterality was calculated from the mean values on each side as a percentage and stability of chewing movement expressed as the coefficient of variation. Values were compared between pre- and post-treatment, and with those in 10 subjects with normal occlusion. The following results were observed and conclusions reached:

1. The laterality rate of chewing movement rhythm was higher in the skeletal class III patients than in the subjects with normal occlusion, but decreased to levels close to that in subjects with normal occlusion after treatment.

2. Pre-treatment stability of chewing movement rhythm was more irregular and unstable than that in subjects with normal occlusion, but with both values reaching levels close to those in subjects with normal occlusion after treatment.

These findings suggest that morphological change brought about by orthognathic treatment in skeletal class III patients improves the function of chewing movement to levels close to those in subjects with normal occlusion.

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