Comparison of masticatory function in patients with mandibular prognathism receiving orthognathic surgery using two different fixation materials

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Received 2 August 2019; revised 25 August 2019; accepted 19 September 2019

Abstract

This study aimed to compare masticatory function in patients with mandibular prognathism who received orthognathic surgery using two different fixation materials, namely bone plates and screws. The study population consisted of patients with mandibular prognathism who underwent orthognathic surgery by the bialith-Cojethal split ramus osteotomy method. The study was divided into two groups, the experimental group received bone plate fixation and screws, while the control group received bone plate and screws made of titanium. The study evaluated masticatory function through the measurement of food clumping ability and maximum bite force before surgery, 3 months after surgery, and 6 months after surgery. Statistical tests used to compare masticatory function were the Wilcoxon and Mann-Whitney tests. A total of 28 patients with mandibular prognathism were selected for the study. The results showed that food clumping ability increased significantly after surgery in both groups, while maximum bite force decreased significantly at 3 months after surgery and increased significantly at 6 months after surgery.

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Introduction

Orthognathic surgery is considered for correcting the skeletal-based severe malocclusion that cannot be treated using orthodontics alone. The surgical procedures used to correct the existing musculoskeletal deformities must provide optimal functional and esthetic results with good stability. After bilateral sagittal split ramus osteotomy (BSSRO), the distal and proximal bone segments need to be repositioned and fixed to stabilize the fragments and to promote bone healing. Formerly, the method of fixation was intrasosseous wiring coupled with rigid intermaxillary (upper to lower jaw) fixation. Currently, titanium plates and screws are accepted as the gold standard for rigid fixation in BSSRO. The disadvantages of using titanium plates and screws are their extreme stiffness that may cause stress shielding of the underlying bone and they should be removed after osteotomy site healing is complete or in case of the occurrence of complication.

In the past 15 years, the use of biodegradable materials has gained acceptance in the management of patients with dentofacial deformities. These biodegradable materials include; polymers consisting of varying compositions of α-hydroxy acid, polylactic acid and polyglycolic acid copolymers. These polymers...
degraded through hydrolysis, generating lactic or glycolic acid, a common byproduct of physiological biochemical pathways.\(^{(2,4)}\) Thus, the advantage of a resorbable plating system over a titanium plating system is that resorbable plates do not require postsurgical removal, however, they have less strength compared with titanium plates.\(^{(5)}\)

Masticatory function is an important parameter used to evaluate the outcome of orthognathic surgery.\(^{(6)}\) Masticatory function can be assessed subjectively via questionnaires or objectively using clinical tests.\(^{(7)}\) Of the various objective assessment, mixing ability and bite force measurement are considered as reliable tools for evaluating treatment outcomes.\(^{(8)}\)

Numerous studies have assessed masticatory function, including bite force, occlusal contact and masticatory efficiency, in patients with mandibular prognathism receiving orthognathic surgery with titanium plate systems.\(^{(9-17)}\)

Many studies have compared the treatment outcomes between resorbable and titanium plates and screws using subjective clinical parameters such as wound discomfort, clinical stability of the osteotomy segments, plate palpability, overall satisfaction, and objective parameters including wound healing, complications, and mechanical properties.\(^{(3,18-23)}\)

However, there is no report objectively comparing the masticatory function between titanium and resorbable plate and screw fixations using mixing ability and maximum bite force. Thus, the objective of our study was to compare masticatory function between patients who underwent orthognathic surgery using titanium and resorbable plate and screw fixations.

**Materials and methods**

This prospective study was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2018-016) and conducted from January 2018 to January 2019. Skeletal class III patients with a normal maxilla and mandibular prognathism were recruited in the study. Patients were excluded if they had temporomandibular disorder (TMD), craniofacial syndrome, history of previous maxillofacial trauma, degenerative conditions (e.g., muscular atrophy, myasthenia gravis) or systemic conditions limiting surgery. All of the participants had undergone orthognathic surgery with BSSRO setback by Thai Board qualified oral and maxillofacial surgeons at the Faculty of Dentistry, Chulalongkorn University.

The patients were divided into two groups. In the resorbable group, the patients were operated using Epker’s modification technique\(^{(24)}\) and the bone segment were fixed with straight resorbable plates (4 holes) & screws (4 screws) using the Champy technique.\(^{(25)}\) For the titanium group, the patients were operated using the same method and fixation with straight titanium plates (4 holes) & screws (4 screws).

**Sample size calculation**

The sample size was calculated using the t-test, and Wilcoxon and Mann–Whitney tests (two groups) with the G*Power program using an alpha (one tail) of 0.05, power 0.8 and an effect size (E) = 1. Based on these parameters, the required sample size was 14 patients per group.

**Objective assessment**

In each group, masticatory function assessment, consisting of the mixing ability and maximum bite force tests, was performed one day before BSSRO, 3-month and 6-month post-surgery, as described by Wanjarrurat et al.\(^{(7)}\) and Suksang and Pimkhaokham.\(^{(16)}\) Briefly, the patients was seated in a dental chair, with
their head in upright and looking forward position. Firstly, patient demographic data and facial soft tissue were recorded. Secondly, their occlusion was evaluated and the number of missing teeth were determined. Finally, the objective assessment was performed using the mixing ability test and maximum bite force test.

1. Mixing ability test. The Xylitol chewing gum (Lotte Co., Ltd. Saitama, Japan), a color-changeable chewing gum, was used to evaluate masticatory performance. The chewing gum is a stick-type gum. The gum base contains red, yellow, and blue dyes, citric acid, and xylitol. The red dye is pH-sensitive and loses its color at acidic pH. The low pH inside the chewing gum is maintained by the citric acid, and the chewing gum appears yellowish-green before mastication. When the chewing gum mixes with saliva during mastication, the increased pH inside the chewing gum as a result of elution of the citric acid makes the color of the chewing gum change from yellowish-green to red.\(^{(26)}\) Using the color scale provided with the chewing gum seal, the visual evaluation accuracy of the color change by clinicians was similar to that of using image processing techniques.\(^{(27,28)}\)

The chewing gum was prepared in 3 pieces (Fig. 1A). The patient was instructed to chew the chewing gum bilaterally for 50 cycles then remove the gum from the mouth. The color of the chewed gum was compared with the color scale on the package (yellowish-green = 1 to red = 5) (Fig. 1B). The mixing ability test was performed three times by one examiner. The mean value was then calculated.

2. Maximum bite force measurements. An occlusal force meter (GM10, Keiki, Japan) was used for measuring the maximum bite force.\(^{(29-31)}\) The meter consists of a hydraulic pressure gauge with a biting element made of a vinyl material, encased in a polyethylene tube called the disposable occlusal cap. The bite force was calculated by the meter and displayed digitally in Newtons. The main advantages are 1) portable, 2) easy to use, 3) soft biting element that enables safe, accurate, and comfortable bite force recording, and 4) bite force can be measured unilaterally or bilaterally.\(^{(32)}\)

To evaluate the bite force of the upper first molar both sides and the central incisors, the occlusal force meter was placed on the occlusal tables of the teeth (Fig. 3). The patients were requested to bite as hard as they could without causing any pain or injury and then stop when they heard the meter beep. The maximum bite force measurement was done three times per investigated tooth. The mean value of the bite force of each tooth were used for calculating an overall bite force.\(^{(7)}\)
Statistical analysis

The reliability test for mixing ability and maximum bite force methods were performed as follow. One examiner performed the mixing ability and maximum bite force test three times with three subjects, data were used for calculating intra-examiner reliability. Subsequently, the mixing ability and maximum bite force retest was performed one week later for calculating test–retest reliability. Then, the results were assessed by computing an intraclass correlation coefficient (ICC) using SPSS program.

The Shapiro-Wilk test was used to determine data normality. The mixing ability and the maximum bite force between resorbable and titanium group were analyzed by the Mann–Whitney U test. The Wilcoxon T test was used to compare pre- and post-operative values within each group. Statistical significance was defined as \( p < 0.05 \).

Results

Twenty-eight patients diagnosed with true mandibular prognathism who had undergone orthognathic surgery with bilateral sagittal split ramus osteotomy using equally two different fixation materials (titanium and resorbable) participated in this study. The demographic data showed a normal distribution and no significant differences in sex, age and the amount of mandibular setback between the resorbable and titanium groups (Table 1). The surgery was performed as planned, and no complications occurred during the surgery or follow-up period. Postoperative stability was well maintained in both groups during the 6 months follow-up period.

The ICCs for the intra-examiner reliability and test–retest reliability in mixing ability reliability were 0.86 and 0.92 respectively, while the ICCs for the intra-examiner reliability and test–retest reliability in maximum bite force reliability were 0.99 and 0.99 respectively.

Mixing ability

The average mixing ability value was demonstrated in Table 2. The results demonstrated that the preoperative mixing abilities of the resorbable and titanium groups were not significantly different. Even though the average mixing ability value at 3-month postoperative increased in each group when comparing to the preoperative value, there was no significant difference \( (p = 0.058) \). Moreover there was no significant difference between groups. In contrast, at 6-month postoperation the mixing ability of each group was significantly increased when compared with pre-surgery and 3-month postoperative respectively \((p < 0.001 \text{ and } p < 0.001)\) (Fig. 3). However, there was no significant
The average maximum bite force was shown in Table 3. The pre-surgery bite force was similar between the groups. We found that the maximum bite force at 3-month post-surgery was significantly lower than before surgery in both groups (p < 0.001), however, there was no significant difference between the groups. The greatest change in bite force during the postoperative period was observed between 3- and 6-month postoperative in both groups (p < 0.001). The bite force at 6-month postoperative was also significantly higher compared with pre-surgery value (p < 0.001) (Fig. 4). At 6-month postoperative, there was no significant difference between the groups (Table 3).

**Discussion**

The present study evaluated the masticatory function, based on mixing ability and bite force, between mandibular prognathism patients treated using resorbable or titanium plate fixation materials. We found that both groups demonstrated similar values at 3- and 6-month postoperative.

The resorbable material has sufficient mechanical strength and retains over 200 MPa up to 24 weeks, enough to support bone healing. Thus, both materials provide similar morphological and functional conditions to create a new neuro-muscular mechanism to
form a stable oral environment. Therefore, both groups showed no significant difference in these parameters.

Our study found similar preoperative and postoperative mixing abilities and bite forces in patients with mandibular prognathism treated using a titanium fixation system compared with previous reports. Kikuta et al reported that mixing ability was significantly increased at 6 months after BSSRO surgery. Although the biting force decreased at 3-month postoperative, it significantly increased at 12-month postoperative. Shiratsuchi et al reported that mixing ability was slightly increased at 2 months postoperative. Subsequently, mixing ability steadily increased with significant improvement at 3-, 6-, 12-, and 24-month postoperative. In contrast, they found that biting force was decreased at 2-month postoperative. Subsequently, the biting force showed a gradual increase at the time point evaluated. Ohkura et al evaluated the bite force in 21 patients with mandibular prognathism before and 1 year after mandibular setback surgery. They reported that the average bite force was significantly greater increased at 1-year postoperative. Islam et al demonstrated that the mixing ability at 3-month postoperative was greater than those at preoperative. Moreover, mixing ability was significantly increased at 6-month postoperative. While the bite force was reduced to minimal values at 8-week post-surgery and returned to or exceeded the preoperative values at 6-month postoperative.

Our study found that the mixing ability and maximum bite force value improved at 6-month post orthognathic surgery in both groups. Although the bite force was significantly decreased at 3-month postoperative, it significantly increased at 6-month postoperative in both groups.

The reduction in bite force at 3 months after surgery we observed in both groups likely resulted from recording the value as the maximum bite force, which could lead to some discomfort and affected the willingness of the patient and investigator to get a true maximum result. It has been suggested that the patient’s willingness to exert maximum effort was a major factor affecting bite force. Proffit et al, Iwase et al and Shiratsuchi et al postulated that patients might be concerned that their jaws had not healed completely and might be reluctant to clench their jaws vigorously after surgery. Thus, at the 3-month follow-up, the patients might have been concerned about the amount of healing/stability of their jaw and might not have used their true maximum force. In contrast, at the 6-month follow-up, the patients likely had more confidence in their jaw healing and used their true maximum bite force.

In contrast to the bite force results, we observed that the mixing abilities at 3-month postoperative in both groups were greater than those found presurgically. This might be due to the recovery of the periodontal tissue, the amount of masticatory muscle activity and stability of the skeletal structures. The patients could chew soft chewing gum and did not experience any pain when chewing.

However, Yang et al reported that changes in skeletal morphology, such as the mandibular plane angle and mandibular body length had poorly correlated with changes in bite force. In addition, Moroi et al demonstrated that the setback amount did not influence the bite force or occlusal contact area in sagittal split ramus osteotomy patients. Therefore, the increasing of mixing ability might associate with the result from recovery of the periodontal tissue, the amount of masticatory muscle activity or stability of the skeletal structures.

Orthognathic surgery creates a greater intercus-
pation of the dentition compared with those of pre-
surgery, and a post-surgical improvement in bite force
is partially due to this recovery from pre-surgical ortho-
dontic treatment.\(^\text{[40]}\) Thus, 6-month postoperative in
both groups we found significantly increased of mixing
ability and maximum bite force.

Although this study concentrated mainly on mixing
ability and maximum bite force of the 2 fixation
systems, we noted that there was no statically signi-
ficant difference between the use of titanium and re-
sorbable plates and screws fixation. However, several
factors that have the potential to alter the bite force
after orthognathic surgery, such as changes in the
muscles themselves, occlusal contacts, and the
sensitivity of the teeth and temporomandibular joints
must be taken in consideration. A future study in-
cluding these factors should be performed. Moreover,
the change of masticatory function when 2 jaws or
multiple segmented surgery performed may be inter-
esting.

Conclusion

Within the limitation of this study, the resorbable
plating fixation system provides similar masticatory
function as titanium plating fixation systems for orthog-
nathic surgery in mandibular prognathism patients.

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