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Cephalometric Evaluation of Occlusal Plane and Gonial Angle Changes in Orthognathic Surgeries

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Abstract

Background and objectives: An essential factor in building a harmonious facial profile from an aesthetic view is the change in the gonial angle, which occurs in some orthognathic surgery cases. Occlusal plane alteration is an alternative surgical technique for optimal aesthetic results and function. This study aimed to determine the cephalometric relationship between changes in the occlusal plane and gonial angle.

Materials and methods: In the present study, 76 patients who underwent bimaxillary orthognathic surgery were divided into class II and III groups. All patients had lateral cephalometric radiographs before and for a short time (maximum three weeks) after surgery. Then, cephalometric analysis of these radiographs was conducted by an orthodontist using Hexagon Imaging software, and changes in cephalometric angles were compared using two series of radiographs. Variables before and after surgery were assessed using paired t-tests, and differences in their changes were assessed using a regression test. The Pearson correlation test assessed the association of different values of the occlusal plane slope before surgery with changes in different variables.

Results: Changes in the occlusal plane were not significantly associated with changes in the gonial angle. However, changes were significant regarding the relationship between the articular and gonial angles, especially in class II patients. Gonial angle also increased significantly in class II patients and slightly decreased in class III patients. In patients whose occlusal plane rotated clockwise (mean 2.6 degrees) and those whose occlusal plane rotated counter-clockwise (mean 4.06 degrees), a strong association was observed between changes in gonial angle and articular angle.

Conclusion: There is no association between cephalometric changes in occlusal plane angle and changes in gonial angle in class II and III patients undergoing bimaxillary surgeries.

Keywords: Occlusal plane; Gonial angle; Orthognathic surgery; Cephalometry.

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1. Introduction

Alterations in the gonial angle observed in certain patients play a crucial role in creating a balanced facial profile from an aesthetic perspective (1). An open gonial angle is a common feature in individuals with mandibular prognathism, making its correction an important goal during mandibular setback procedures for surgeons.

This angle also plays an essential role in the morphology of the mandible (2). Obwegeser introduced the Bilateral Sagittal Split Osteotomy (BSSO) technique in 1957, which is now widely used to correct mandibular deformities (3, 4). He also claimed that the gonial angle decreases following the mandibular setback. However, previous studies have concluded that this angle increases following the mandibular setback, primarily due to vertical changes (5, 6).

In lateral cephalometric radiography, the functional occlusal plane is a line tangent to the mandibular premolar's cusp tip and the second molar's buccal groove. The average angle of this plane with the Frankfurt

horizontal plane in adults is 4 ± 8° (7). Clockwise changes of the mandibular proximal segment in BSSO surgery following the mandibular setback can affect the gonial angle. Gonial changes are also predictors of relapse following mandibular osteotomy (7). Patients with increased or decreased occlusal plane angles are candidates for occlusal plane changes during orthognathic surgery. Making such changes and rotating the maxillomandibular complex (clockwise and counter-clockwise) is an alternative surgical technique to achieve optimal aesthetic results and better function (8, 9).

The usual treatment plan in bimaxillary orthognathic surgeries maintains the existing occlusal plane angle or changes it by rotating the mandible after vertical, anterior, and posterior maxillary changes. For example, in some cases, sufficient mandibular sagittal movement while maintaining the original occlusal plane is not possible; in such cases, relevant results can be obtained via changes in the occlusal plane (7, 10, 11).

Although several studies have been conducted on the gonial angle and occlusal plane changes, the relationship between their changes in bimaxillary orthognathic surgeries and the bilateral mandibular sagittal split technique (BSSO) has not been investigated (12, 13). Besides, most previous studies have used lateral and posterior-anterior cephalometry radiographs to examine gonial and occlusal plane angle changes. In these studies, preoperative lateral cephalometry has been usually compared with lateral cephalometry taken six months to one year after surgery. In the present study, we tried to compare preoperative cephalometry with cephalometry taken shortly after surgery (after 3 weeks), only to study the geometric changes caused by surgery in the angles of the occlusal and gonial plane; as changes due to bone remodel seem unlikely to occur in such a short time after surgery. In some previous studies, cephalometric tracings were done manually, but in the present study, hexagon Imaging software was used to reduce the possibility of error by the operator. Knowing that the points and lines forming the gonial angle are affected by the horizontal and vertical changes of the maxillomandibular complex and the changes of the mandibular proximal segment (Figure 1, A), it seems that the changes of the occlusal plane and the maxillomandibular complex may provide helpful information about changes in this area and gonial angle after surgery (Figure 1, B).

2. Materials and methods

This study analyzed 76 patients who underwent orthognathic surgery in Ayatollah Taleghani and Imam Hossein hospitals between 2010 and 2021. All patients were treated orthodontically in the Orthodontic Department of the Dental School of Shahid Beheshti University of Medical Sciences. All patients had complete records, including lateral cephalometric radiographs before and shortly after surgery (up to 3 weeks), complete orthodontic and surgical documents, photo slides, and study cast. It should be noted that these patients had class II (underwent mandibular advancement and Lefort I maxillary surgeries) and class III (mandibular setback and Lefort I maxillary surgeries) abnormalities. Patients with syndromic problems or cleft lip and palate, those with maxillary and mandibular cant, and wide and asymmetric edentulous were excluded. Patients were divided into two groups with deformities before class II and III. Patients were also divided into two groups of clockwise and counter-clockwise rotation of the occlusal plane during surgery. For the recent classification, patients with occlusal plane changes of more than 2 degrees (similar to the method performed by Reyneke) were divided into two groups according to the direction of change (11). Then, radiographic scans were added to the cephalometric analysis software in the standard format. The software defined the desired cephalometric analysis. Two orthodontists performed landmark determination twice for each patient, and the software calculated their mean. Then, through cephalometric analysis of these radiographs using Hexagon Imaging software, cephalometric factors, including occlusal plane, gonial angle, articular angle, and mandibular plane, were compared between the two radiographs before and after the operation (Figure 2).

The research data were analyzed using the SPSS software version 26. Variables before and after surgery were assessed using paired t-tests, and differences in their changes were assessed using a regression test. Moreover, the Pearson correlation test assessed the association of different values of the occlusal plane slope before surgery with changes in different variables. In this study, only lateral cephalometric records of patients were used, which was part of the routine documents of patients before and after surgery, and no additional radiographs were taken from patients. Level of significancy was considered as P-value < 0.05.

3. Results

The relationship between changes in variables such as occlusal plane inclination, gonial, articular angle, and mandibular plane angles before and after orthognathic surgery (Table 1) (the following results are obtained according to Regression analysis):

A significant relationship (P = 0.924) was not obtained between changes in the gonial angle and occlusal plane angle before and after surgery.

There was a significant and strong correlation (P < 0.01) between mandibular plane angle and gonial angle changes before and after surgery.

A significant and strong correlation (P < 0.01) existed between articular angle and gonial angle changes before and after surgery.

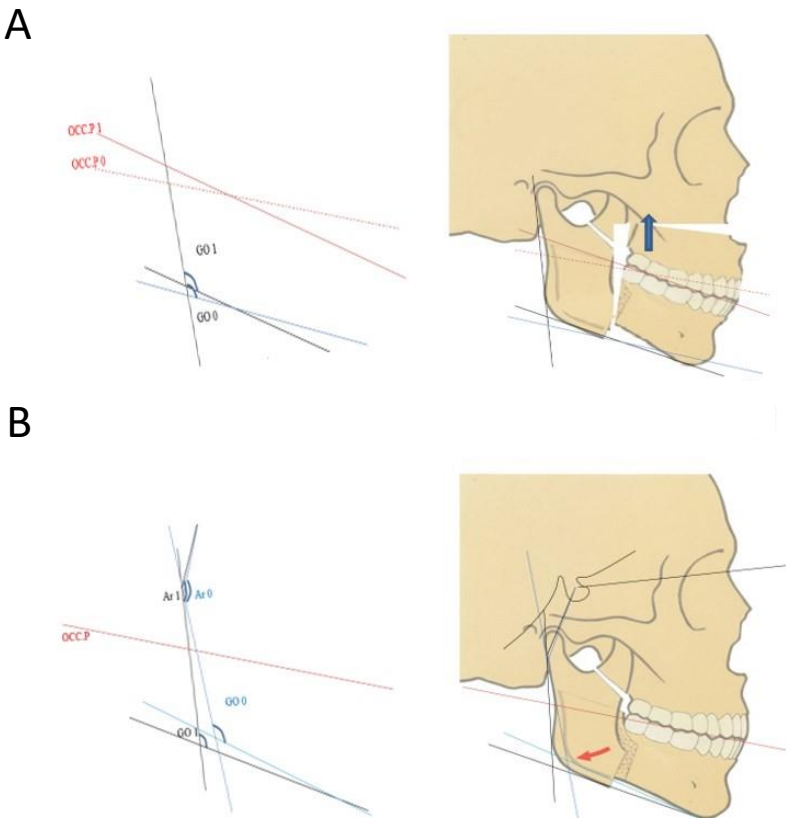

Figure 1. (A) Clockwise rotation of the maxillomandibular complex and consequent changes in the occlusal plane, which causes a change in the horizontal arm of the gonial angle. (B) Clockwise rotation or backward movement in the proximal segment that changes the gonial angle's horizontal and vertical arms.

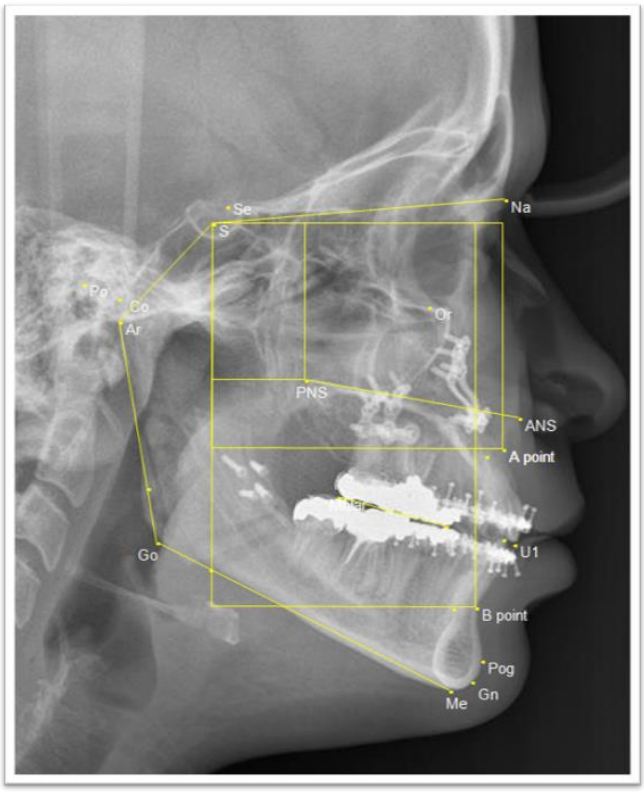

Figure 2. Double Lateral cephalometric tracing by Hexagon Imaging software (Go: Gonial angle).

It can be elicited that:
1) In patients with class II (advancement of the mandible), a significant increase in the gonial angle ($P < 0.01$), and in patients of class III (setback of the mandible), a significant decrease ($P = 0.025$) was seen in this angle.
2) Articular angle was significantly reduced ($P < 0.01$) in class II patients, but no significant change ($P = 0.19$) was found in class III patients.
3) In patients whose occlusal plane rotated clockwise (mean 2.6°), changes in gonial angle were strongly correlated ($P < 0.01$) with changes in the articular angle and angle of the mandibular plane. However, no correlation was observed between changes in the occlusal plane and changes in the gonial angle. Similar results were observed in patients with counter-clockwise occlusal plane rotation (mean 4.01 degrees).

Table 1. Statistical characteristics of MMP-9 before and after root canal treatment in the three studied groups

MMP-9 level / Group	Mean ± SD		P-Value
	Before treatment	After treatment	
Asymptomatic irreversible pulpitis	0.496 ± 0.042	0.436 ± 0.039	0.0001
Symptomatic irreversible pulpitis	0.494 ± 0.047	0.424 ± 0.066	0.0001
Healthy	0.476 ± 0.046	0.476 ± 0.046	
P-Value	0.325	0.011	

4. Discussion

Today, due to various advances in orthognathic surgery, the prognosis of this treatment has improved in terms of function and beauty. At the same time, adverse changes in the gonial angle have been prevented in this treatment. The gonial angle has played an essential role in achieving a harmonious and beautiful profile, and it has been possible to create a harmonious face by considering it. The gonial angle of the mandible consists of a line tangent to the posterior border of the ramus and a line tangent to the lower border of the mandible. Changes in the gonial angle in some patients are essential in building a harmonious facial profile from an aesthetic point of view (1). The open gonial angle is one of the characteristics of people with mandibular prognathism, and it is desirable for surgeons to correct this angle in treating these patients.
According to the definition, the functional occlusal plane is a linear tangent to the mandibular premolars' cusp tip and the second molar's buccal groove in lateral cephalometric radiography. The average angle of this line with the Frankfurt horizontal line in adults is 8 ± 4° (7). Clockwise changes of the mandibular proximal segment in BSSO surgery following mandibular setback can affect the gonial angle. Patients with increased or decreased occlusal plane angles are candidates for occlusal plane changes. Moreover, making such changes and rotating the maxillomandibular set (clockwise and counter-clockwise) is considered an alternative surgical technique to achieve optimal aesthetic results and better function (8, 9).
In the present study, the relationship between occlusal plane changes and gonial angle, as well as the relationship between gonial angle and other cephalometric variables (articular angle, mandibular plan), were assessed in 76 pa-tients (including 32 class II patients and 44 class III patients) undergoing Bimaxillary orthognathic surgery. All these patients had Mandibular Bilateral Sagittal Split (BSSO) and Lefort I Maxillary osteotomies. The obtained results showed that following mentioned surgeries (BSSO) in class II patients (mandibular advancement), the gonial angle showed a significant increase with an average of 5.82 degrees, and in class III patients (mandibular setback) showed a slight reduction of 1.55 degrees.
Obwegeser introduced the Bilateral mandibular sagittal split technique in 1957, which is now widely used in mandibular deformity correction. He also claimed that the gonial angle reduces following mandibular setback(3, 4). In the study of Yazdani et al., in treating mandibular prognathism by BSSO and vertical ramus osteotomy, the gonial angle was reduced by 2 and 7 degrees, respectively. Gugliemi et al. also reported that the gonial angle was reduced by 2.6 degrees after mandibular setback surgery in 62 patients (12, 13). In the present study, following the mandibular setback in class II patients, the gonial angle decreased by 1.55 degrees. Some previous studies found that the gonial angle increases following the setback of the mandible (5, 6). For example, the study of Ja'farian et al. showed that in the non-rigid fixation group, the gonial angle decreased by 6.2 after the operation. In the rigid fixation group patients, the gonial angle decreased by 10.3 after the surgery (5). Differences in results of this area can be due to several reasons, including differences in duration and type of fixation, application of intra-maxillary elastics, differences in the type of modification in the BSSO bone cut, the amount of gonial and occlusal plan angles before surgery, and the orthognathic operation type (double or single jaw surgeries).

In separate studies, Singer et al. and Tabrizi et al. reported that the gonial angle increases following mandibular advancement surgery (14, 15). In the present study, following the advancement of the mandible, the gonial angle showed an apparent increase of 5.82 degrees. Claudio et al. also showed that following the maxillary and mandibular height reduction surgery, the gonial angle was increased in patients (1). Jonsson et al. also reported that following BSSO mandibular surgery, the gonial angle increased by an average of 5 degrees compared to the preoperative state; however, in treatment via oblique sliding osteotomy, the average decrease in treatment via oblique sliding osteotomy gonial angle was 3.3 degrees (16). However, in the Jonsson study, cephalometric radiographs were taken 11 to 53 months after surgery. In the present study, postop radiographs were taken shortly after surgery to minimize changes in bone remodeling after surgery. This study obtained postop radiographs in all patients less than one month after surgery, during which remodeling and gonial bone resorption is unlikely. Besides, in the present study, Hexagon Imaging software was used for tracing to reduce the possibility of errors by the operator in the manual method (17).

There are several reasons for the increase in gonial angle values following BSSO surgery, one of which is the tendency of the mandibular proximal parts to move forward during surgery. Another reason is the destruction of the gonial angle, which may be caused by ischemia in the proximal parts (18). In the Dal Ponte BSSO bone cut modification, muscle is stripped from the proximal segment, impairing blood flow (19, 20). However, changes have been made in this technique, in which many muscles remain intact. As a result, it can prevent atrophy in the gonial region and eliminate one of the reasons associated with increasing the gonial angle (9, 21).

The occlusal plane in class II and class III patients decreased in the present study, although these changes were not statistically significant. Besides, in class II patients, the articular angle was significantly reduced, indicating the proximal part's displacement to the anterior during surgery in these patients. In these patients, the angle of the mandibular plane did not show significant changes. In a study performed by Reyneke et al., it was stated that in patients with an occlusal plan of 14 degrees before surgery, changes of 10 mm in the vertical dimension of the maxilla during bimaxillary surgery cause a change of one degree in the occlusal plane. Therefore, their method considered patients with occlusal plan change greater than 2 degrees as surgical treatment with occlusal plane rotation (11). This study found no correlation between changes in gonial angle and occlusal plane in patients who had displaced the occlusal plane during surgery either clockwise or counter-clockwise (more than 2 degrees). There was still a strong significant relationship between changes in the articular angle and gonial angle during the surgery. Considering that the enhanced gonial changes are evident in class II patients and considering the absence of changes in the mandibular plane and occlusal plane, as well as apparent changes in the articular angle, it can be concluded that the gonial angle changes are more affected by the position of the proximal mandibular segment during surgery. It is less affected by changes in the mandibular plane and occlusal plane. Despite fewer changes in the gonial angle in class III patients, the articular angle change was more evident than in the mandibular and occlusal plans.

In the study of Yazdani et al., there was no difference in changing the occlusal plan before and after surgery (12). Besides, in the study of Jafarian et al., changes in the occlusal plane angle in the two groups of rigid and non-rigid in the stages immediately after surgery and three months later compared to before surgery or after the opening of the IMF were negligible (6). However, in the results of the above studies, the gonial angle has changed. In the present study results, in all patients (class II and class III), no significant relationship was observed between changes in occlusal plane angle and gonial angle before and after surgery ($P = 0.9$). However, a significant solid correlation ($P < 0.01$) was observed between articular angle changes and gonial angle changes before and after surgery, which could indicate the role of changes in the mandibular proximal segment on the gonial angle relative to the occlusal plan changes. Besides, this study showed a significant relationship between changes in mandibular plan and gonial angle ($P = 0.001$).

A study by Yoshida et al. showed that specific facial patterns (depending on the type of anchorage, growth direction, and horizontal and vertical calculations) could predict the results of orthognathic surgery treatments. In their study, the most changes were seen in the brachyfacial pattern, suggesting that more severe deep bites and stronger muscle structures can create stronger natural anchorage, providing more excellent resistance to mandibular rotation. Moreover, cranial calculations related to the mandibular plane may provide specific ideas for classifying different types of faces by orthodontists and surgeons. Therefore, it is required to provide further definitions based on practical muscle function and design treatments based on calculations performed directly on the internal form of the mandible (22).

Different types of faces show different reactions to BSSO surgery. These different reactions should be considered when presenting a surgical treatment plan. On the other hand, the surgical and orthodontic treatment should be adjusted according to different facial patterns to prevent adverse changes and establish therapeutic stability in the mandibular position and occlusion. Compared to preoperative time, a good prognosis is not achieved simply by creating a single set of mandibular components. Any definition of therapeutic success must be achieved to

create an acceptable profile with matching tissue stability to the new position (23).

The desire to have an acceptable facial profile is one of the main reasons patients seek surgical treatment. In addition, having a stable mandible, necessary for adequate chewing, is very important for all patients. Therefore, appropriate and accurate surgical treatments for these patients can provide their expected results.

5. Limitations

Similar to other studies, the present study also had some limitations. The number of patients was insufficient because, with the increase in the patients' frequency, the difference in some variables may become statistically significant. In addition, our patients were followed up for a short period, and long-term results seem necessary. Also, this study was conducted on a limited population of people referred to Ayatollah Taleghani and Imam Hossein hospitals in Tehran, so these results may not be generalizable to all people.

6. Conclusion

In assessing the facial aesthetics of orthognathic surgery candidates and postsurgical results prediction, specific cephalometric angle changes such as occlusal plane angle, articular angle, and gonial angle can be predicted considering types of patient skeletal abnormality (class II and class III) and type of corrective surgery. The treatment plan should consider these factors to achieve a harmonious face after surgery. This study showed that in class II and class III patients (both clockwise and counter-clockwise changes of the occlusal plane), there was no significant relationship between the changes of the occlusal plane and the gonial angle. However, a solid significant relationship was observed between articular angle (proximal segment) and gonial angle changes.

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Ethics

The research was conducted following the tenets of the Declaration of Helsinki. This study resulted from a thesis project (No. 935) approved by the ethics committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Author contributions

Mohammad Jafarian: Conceptualization, Methodology, Investigation, Writing – Original draft, Supervision, Project administration

Mohsen Golkar: Conceptualization, Methodology, Investigation, Data curation, Writing – Original draft, Project administration

Mohammad Behnaz: Conceptualization, Methodology, Supervision

Mostafa Alam: Investigation, Writing – Review & editing, Supervision

Ardeshir Khorsand: Investigation, Data curation, Writing – Review & editing, Visualization

Ramin Ansari: Investigation, Data curation, Writing – Review & editing, Visualization

Amir Arsalan Keshtkar: Conceptualization, Methodology, Investigation, Data curation, Writing – Original draft, Visualization, Project administration

Conflict of interest

The authors declare no conflict of interest.

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