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The accuracy and stability of intentional change of frontal ramal inclination in orthognathic surgery for the correction of facial asymmetry

안면 비대칭 교정을 위한 악교정 수술에서 전두단면 하악지 경사의 의도적 변화시 정확성과 안정성

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Abstract

Objective:

To assess the accuracy and stability of intentional change of frontal ramal inclination (FRI) in orthognathic surgery for the correction of facial asymmetry.

Materials and methods:

The study included 20 patients (5 males and 15 females) who were diagnosed as skeletal Class III malocclusion with facial asymmetry, underwent orthognathic surgery including intentional change of FRI for the correction of facial asymmetry, and had Cone-Beam Computed Tomography (CBCT) 2 – 3 weeks before surgery, 3 days after surgery (T1), and 6 months after surgery (T2). After performing virtual surgical planning, the data of virtual surgical planning (Tv) was utilized to assess the right and left FRI one time. The accuracy of FRI correction (ΔT1-Tv) and the stability of corrected FRI (ΔT2 -T1) was evaluated.

Results:

Surgery was successful for all the patients. All patients achieved good final occlusion and facial asymmetry were resolved. The mean absolute value of accuracy of FRI correction (ΔT1-Tv) and the stability of corrected FRI (ΔT2 –T1) were $0.87 \pm 0.25^{\circ}$ and $0.58 \pm 0.34^{\circ}$, respectively. No statistically significant values were found in both accuracy and stability.

Conclusion:

Results indicated that computer aided design and computer aided manufacturing (CAD/CAM) assisted orthognathic surgery might have a high degree of surgical precision and stability of intentional change of FRI.

Keywords:

Stability of frontal ramal inclination, facial asymmetry, CAD/CAM, BSSRO, orthognathic surgery.

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Abbreviations in this study

FRI	frontal ramal inclination
FA	facial asymmetry
CBCT	cone-beam computed tomography
VSP	virtual surgical planning
T1	post surgery
T2	after 6 months of surgery
Tv	virtual surgical planning
SD	standard deviation
COA	conventional orthognathic approach
BSSRO	bilateral sagittal split ramus osteotomy
3D	three dimensional
2D	two dimensional
CAD/CAM	computer aided design and computer aided manufacturing
TMJ	temporomandibular Joint
STL	stereolithography
MSP	mid-sagittal plane
CLP	cleft lip and palate
DICOM	digital imaging and communication in medicine

Introduction and background

Facial asymmetry (FA) can be defined as significant differences in the position of soft tissues and skeleton on the left and right sides of the face[1]. It is reported that having facial asymmetry would negatively impact facial beauty and harmony[2,3] and subsequently it would not only affect the patient's psychological wellbeing, but it also affects their quality of life [2,4].

It is reported that FA occurs among more than 42% individuals in South Korea[5]. It is also observed in approximately 40% of people in the USA[5] and in a smaller number (25%) of population in Hong Kong[5,6].

FA can be categorized into the following three categories. First category is congenital FA, and can present as cleft lip and palate- hemifacial microsomia- vascular disorder. Second category, developmental FA can arise during growth with inconspicuous etiology. The final category is acquired FA, and can occur because of injuries or diseases, such as facial trauma, temporomandibular joint disorder, ankylosis, and facial tumor[7].

Despite being researched extensively, the etiology of FA remains unknown. It is postulated however that it could be related to class I occlusion and to class II and III to a lesser extent[7].

A variety of events can influence the skeletal and dental components, resulting in FA vertical and lateral displacement of the mandible due to mandibular or condylar proliferation[8], rotational displacement of the mandible[9], difference in the length of the left and right mandibles, lateral or frontal ramal inclination difference, difference in size or shape of craniofacial structure and lateral odontogenic compensation[10,11]

Conventional orthognathic approach (COA), does not apply CAD/CAM technology with these methods although it has been used for facial asymmetry treatment[12]. However, it has several limitations that may negatively affect the surgery. It might lead to inaccurate positioning of condyles, displacement and errors in the repositioning of the condylar segment and facial asymmetry cannot resolve correctly. Thus, CAD/CAM technology is used to overcome limitations of COA[7,12].

It is essential to know that the diagnosis of FA cannot be done by two dimensions (2D) cephalometric because not only does it provide limited information about facial asymmetry, but it also does not help in determining the appropriate plan for treatment[13]. However, the recent three dimension (3D) image indicates its effectiveness in rotating and showing different angles of the skull[14]. Such rotation would help surgeons in taking accurate and precise measurements. This would then assist in analyzing the structure of facial asymmetry and help in visualizing the structures clearly, which cannot be seen in 2D compared to 3D[15].

The 3D imaging and CAD/CAM technologies have been applied widely both nationally and internationally. Such technologies help clinicians by providing accurate guidance for assessment, which helps in planning for treatment in clinical practice easier. In order to enhance the outcome of surgery, advanced technology has been used in orthognathic surgery[14,16]. The implementation of such technology in this field would not only enhance gaining the optimal function, but it also improves aesthetic outcomes, patient satisfaction, precise translation of the treatment plan, and facilitate intraoperative manipulation [15,16].

FRI has been defined as the angle between mid-sagittal plane and Cd_{lat}- Go_{lat} [5]. It is one of the important factors in identifying facial asymmetry. There are some differences in

FRIs between both sides among patients with facial asymmetry. It is essential to know that if FRIs are corrected inappropriately, facial asymmetry would not be corrected accordingly even if the orthognathic surgery is performed[2]. It seems that the FRI is rarely examined to find the effectiveness of COA on patients with facial asymmetry.

Orthognathic surgery is performed for the treatment of facial asymmetry, but there was no quantitative method to overcome the difference between the left and right of FRI, which is commonly observed in patients with facial asymmetry after bilateral sagittal split ramus osteotomy (BSSRO)[16]. In this case, more symmetrical correction to facial asymmetry is impossible[14-15,17].

With the recently introduced CAD/CAM technology to orthognathic surgery, it is possible to intentionally change the FRI in patients with facial asymmetry by applying virtual surgery using a simulation software, cutting guides, and customized plates, to correct facial asymmetry more accurately[14,17-19].

In order to effectively manage the above-mentioned problems, different methods including pre-operative orthodontic treatment and orthognathic surgery can be implemented. However, it is found that CAD/CAM technology was accurate and effective in reducing the aforementioned problems. Therefore, it is crucial to consider the FRIs in diagnosis and treatment plan[19]. Minimization in the proximal segment displacement of the mandible, distal segment position, and symmetrical FRI in both sides would help in minimizing residual asymmetry after orthognathic surgery[16,20].

It is possible that residual asymmetry may remain after surgery by using COA of BSSRO, but using 3D virtual surgery and CAD/CAM technology would help in achieving facial asymmetry accurately. However, there are some chances of relapse tendency when using 3D technology. Therefore, the aim of this study is to evaluate the accuracy of intentional change in FRI between VSP and 3 days post-surgery. The study will also evaluate stability of intentional change in FRI between post-surgery (3 days) and after 6 months of surgery to suggest novel treatment methods to orthognathic surgery for treating patients with facial asymmetry.

Materials and methods

Subject:

Patients who underwent orthognathic surgery at Seoul National University Dental Hospital (SNUDH) from 1st January - 2019 to 31st December - 2021 were included in this study. There were 20 patients, consisting of 5 males and 15 females, who had been diagnosed as skeletal Class III malocclusion with facial asymmetry. The total number of FRI was 40.

The inclusion criteria were as follows: 1- patients who underwent orthognathic surgery of LeFort I osteotomy and BSSRO including intentional change of FRI by both virtual surgery and actual surgery by a single surgeon, who uses CAD/CAM-made customized surgical guide stents (cutting guides), wafers, and metal plates using FACEGIDE® system (MegaGen implant, Daegu, Republic of Korea) 2- patients who did not have mandibular angle reduction surgery to change the shape and position of gonion.

The exclusion criteria included patients who had a syndrome or a congenital deformity (i.e., hemifacial microsomia, CLP), degenerative temporo-mandibular joint diseases or any other condition which can affect condyle stability, as well as who had one jaw surgery.

This retrospective study was reviewed and approved by the Institutional Review Board of the Seoul National University Dental Hospital (SNUDH), Seoul, Republic of Korea (IRB number ERI211034).

Methods:

1- Acquisition of skull and dentition data for virtual surgical planning

In order to provide consistent measurements, it is crucial to go through the data acquisition. Information about size and shape of soft and hard tissues should be provided in the data acquisition stage in VSP and standard methods should be used to capture images. Information about texture and color can be provided in a high resolution through 3D.

When the surgical planning of patient was established, 3D facial CBCT was taken and dental cast model was fabricated. By using R2GATE system, re-orientation of CBCT image was done to align natural head position of the patient. Re-orientated CBCT image then translated to STL file for 3D virtual surgery. Scan file of the dental cast model was achieved and superimposed to the STL file of 3D virtual skull image to compensate for unclear dental images because of artifact from the orthodontic bracket and wire. Finally, virtual surgery was performed by using Geomagic Freeform Plus (3D systems).

2- Procedure of virtual surgical planning including intentional change of FRI

After preparation of 3D virtual skull images, the virtual surgery was done. By using Geomatic Freeform Plus (3D systems), maxillary segment and mandibular distal segment were repositioned as per surgical planning. Cant correction, horizontal and vertical movements of the maxilla-mandibular complex was conducted. Restoration of the symmetry of the dental arch in relation to the midsagittal plane was achieved through the yaw correction. It was performed by rotating the maxilla-mandibular complex on horizontal plane with the center of rotation at the interdental central incisors tip #11,21 to keep the alignment between dental midline and facial midline.

Then, intentional change of FRI was done. When medial rotation was needed to change the FRI, the uppermost point medial pole of condyle was adopted to rotation center. When lateral rotation was needed, the uppermost point of lateral pole of condyle was adopted to rotation center. These can avoid the narrowing of intra-capsular space to prevent post-operative TMJ pain and relapse tendencies. The final skull images of virtual surgery were reviewed and confirmed by surgeon (Figure 1, 2)**.**

3- Fabrication of computer-aided design and computer -aided manufacturing – made customized surgical guide stents, wafer, and customized titanium plates

When the VSP was performed, surgical stents, wafers, and customized titanium plates were designed and manufactured. Surgical stents contain osteotomy lines and drill holes for fixation after repositioned segments. Intermediate wafer was designed for maxillary first surgery, so the repositioned position of maxilla can be translated to mandibular position. Final wafer was designed for desired final occlusion to make ideal upper and lower dental coordination. Customized plates were designed to fix maxillary and mandibular segment after osteotomy and repositioned segments. Notably, mandibular customized plates can reflect the change of FRI by connecting bridge angle. Surgical stents and wafers were made by 3D printing machine ((Meg-printer II and White CAP Pro, MegaGen Implant, Daegu, Republic of Korea) and customized plates were made by CAM machine (ARDEN, TPS Korea Ltd., Gwangju, Republic of Korea) (Figure 3).

4- Orthognathic surgery

All patients underwent orthognathic surgery under general anesthesia using nasotracheal intubation. For the Le Fort I osteotomy, surgical stents for osteotomy lines and drill holes were applied and marked after exposing the maxilla. Osteotomy was done along the marked line and down fracture of maxillary segment was performed. By using intermediate wafer, maxillary segment was repositioned to planned position and fixed with customized titanium plates. Next, BSSRO of mandible was done. Surgical stents for the mandible were also applied and osteotomy lines and drill holes were marked. Following this, the sagittal split ramus osteotomy was performed. Distal segment of mandible was repositioned by final wafer, and internal fixation was done with customized plates. In this step, intentional change of FRI can be performed using customized plates. After the fine occlusion was confirmed, layered suture was done with resorbable materials (Figure 4).

5- Evaluation of the accuracy of intentional change of FRI

CBCT was taken at 3 points; 2-3 weeks before surgery, 3 days following surgery (T1) and 6 months after surgery (T2) at the natural head position and Centric Occlusion (CO) bite (Dinnova 3, HDX, Seoul, Korea: field of view, 20x 19 cm;100Kvp,9 mA). The skeleton and soft tissue information of CBCT were transformed into Digital imaging and communications in Medicine (DICOM) data. Cast model of dentition was made from patient cast model information and was digitalized with a scanner (DOF Freedom HD, DOF, Seoul, Republic of Korea) and converted into STL then data was merged with the 3D skull image of the software FACEGIDE® system (R2GATE, Megagen implant, Daegu, Korea). Finally, we used the data of VSP (Tv).

To evaluate the FRI accuracy, the difference of FRI was calculated with each landmark at skull point by using 3D merging software (Geomagic Control X, 3D systems). The definition of landmarks, reference lines and measurements used in this study were enumerated (Table1). The accuracy of intentional change of FRI was measured following the superimposing of FRI, which was modified by 3D virtual surgery (TV). FRI was also measured post-operatively through CBCT image (T1). The amount of FRI change after virtual surgery and after actual surgery (Δ T1-Tv) were calculated (Figure 5, 6).

6- Evaluation of the Stability superimposed of FRI

After measuring the accuracy of modified FRI through VSP and post-operative, the stability of FRI was checked. T1 (post-surgery) and T2 (6 months after surgery) were superimposed and measured then the stability was calculated (Δ T2 -T1). 3D facial CBCT images of T1 and T2 were converted to STL files, and superimposed by using 3D merging software (Geomagic Control X, 3D systems) (Figure 7).

Data analysis:

Measurements were taken three times, including Tv, T1 and T2 of surgery. The mean absolute value of the two measurements (Tv and T1) were used for accuracy of FRI whereas the other two measurements (T1 and T2) were used for stability of FRI. The IBM Statistics (SPSS) version 21.0 was used for data analysis. Descriptive analysis was used for participants' data presentation. Frequency, percentage, mean, and standard deviation were presented. Wilcoxon signed rank test (non-parametric) was also used for statistical analysis. *P*-value 0.05 was considered statically significant.

Results

The total number of participants who participated in the study was 20 patients. The mean ages are 23.9 $\pm$ 4.5 years (Table 2). The mean absolute value of virtual FRI correction is 3.8 $\pm$ 2.5° and the actual change of FRI is 4.0 $\pm$ 2.7° (Table 3).

The outcome of the study illustrates that the mean differences of the amount of change in FRI in accuracy between (ΔT1-Tv) is 0.87 $\pm$ 0.25° and the mean of changes of stability in FRI between (ΔT2-T1) is 0.58 $\pm$ 0.34° (Table 3,4).

The study shows that the p-value of mean difference of FRI between the T1-Tv is $p>$ 0.05. Therefore, the difference is not significant. This indicates that the intentional change of FRI was accurate.

Also, the p-value for the mean difference between T2-T1 was $p>$ 0.05, showing that the difference was not significant. This implies that the FRI of subjects were stable even after 6 months.

Discussion

Bone discrepancy is reflected in the facial soft tissues, causing an unfavorable aesthetic impact[21,22]. Patients with these disharmonies are usually treated with a combination of orthodontic treatment and orthognathic surgery to improve occlusion and facial aesthetics[21,22].

BSSRO is one of the most popular surgical methods for correction of mandibular skeletal deformities and divides the mandible into distal and proximal segments. Most changes occur in the distal segment of the mandible as surgeons put great effort into keeping the proximal segment unchanged in position during surgery, for the sake of stability of the intended mandibular position[23,24].

It was reported that BSSRO was first used in Europe by Trauner and Obwegeser in 1957. It has been modified by several surgeons. However, BSSRO can still be used for correcting a wide range of dentofacial deformities like facial asymmetry[25].

Changes in FRI after orthognathic surgery in skeletal class III asymmetry patients were observed even if the surgeon did not intend for these changes to occur and aimed to maintain the mandibular proximal segment unaltered[26]. Correction or change of FRI involves changes in the proximal segment of the mandible[26]. As a result, the stability of its correction is an issue that must be addressed.

There are a limited number of studies which have been carried out to investigate the stability of intentional FRI changes during surgery. Results showed that FRI can change during BSSRO orthognathic surgery in skeletal class III asymmetry patients even without intended manipulation of the mandibular proximal segments [20,23,26].

Kim et al.[28] conducted a study to investigate proximal segment changes in facial asymmetric patients who underwent orthognathic surgery[28]. They found that there were no significant differences in the condylar head position among patients[28]. Another study was carried out by Angle et al.[29] to evaluate changes in proximal segment after BSSRO advancement surgery. The results of their study showed that such changes had no influence on postsurgical relapse[29].

Mandibular asymmetry can be corrected using COA[12] and this method might help in modifying FRI during the procedures of surgery[26]. Most surgeons make great efforts to minimize the gap between proximal segment and distal segment, where the proximal segment can be rotated near the distal segment during plate fixation[12,28]. Following the surgery, some postoperative relapse, including pain in TMJ, displacement in disc and resorption in condyle can occur due to displacement[30].

There are other limitations that have been identified in using COA. One of these is that the COA is not a quantitative method. Thus, surgeons will not be able to correct FRI quantitatively because COA depends on the experience of surgeons [12,26]. Therefore, residual asymmetry of FRI can remain. Using CAD/CAM would help surgeons to correct FRI accurately through 3D technologies, as these methods are quantitative which assist in facial asymmetry correction by intentional FRI correction[12,14,19].

The 2D radiographs and manual model surgery has some weaknesses, especially in the case of patients with major facial asymmetry [13,14] as 2D cephalometric images cannot provide full information about the 3D structures. When conventional 2D surgical plans are executed, unexpected problems such as a bony collision in the ramus area, the discrepancy in pitch, roll, yaw rotation, midline difference and chin inadequacy may occur[13,15,31].

Using preoperative 3D and VSP allows achieving an accurate and realistic vision of the surgical plan in orthognathic surgery[32,33]. This helps the surgeons conduct the evaluation in a precise and accurate way on how to perform the surgery. It is indeed true that the use of VSP improves accuracy, especially for correlation with the skeletal structure[32,33].

In this study, FRI was intentionally modified to correct facial asymmetry by CAD/CAM technology through applying virtual surgery using a computer simulation, surgical stent, and customized plate.

The following points need to be taken in consideration in facial asymmetry correction. Firstly, the mandible should be symmetric in the axial plane. Secondly, FRI on the right and left sides should have the same degree of changes. Thirdly, the interference between both distal and proximal segments should be minimized, and finally, a customized plate can be used for maintaining the proximal changes[28,34].

In this study, VSP and custom plate for intentionally modifying FRI were used to decrease postoperative residual asymmetry by using different centers of rotation. When medial rotation was needed to change the FRI, the uppermost point of the medial pole of the condyle was adopted to the rotation center. When lateral rotation was needed, the uppermost point of the lateral pole of the condyle was adapted to the rotation center. These can avoid the narrowing of the intra-capsular space to prevent postoperative TMJ pain and relapse tendencies.

As there have been no previous studies conducted on where to set the rotational center during intentional change of FRI, we planned not to reduce the joint space in order to reduce TMJ discomfort caused by narrowing the joint space.

From the researchers' clinical experience in this study, they found that no complications, such as TMJ pain, clicking, or condylar resorption were identified among patients. Importantly, patients reported satisfaction with the outcomes of surgery and they did not report any complications following the surgery, even though more studies are needed about center of rotation.

The findings of this study showed that the mean absolute value of actual change of FRI was 4.0° and the difference mean absolute value of accuracy of FRI correction from VSP and post -operative was 0.87°. This finding broadly supports the work of other studies in this area[17,26,34]. It is reported that in order to accept the accuracy in computer-assisted surgery the clinical feature of angular differences should be less than 4° [34,35].

Another study found that the mean absolute value of accuracy of intentional change of FRI from VSP to actual surgery was 0.1°[34]. Additionally, a recent study of Zhang et al.[36]. evaluated the accuracy of VSP to actual surgery. The outcome of their study demonstrated that the overall mean angular difference was 0.95[36], which was an improvement as compared with their previous study. This was thought to be as a result of surgical experience, 3D printing technology, and improvement of the elasticity modulus of 3D-printed surgical templates[37]. This means that the accuracy in this study met the clinical feature and it is accepted indicating the VSP can be transferred to the actual surgery. However, Zhang et al.[36] used a custom plate without intentional changes of FRI and this was the differences between their study and this study.

Some studies compared computer-assisted planning with classical planning and found that a good degree of accuracy was observed in facial asymmetry correction when computer-aided planning was used [34,38-40]. The 3D simulation method has been accepted for planning in orthognathic surgery and led to significant improvements in surgical outcomes[14,38].

Stability is another area that is evaluated in this study. It can be defined as the absence of relapses following surgery[41]. It is one of the most important criteria for clinicians to determine the success of treatment in orthognathic surgery for patients[42,43].

The new position of the mandible was determined by FRI. To minimize unbalanced tension, proper positioning was confirmed by comparing the FRI in the immediate postoperative from CBCT image with VSP[26].

In this current study, the mean change of stability in FRI between post-operative and 6 months after operative is 0.58°. It is reported that the less the value in stability indicates a more stable of FRI [42,45] and this indicates that the stability of FRI was presented. This result may be explained by the fact that a custom plate was used in the surgery. This may improve the stability of FRI after bone fixation reducing the osteotomized mandibular tension[44]. Park et al.[45] reported that facial asymmetry was improved due to the occurred changes in FRI although direct manipulation was not performed in the proximal segment[45].

Following the surgery, CBCT was used with patients twice (3 days post-operative and 6 months after) to evaluate the stability and it was noticed that the FRI changes were stable for 6 months without any identified complications. Similarly, Park et al.[45] found that the changes in FRI were stabled for more than 6 months following the surgery[45]. Pan et al.[43] demonstrated that the ramus angle and ramus inclination angle increased stability after orthognathic surgery and then regressed by using CAD/CAM technology[43,45]. However, this result can be difficult to explain or compared with other studies as to the best of our knowledge, as limited studies have been conducted to evaluate the stability of intentional change of FRI among patients with facial asymmetry.

Although this study showed significant findings that accuracy and stability were accepted, some limitations were identified. One of the identified limitations of this study is that the sample was small as only 20 patients (40 FRIs) were included in the study. Several questions still were unanswered regarding the stability of FRI. Therefore, it is recommended to conduct further studies to evaluate the stability of FRI after one year or for a longer duration following the surgery to gain better understanding in such areas.

Summary

The present results tend to confirm that the use of CAD/CAM technology and virtual surgical planning might assist orthognathic surgery in having a high degree of the accuracy and stability of intentional change of FRI.

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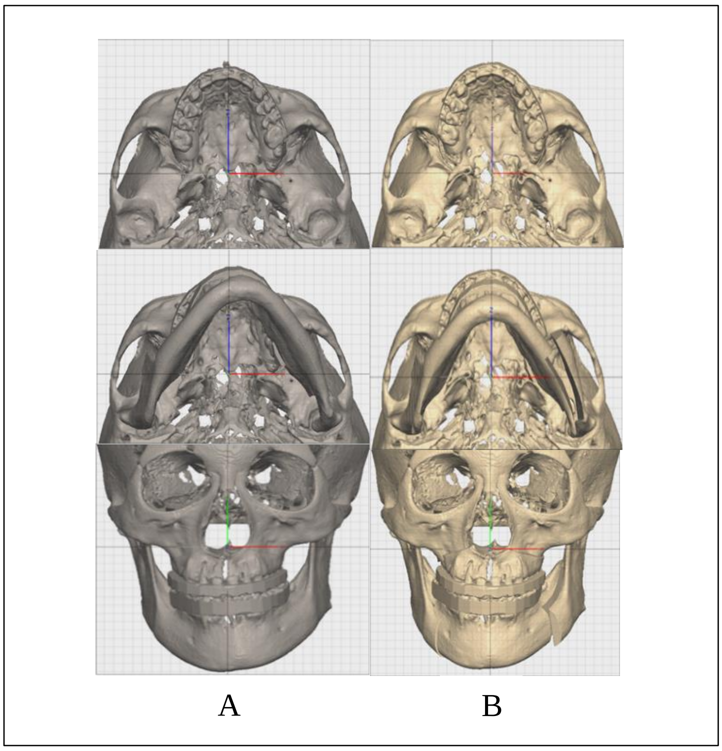

Figure 1: Virtual surgical planning was performed A. Pre operative 3D skull B. Pitch, roll, and yaw movement in surgical plan.

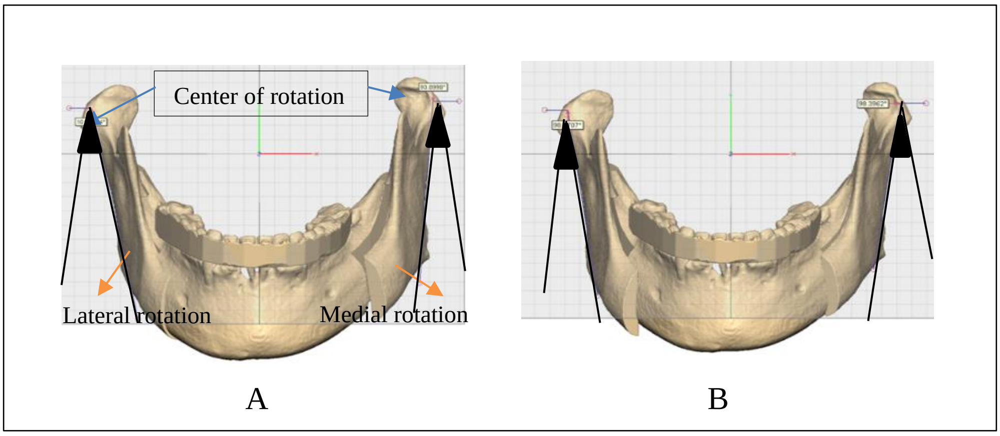

Figure 2: FRI. A. Before FRI change B. After intentional FRI change when medial rotation was needed to change the FRI, the uppermost point medial pole of condyle was adopted to rotation center. When lateral rotation was needed, the uppermost point of lateral pole of condyle was adopted to rotation center in VSP.

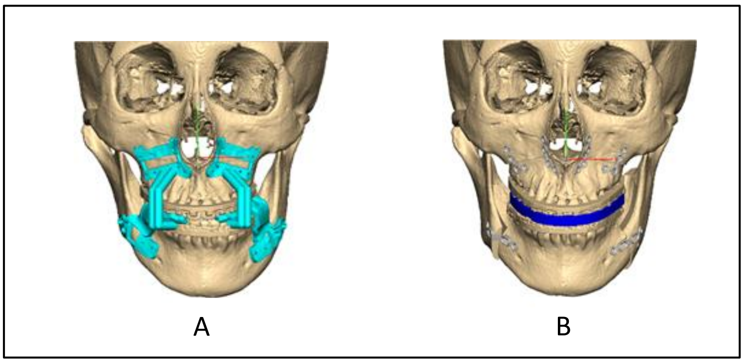

Figure 3: Customized surgical guides, occlusal wafers and metal plates. A. Cutting guide designs in VSP B. Occlusal wafer, maxillomandibular customized metal plates.

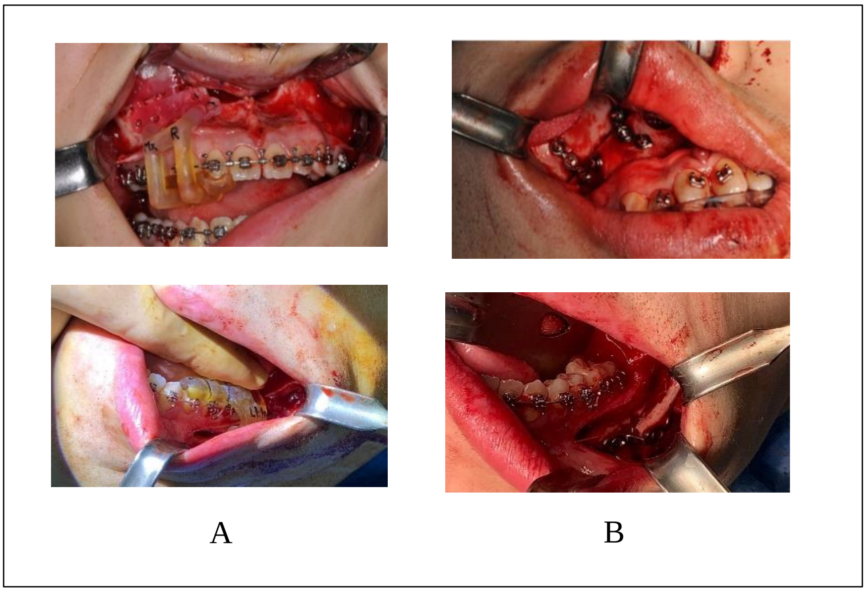

Figure 4: Intraoperative images A. Cutting guides for maxilla and mandible B. Customized metal plates for maxilla and mandible.

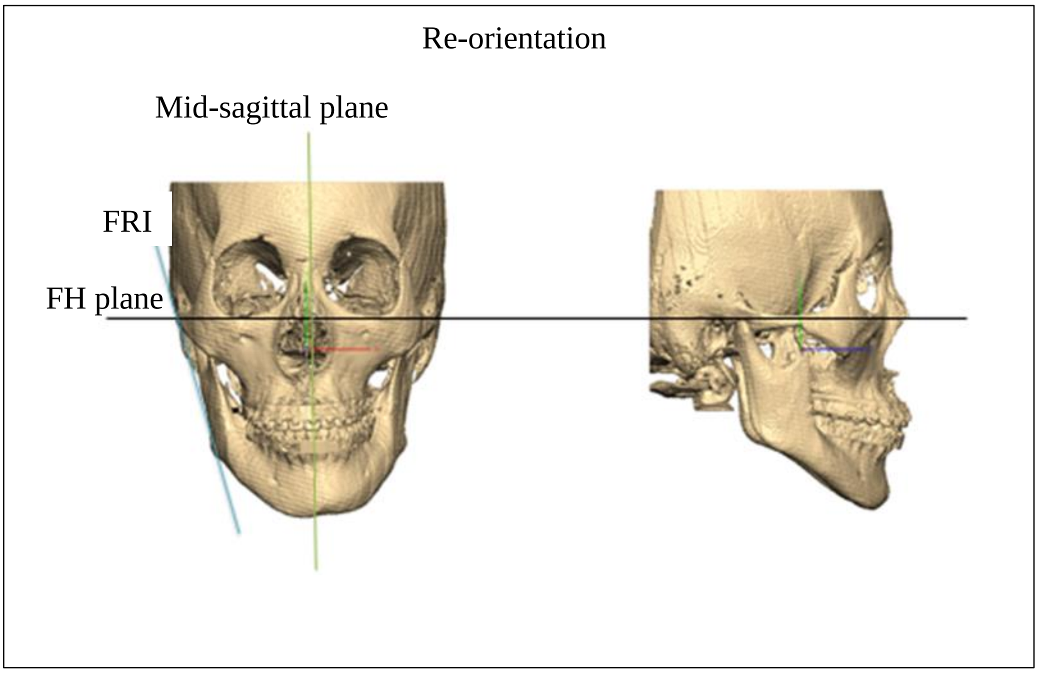

Figure 5: Re-orientation of 3D skull image for measuring FRI. The FRI was measured at frontal plane, skull image was re-oriented by mid-sagital plane and FH plane to set the FRI in standard position .

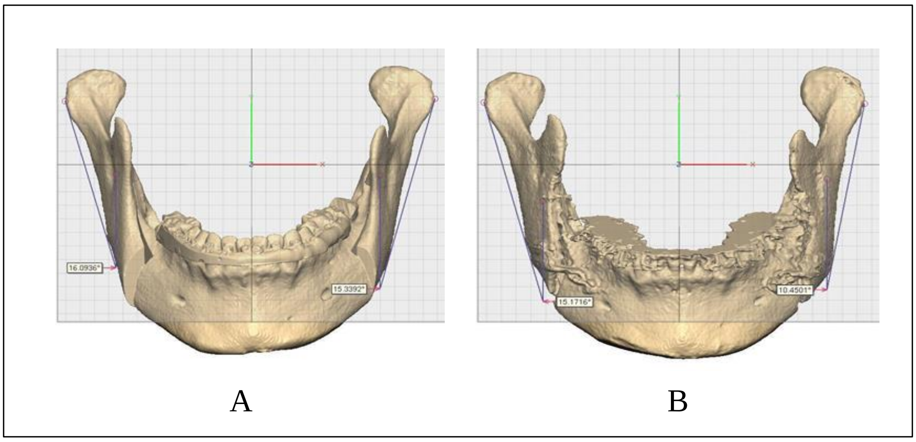

Figure 6: Measurements of FRI to evaluate the accuracy A. Virtual surgical planning (Tv) B. Post-surgery (T1).

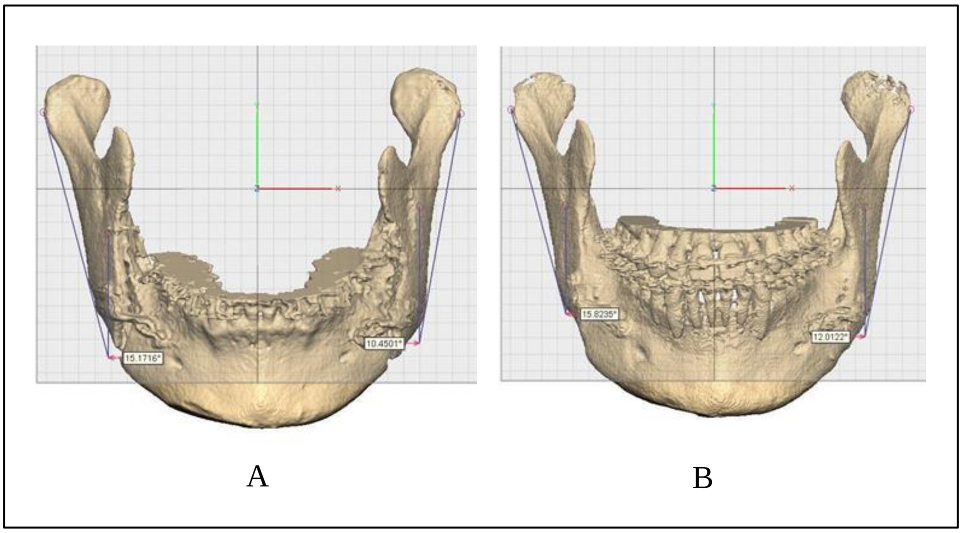

Figure 7: Measurements of FRI to evaluate the stability A. Post surgery (T1) B. After 6 months post surgery(T2).

List of tables

Table 1: The landmark, measurements and reference lines used in this study

Landmark, measurements and reference lines	**Abbreviations**	**Definition**
Mid-sagittal plane	MSP	The plane passing through the nasion, crista galli, and basion perpendicular to the FH plane.
Frontal ramal inclination	FRI	Angulation between (Cd_{lat} -Go_{lat}) and the MSP.
Frankfort - horizontal plane	FH plane	The plane passing through three points of the right and left porion and the left orbitale.
Nasion	Na	The most anterior point of the frontonasal suture.
Basion	Ba	The midline points of the anterior margin of the foramen magnum.
Menton	Me	The lower point on the mandibular symphysis.
Orbitale	Or	The most inferior point of the lower margin of the bony orbit.
Porion	Po	The most superior point of the external auditory meatus.
Lateral point of condylar head	Cd_{lat}	The most lateral on the condyle head of the mandible on frontal view.
Lateral point of gonion	Go_{lat}	The most lateral point on the lateral and lower of the mandible angle on frontal view.

Table 2: Demographic data of participants.

Gender	**N**
Female	15
Male	5
Age	23.9 ± 4.5

Table 3: The mean absolute value of intentional change of FRI from Tv to T1 for accuracy evaluation.

		FRI (Rt)		
FRI	T0°	Tv°	T1°	(Δ T1-Tv)°
1	107	104.7	104.9	0.2
2	103.3	101.2	100.3	0.9
3	107.7	107.6	106.4	1.2
4	109.4	101.2	102.1	0.9
5	105.7	104.1	105.2	1.1
6	99	97	97.6	0.6
7	110.00	109.2	110.3	1.1
8	99.00	104.5	105.7	1.2
9	90.70	97.7	98.9	1.2
10	109.30	107	108	1
11	103.10	100	101	1
12	105.00	106.4	105.7	0.7
13	101.20	106.4	107.1	0.7
14	90.00	95.5	96.4	0.9
15	95.30	106	107	1
16	106.10	105.1	104	1.1
17	100.10	97.10	96.00	1.1
18	105.20	102.10	101.10	1
19	104.40	102	101.4	0.6
20	102.10	98.1	97.1	1
		FRI (Lt)		
1	101.7	103.4	104.00	0.6
2	93.8	95.6	96.70	1.1
3	104.3	105.6	106.70	1.1
4	92.5	100.1	99.20	0.9
5	96.5	106.6	107.40	0.8
6	93.8	96	95.10	0.9
7	95.50	101	102.00	1
8	105.4	102.5	102.10	0.4
9	101.70	99.8	100.10	0.3
10	101.2	105.1	106.1	1
11	89.30	94.10	95.00	0.9
12	104.70	102.1	101.70	0.4
13	109.7	106.5	105.80	0.7
14	94.8	92.5	93.60	1.1
15	100.6	93.8	94.80	1
16	95.50	99.5	98.70	0.8
17	90.3	96.4	97.30	0.9
18	98.80	100.5	100.10	0.4
19	101.20	105.4	106.20	0.8
20	95	100.0	101.0	1
Mean	(Δ **Tv − T0**)	(Δ **T1 − T0**)	(Δ **T1 − Tv**)	
	3.8 ± 2.5°	4.0 ± 2.7°	0.87 ± 0.25 °	
		P > 0.05 (*p*= 0.69)		

Table 4: The mean absolute valuet of change FRI in T1and T2 for stability evaluation.

	FRI (Rt)		
FRI	T1°	T2°	(Δ T2-T1)°
1	104.9	103	1.9
2	100.3	100.6	0.3
3	106.4	106.2	0.2
4	102.1	101	1.1
5	105.2	105.9	0.7
6	97.6	98.4	0.8
7	110.3	110.8	0.5
8	105.7	105.6	0.1
9	98.9	98.3	0.6
10	108	109	1
11	101	101.3	0.3
12	105.7	104.7	1
13	107.1	108.1	1
14	96.4	94.7	1.7
15	107	107.4	0.4
16	104	105.3	1.3
17	96.00	95.9	0.1
18	101.10	100.1	1
19	101.4	102.6	1.2
20	97.1	97.7	0.6
	FRI (Lt)		
1	104.00	104.1	0.1
2	96.70	97.4	0.7
3	106.70	105.9	0.8
4	99.20	99.1	0.1
5	107.40	108.2	0.8
6	95.10	94.9	0.2
7	102.00	101.7	0.3
8	102.10	102.3	0.2
9	100.10	99.5	0.6
10	106.60	106	0.6
11	95.00	95.6	0.6
12	101.70	101.2	0.5
13	105.80	106.2	0.4
14	93.60	95.8	2.2
15	94.80	95.4	0.6
16	98.70	98.9	0.2
17	97.30	97	0.3
18	100.10	100.4	0.3
19	106.20	106.6	0.4
20	101.0	101.1	0.1
Mean	**(Δ T2-T1)**		
	$0.58 \pm 0.34^{\circ}$		
	$P > 0.05$ ($p = 0.50$)		

국문초록

목적:

안면 비대칭 교정을 위한 악교정 수술에서 전방 하악지 경사(FRI)의 의도적인 변화의 정확성과 안정성을 평가한다.

방 법:

안면비대칭을 동반한 골격성 III 급 부정교합 진단으로, 의도적인 전방 하악지 경사도 수정을 동반한 악교정 수술을 시행 받은 20 명의 환자(5 명의 남성, 15 명의 여성)를 대상으로 하였다. 각 환자는 술전 2-3 주, 술후 3 일(T1)과 6 개월(T2)에 각각 콘빔전산화단층촬영(Cone-Beam Computed Tomography, CBCT)을 시행하였다. 가상 수술 계획을 세웠으며, 가상 수술 데이터(Tv) 상에서 좌우 양측의 전방 하악지 경사도를 측정하였다. 전방 하악지 경사도 수정의 정확성은 가상 수술 데이터와 술후 3 일 데이터의 차이(ΔT1-Tv)를, 수정된 전방 하악지 경사도의 안정성은 술후 3 일과 6 개월의 차이(ΔT2-T1)를 계산하여 평가하였다.

결 과:

모든 수술은 성공적으로 시행되었고, 모든 환자들에서 계획된 최종교합으로 유도되었으며 안면 비대칭 또한 개선되었다. 전방 하악지 경사도 수정의 정확성(ΔT1-Tv)은 0.87 ± 0.25˚, (p> 0.05, p=0.69) 수정된 전방 하악지 경사도의 안정성(ΔT2-T1)은 0.58 ± 0.34˚, (p> 0.05, p=0.50) 로 측정되었다.

요약:

악교정 수술 시 컴퓨터를 사용한 가상 수술과 CAD/CAM 을 활용하여 의도적 전방 하악지 경사도 수정이 계획대로 수술에 반영되었으며, 또한 안정적으로 유지할 수 있는 것으로 평가된다.

주요어:

전방 하악지 경사도, 안면 비대칭, CAD/CAM, 양측성 하악지 시상분할술, 악교정수술.

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