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Case Report

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Evaluation of Mandibular Autorotation Following Maxillary Impaction: A Case Report Using ProPlan CMF Software

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Abstract

Background and objectives: Vertical Maxillary Excess (VME) is one of the clinical scenarios resulting from excessive vertical growth of the maxilla. The degree of mandibular autorotation affects the achievement of the desired occlusion. We aimed to determine the degree of autorotation of the mandible after maxillary impaction using cephalometric analysis with ProPlan CMF software.

Materials and methods: One individual with class 1 malocclusion and one with class 1 malocclusion and VME were included. Three-dimensional models of the jaw and face were reconstructed using cone beam computed tomography (CBCT) data for cephalometric analysis. Le Fort 1 osteotomy with three levels of maxillary impaction (2, 4, and 6 millimeters) was simulated as a whole impaction in the three-dimensional model.

Results: With a 1-millimeter impaction of the entire maxilla, autorotation of the mandible was 0.45 degrees, which increased with an increase in the impaction of the maxilla. There was an association between the impaction of the maxilla and the autorotation of the mandible. The Sella-Nasion-Basion angle increased with maxillary impaction. Consequently, the autorotation of the mandible decreased the Frankfort mandibular plane angle, from 31.8 to 29 degrees. Edge-to-edge occlusion and the necessity for mandibular osteotomy were demonstrated for impaction values exceeding 2 millimeters.

Conclusion: With a 1-millimeter impaction of the maxilla, the mandible rotated by 0.45 degrees. Further large-scale studies are recommended.

Keywords: Total maxillary impaction; Mandibular autorotation; Vertical maxillary excess; Orthognatic surgery; ProPlan software.

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1. Introduction

Three factors, including proportions, symmetry, and the quality of the skin's texture, determine the attractiveness of the human face (1). The rule of fifths provides a convenient method for evaluating transverse facial proportions. The face is divided into five equal parts, each approximately the width of the eye, from helix to helix of the outer ears (2). In terms of the vertical measurement, the facial structure can be segmented into three sections: first, an upper third extending from the hairline (trichion) to the area around the glabella; second, a middle third spanning from the glabella to the sub nasal region; and third, a lower third extending from the sub nasal region to the soft tissue menton (2).

Vertical maxillary excess (VME) is an abnormality where the maxilla elongates in the vertical direction (3). Long face syndrome with adenoid faces can be the presentation of the maxillary excess vertical growth (4). There are several surgical treatment options for VME, with the Le Fort 1 osteotomy and its modifications, including different types of osteotomies like horseshoe, unilateral horseshoe, pyramidal, and U-shaped osteotomies, being suggested (5). The Le Fort 1 osteotomy is the preferred treatment modality of this abnormality (6). To correct VME by maxillary impaction in Le Fort 1 osteotomy, the maxilla is repositioned upwards, and the mandible often rotates superiorly and anteriorly following maxillary impaction causing the chin to get more protruded (7). Since the amount of autorotation of the mandible affects the amount of mandibular movement to achieve the desired occlusion following bilateral sagittal split osteotomy, it is essential for surgeons to accurately predict the amount of autorotation occurring after maxillary impaction prior to the surgery (8).

The ProPlan CMF software is a powerful tool for three-dimensional (3D) facial cephalometric analysis, in addition to using computed tomography (CT) scans and magnetic resonance imaging (MRI) to create an accurate 3D facial reconstruction for osteotomy planning (9). Although using this service can increase the quality of reconstructive surgeries, its higher cost compared to other routine techniques poses a challenge (10).

To date, the amount of autorotation of the mandible after total maxillary impaction has not been comprehensively investigated using 3D facial reconstruction with the ProPlan software (9). The aim of this study was to perform cephalometric analysis on the 3D facial reconstruction of a normal patient with class 1 malocclusion and a patient with class 1 malocclusion plus VME, using the ProPlan CMF software. Following the maxillary impaction, the degree of mandibular autorotation was evaluated based on the amount of maxillary impaction.

2. Materials and Methods

2.1. Study subjects

Two female patients who were candidates for cosmetic surgery who and were referred to the Faculty of Dentistry, Tehran University of Medical Sciences in 2021 were included. The first participant was a 25-year-old woman with class 1 malocclusion who was eligible for bilateral mandibular angle and cheek augmentation. The second participant was a 20-year-old woman with class 1 malocclusion and VME, and a Frankfort mandibular plane (FMA) greater than the normal range.

2.2. Definitions

The height of the face was evaluated based on several essential parameters, such as the anterior facial height (AFH), which refers to the vertical distance between the landmarks nasion (N) and menton (Me). Another key parameter was the FMA, which is the angle between the mandible plane and the Frankfurt plane. In an ideal occlusion, the AFH parameter in the coronal plane is within the normal range of 117.36 ± 5.31 mm, and the FMA angle in the sagittal plane is within 25 ± 5 degrees. If the FMA angle is higher than the normal range, it is referred to as a high angle (11).

2.3. Study procedures

This study used a 3D model to explore the interrelations among various components of the facial skeleton. Anatomical landmarks on the patient's skull 3D model, reconstructed using Mimics software, were identified and interconnected. The cranial base, recognized as the most stable and dependable anatomical structure in the craniofacial complex, served as the reference point in cephalometric analyses.

The cone beam computed tomography (CBCT) data of patients, previously acquired as a part of their treatment plans, were used. They were extracted from the Planmeca Romexis software (Helsinki, Finland: Planmeca Oy). The CBCT scans with a layer thickness of less than 0.7 mm were used to reconstruct 3D models of jaw and face. 3D facial reconstructions were utilized to perform cephalometric analysis using the ProPlan CMF version 3.0 software. Bone landmarks, comprising a series of points on the facial skeleton, were identified on the reconstructed 3D models of the maxilla and mandible. The software used the 3D facial reconstructions and the intraoral scan performed in centric relation occlusion. For each case, a Le Fort 1 osteotomy was performed with a conventional cut in maxilla, 5 mm above the roots of the canine and first molar teeth, from one side to the contralateral side, using the ProPlan CMF software. Total maxillary impaction values were simulated in 2 mm, 4 mm, and 6 mm. To evaluate the degree of autorotation, the lower part behind the center of the mandible condylar head was considered as the center of mandibular autorotation (12). Following the simulation of the Le Fort I osteotomy surgery, the degree of autorotation of the mandible was calculated based on the change in the position of the incisal angle relative to the mandibular condyle. Additionally, the effects of surgery on occlusal plane angle, mandibular plane, anterior and posterior facial heights, overjet, and overbite were investigated.

2.4. Statistical analysis

To assess the relationship between maxillary impaction and mandibular autorotation, a simple linear regression model was employed. This approach was chosen based on the assumption that skeletal changes in a controlled, software-simulated environment follow a proportional pattern, making linear regression an appropriate model for describing these changes. The R^2 values were reported to quantify the strength of association. Given the small sample size and controlled nature of the study, more complex statistical models, such as nonlinear regression or mixed-effects modeling, were not applied. Future studies should incorporate larger sample sizes and alternative modeling techniques to further validate and refine predictive accuracy.

3. Results

The first participant was a 20-year-old woman with class 1 malocclusion and VME. Photographs of the subject, 3D facial reconstructions, and 3D cephalometric analysis are presented in Figure 1, Figure 2, and Figure 3, respectively. After simulating maxillary impaction of 2 mm (Figure 4), 4 mm (Figure 5), and 6 mm (Figure 6), resulting amounts of autorotation of the mandible were calculated. After performing 2 mm of maxillary impaction, the mandibular autorotation was 0.90 degrees. Additionally, the occlusion remained in the class 1 position, and there were even contacts between maxillary and mandibular posterior and anterior teeth (Figure 4).

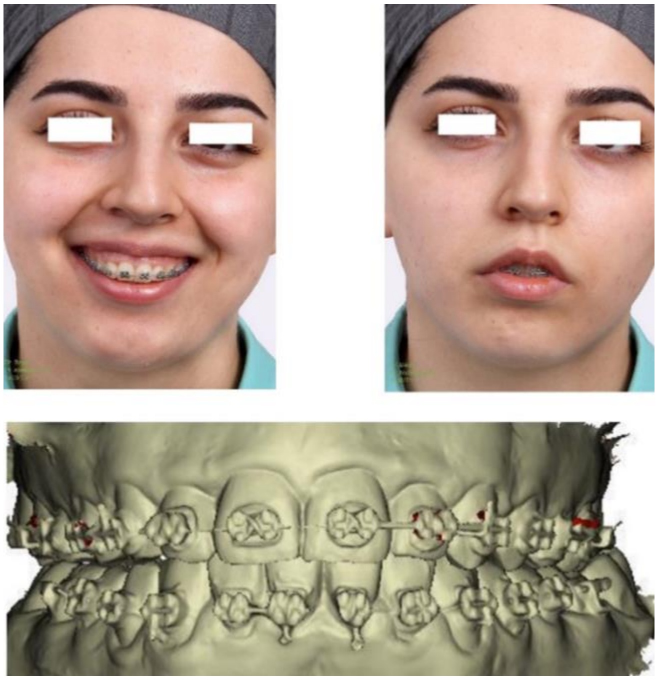

Figure 1. Photographs of the participant with class 1 malocclusion and vertical maxillary excess

During the simulation with 4 mm total maxillary impaction, the mandible autorotated and caused a change in the occlusion from class 1 to an edge-to-edge occlusion. As a result, contacts between the premolar teeth in the posterior region were lost. The mandible's autorotation during this amount of maxillary impaction was 1.72 degrees (Figure 5). Following the 6 mm impaction of maxilla and mandibular autorotation, the primary occlusion of class 1 was changed to an edge-to-edge occlusion, and the posterior contacts between molar and premolar teeth disappeared. The amount of mandibular autorotation in this situation was 2.87 degrees (Figure 6).

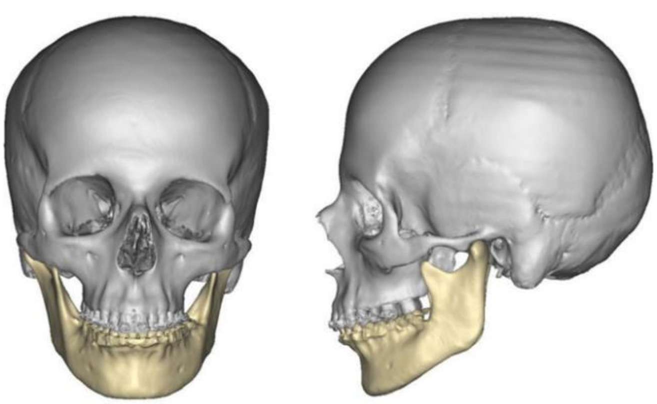

Figure 2. Three-dimensional facial reconstructions of the participant with class 1 malocclusion and vertical maxillary excess.

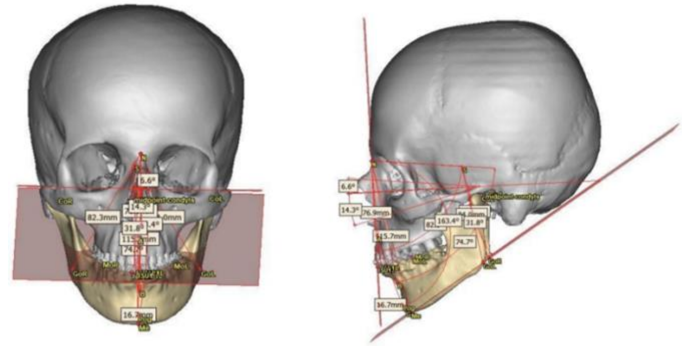

Figure 3. Three-dimensional cephalometric analysis of the participant with class 1 malocclusion and vertical maxillary excess.

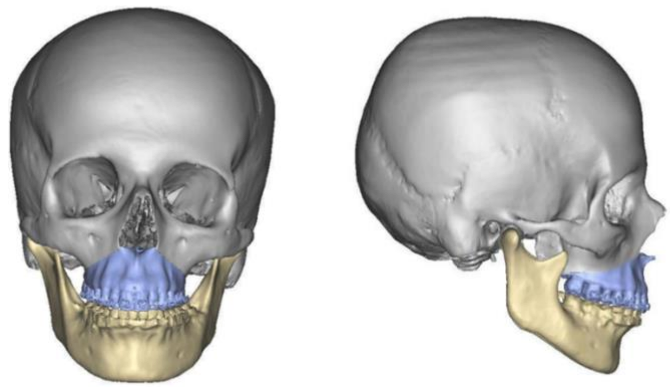

Figure 4. Simulation of Le Fort 1 surgery with 2 mm impaction in the participant with class 1 malocclusion and vertical maxillary excess.

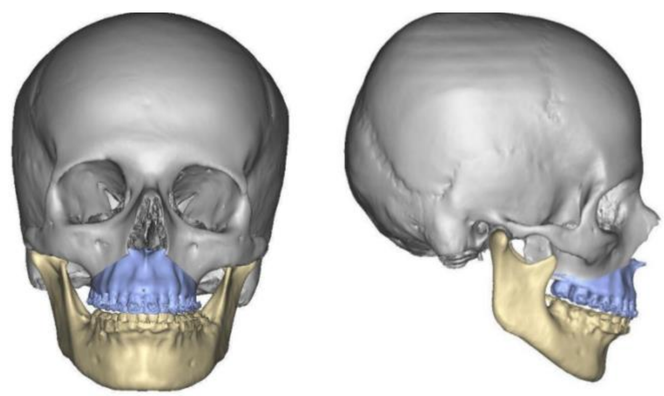

Figure 5. Simulation of Le Fort 1 surgery with 4 mm impaction in the participant with class 1 malocclusion and vertical maxillary excess.

Maxillary impaction in the participant with class 1 malocclusion and VME led to progressive mandibular autorotation, resulting in skeletal and occlusal changes. The Sella-Nasion-A (SNA) point slightly decreased from 82.9 before impaction to 82.4 after 6 mm of impaction, while Sella-Nasion-Basion (SNB) and (SNPog) angles increased from

74.9 to 76.5 degrees and 74.8 to 76.6 degrees, respectively. The angle of convexity decreased from 16.5 to 11.1 degrees, and Pog to NP distance reduced from 16.7 mm to 12.9 mm. Overjet decreased from 2.51 mm to 0.2 mm, and overbite was nearly eliminated, dropping from 1.81 mm to 0.01 mm. The occlusal plane and mandibular plane angles declined from 14.3 to 11.6 degrees and 31.8 to 29.0 degrees, respectively. AFH decreased from 112.1 mm to 109.3 mm, while posterior facial height remained stable (Table 1).

The second case was a normal person with a class 1 malocclusion. We simulated total maxillary impaction of 2 mm (Figure 7), 4 mm (Figure 8), and 6 mm (Figure 9). The occlusion remained in the class 1 state, and the amount of mandibular autorotation was 1.10 degrees following a 2 mm maxillary impaction (Figure 7). Subsequently, a 4 mm impaction was applied, which altered the occlusion to an edge-to-edge state, and the amount of mandibular autorotation increased to 2.20 degrees (Figure 8). After a total maxillary impaction of 6 mm, the patient's class 1 occlusion changed to class 3 state due to 3.40 degrees of mandibular autorotation (Figure 9).

Following maxillary impaction in the participant with class 1 malocclusion, the SNA angle decreased from 79.7 degrees to 78.7 degrees after 6 mm of impaction, while the SNB and SNPog angles increased from 74.5 to 76.8 degrees and 74.7 to 77.2 degrees, respectively, indicating forward mandibular repositioning. The angle of convexity decreased from 7.9 degrees to 2.7 degrees, and Pog to NP distance reduced from 21.5 mm to 15.5 mm. Overjet shifted from 1.0 mm to a negative value, reaching -2.8 mm, while overbite increased from 0.4 mm to 1.5 mm. The occlusal plane and mandibular plane angles also decreased, from 20.5 degrees to 16.8 degrees and 47.7 degrees to 43.9 degrees, respectively. AFH reduced from 122.7 mm to 119.8 mm, while posterior facial height remained relatively unchanged (Table 2).

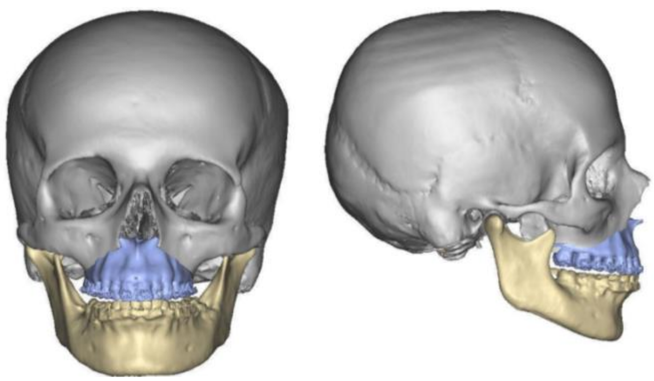

Figure 6. Simulation of Le Fort 1 surgery with 6 mm impaction in the participant with class 1 malocclusion and vertical maxillary excess.

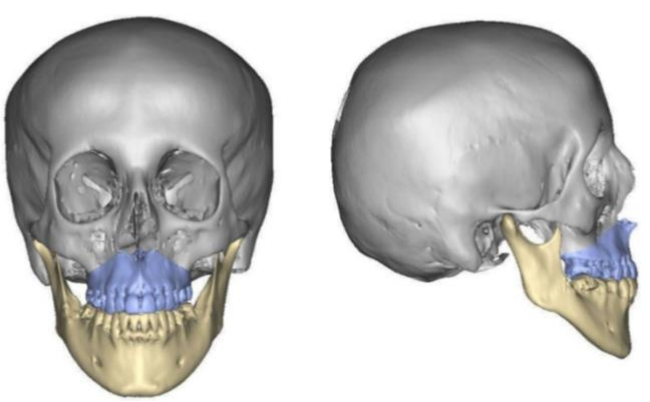

Figure 7. Simulation of Le For 1 surgery with 2 mm impaction in the participant with class 1 malocclusion.

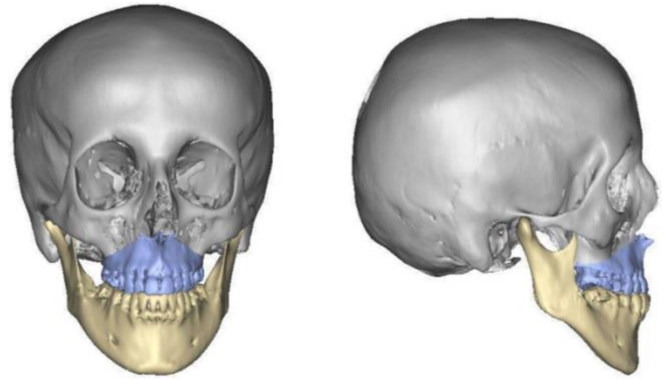

Figure 8. Simulation of Le Fort 1 surgery with 4 mm impaction in the participant with class 1 malocclusion.

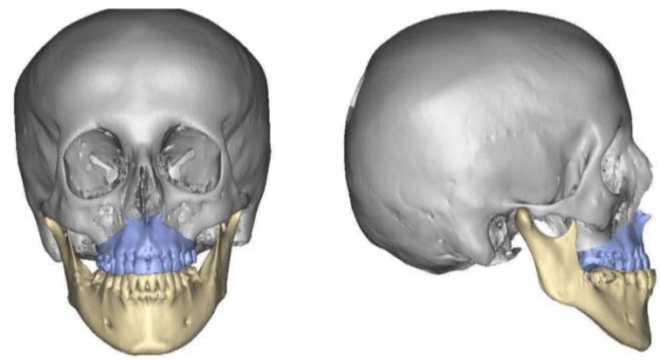

Figure 9. Simulation of Le Fort 1 surgery with 6 mm impaction in the participant with class 1 malocclusion

The linear equations for the relationship between total maxillary impaction and various cephalometric variables in normal individuals and those with VME revealed significant associations. In normal individuals, the SNA angle decreased with increasing impaction, as shown by the equation SNA = 80.05 - 0.34×impaction (R^2 = 0.997), while in VME individuals, the decrease was less pronounced, with the equation SNA = 83.10 - 0.17×impaction (R^2 = 0.980). The SNB and SNPog angles increased in both groups, with normal individuals showing stronger correlations (R^2 = 0.999 and 0.999, respectively), and VME individuals displaying slightly weaker but still strong correlations. The angle of convexity decreased significantly in both groups, with VME individuals showing a perfect correlation (R^2 = 1.000).

Table 1. Effects of mandibular autorotation following maxillary impaction on cephalometric variables in the participant with class 1 malocclusion and vertical maxillary excess.

Variables	Before performing maxillary impaction	Following 2 mm maxillary impaction	Following 4 mm maxillary impaction	Following 6 mm maxillary impaction
SNA	82.9	82.8	82.6	82.4
SNB	74.9	75.4	75.9	76.5
SNPog	74.8	75.3	75.9	76.6
Angle of convexity	16.5	14.7	12.8	11.1
A to NP	0.8	0.9	1.0	0.2
Pog to NP	16.7	15.5	14.3	12.9
FMA	31.8	30.9	30.1	29.0
Overjet	2.51	1.73	1.0	0.2
Overbite	1.81	0.97	0.2	0.01
Occlusal plane angle	14.3	13.4	12.6	11.6
Mandibular plane angle	31.8	30.9	30.1	29.0
AFH	112.1	111.2	110.4	109.3
PFH	81.3	81.25	81.23	81.21

SNA: Sella-Nasion-A Point; SNB: Sella-Nasion-Basion angle; SNPog: distance between the Sella and Pogonion; A to NP: Anterior to Nasal Passage; FMA: Frankfort Mandibular Plane Angle; AFH: Anterior Facial Height; PFH: Posterior Facial Height.

Table 2. Effects of mandibular autorotation following maxillary impaction on cephalometric variables in the participant with class 1 malocclusion.

Variables	Before performing maxillary impaction	Following 2 mm maxillary impaction	Following 4 mm maxillary impaction	Following 6 mm maxillary impaction
SNA	79.7	79.4	79.0	78.7
SNB	74.5	75.2	76.0	76.8
SNPog	74.7	75.5	76.3	77.2
Angle of convexity	7.9	7.4	5.1	2.7
A to NP	5.4	5.5	5.7	5.8
Pog to NP	21.5	19.6	17.7	15.5
FMA	47.7	46.5	45.3	43.9
Overjet	1.0	0.3	-1.48	-2.8
Overbite	0.4	0.4	1.01	1.46
Occlusal plane angle	20.5	19.2	18.1	16.8
Mandibular plane angle	47.7	46.5	45.3	43.9
AFH	122.7	121.9	120.9	119.8
PFH	82.85	82.8	82.75	82.7

SNA: Sella-Nasion-A Point; SNB: Sella-Nasion-Basion angle; SNPog: distance between the Sella and Pogonion; A to NP: Anterior to Nasal Passage; FMA: Frankfort Mandibular Plane Angle; AFH: Anterior Facial Height; PFH: Posterior Facial Height.

Overjet and overbite both showed different trends in the two groups: in normal individuals, overjet increased with impaction ($R^2 = 0.649$), while in VME individuals, overjet decreased ($R^2 = 1.000$). Similarly, AFH and posterior facial height both decreased with increasing impaction in both groups, with strong correlations, especially in PFH ($R^2 =$

1.000 in normal individuals). The occlusal plane angle and mandibular plane angle both decreased significantly in both groups, with near-perfect correlations (R^2 = 1.000). Mandibular autorotation was positively correlated with impaction in normal individuals (R^2 = 1.000), but negatively in VME individuals (R^2 = 0.995), indicating differing trends in mandibular response to impaction between the two groups (Table 3).

Table 3. Linear equation of the relationship between the amount of total maxillary impaction and cephalometric variables in normal person and person with vertical maxillary excess.

Patient Characteristics	Normal		VME	
	Linear regression formula	R^2	Linear regression formula	R^2
SNA	80.05-0.34×impaction(mm)	0.997	83.10-0.17×impaction(mm)	0.980
SNB	73.70+0.77×impaction(mm)	0.999	74.35+0.53×impaction(mm)	0.998
SNPog	73.85+0.83×impaction(mm)	0.999	74.15+0.60×impaction(mm)	0.994
Angle of convexity	10.25-1.79×impaction(mm)	0.939	18.30-1.81×impaction(mm)	1.000
A to NP	5.25+0.14×impaction(mm)	0.980	0.70+0.10×impaction(mm)	1.000
Pog to NP	23.55-1.99×impaction(mm)	0.999	18.00-1.26×impaction(mm)	0.998
FMA	49.00-1.26×impaction(mm)	0.998	32.75-0.92×impaction(mm)	0.996
Overjet	-0.25+0.66×impaction(mm)	0.649	3.28-0.77×impaction(mm)	1.000
Overbite	-0.13+0.38×impaction(mm)	0.899	2.29-0.62×impaction(mm)	0.941
AFH	123.75-0.97×impaction(mm)	0.995	113.05-0.92×impaction(mm)	0.996
PFH	82.90-0.05×impaction(mm)	1.000	81.32-0.03×impaction(mm)	0.940
Occlusal plane angle	21.75-1.23×impaction(mm)	1.000	15.20-0.89×impaction(mm)	0.998
Mandibular plane angle	49.00-1.26×impaction(mm)	0.998	32.75-0.92×impaction(mm)	0.996
Mandibular autorotation	-1.15+1.13×impaction(mm)	1.000	-0.99-0.94×impaction(mm)	0.995

SNA: Sella-Nasion-A Point; SNB: Sella-Nasion-Basion angle; SNPog: distance between the Sella and Pogonion; A to NP: Anterior to Nasal Passage; FMA: Frankfort Mandibular Plane Angle; AFH: Anterior Facial Height; PFH: Posterior Facial Height; VME: vertical maxillary excess.

4. Discussion

The findings of this study showed that mandibular autorotation w increased from 0.45 degrees after a 1 mm maxillary impaction in a person with VME to 0.50 degrees in a normal person. Furthermore, the degree of autorotation increased with more maxillary impaction, indicating a remarkable relationship between total maxillary impaction and mandibular autorotation.

VME is an abnormality in which the maxilla elongates vertically, typically addressed by maxillary impaction with Le Fort 1 osteotomy (6). Our results showed that as the degree of maxillary impaction increased, the angles of the occlusal and mandibular planes, as well as the anterior and posterior facial heights, decreased, in alignment with findings from previous studies (13). Nevertheless, the limited sample size of this study prevented us from drawing robust conclusions about the associations between these markers and treatment outcomes. In addition, a report of five cases with dental open bite who received maxillary Le Fort 1 osteotomy revealed mandibular counterclockwise rotation led to a reduction in mandibular plane angle and an elevation in SNA, overall improved the facial esthetics (14). The discrepancy in terms of SNA can be described by the fact that they evaluated the counterclockwise rotation of mandibular plane (14), whereas we used the maxillary impaction.

According to our results, a cross-sectional study on 20 participants showed for each 1 mm of maxillary vertical changes, the chin is anticipated to shift 0.21 mm horizontally. In addition, in cases with ≤8 mm maxillary impaction, every 1 mm of vertical change in the maxilla led to an estimated 0.71 mm vertical movement of the chin. While, in cases of maxillary superior repositioning >8 mm, for each 1 mm, the chin moved 0.44 mm upward (13). Moreover, a systematic review evaluating the treatment outcomes of maxillary intrusion showed that with each 1 mm of maxillary upward impaction, the chin vertically shifted by 0.6 mm and horizontally shifted by 0.2 mm upward (15). Moreover, a study on 10 people revealed that the mean absolute distance between the surfaces was less than 2 mm, and the number of sagittal surgical movements can determine its accuracy (16). In accordance with our findings, the article by Abuzinada et al. determined that the SNB parameter increased after the differential impaction of the maxilla (14).

Similar to our results, the study conducted by Arabion et al. showed that the angles of the occlusal and mandibular planes were reduced following the maxillary impaction (13). After performing total maxillary impaction in a class 1 individual with VME, an anterior shift in the position of the chin was observed. In a similar study by Jayakumar and colleagues, it was concluded that the chin position shifted horizontally following the maxillary impaction (17). Results of a systematic review (15) and a cross-sectional study (13) showed that maxillary impaction caused a horizontal shift in the position of the chin. Similarly, Abuzinada et al. found the position of the chin moved anteriorly in all patients after the procedure (14).

It has several limitations. First, the study had a very small sample size (N=2), which significantly limits the generalizability of the findings to other populations or clinical conditions. However, given the exploratory nature of this research, our approach allowed for a controlled and detailed assessment of mandibular autorotation following maxillary impaction. Future studies with larger sample sizes are necessary to validate our results and improve the reliability of the conclusions. Second, the predictive accuracy of the ProPlan CMF software was not validated against actual post-surgical outcomes, which limits the clinical applicability of our findings. Future studies should incorporate post-surgical assessments, such as CBCT scans or clinical follow-up data, to validate the accuracy of the software's predictions. A direct comparison of simulated outcomes with actual post-surgical results would be invaluable for assessing the software's practical utility. Third, only ProPlan CMF software was used for prediction, without comparison to alternative methods such as manual cephalometric tracing or other software. Although ProPlan CMF was chosen for its clinical relevance and 3D visualization capabilities, future studies should consider incorporating additional predictive methods as controls to further assess the accuracy and reliability of different approaches.

5. Conclusion

Our study demonstrated that in a person with class 1 malocclusion and VME undergoing a total maxillary impaction of 1 mm, the mandible rotated by 0.45 degrees. However, if the maxillary impaction exceeded 2 mm, the occlusion changed from class 1 to an edge-to-edge position, and a mandibular osteotomy was indicated. Moreover, the degree of maxillary impaction affected the occlusal and mandibular planes, overjet and overbite modification, position of the chin, and the incisal edge of the mandible. Future large-scale studies are recommended to predict the outcomes of surgery and, in at the end, the facial esthetics.

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None.

Ethics

The study was approved by the ethics committee of Tehran University of Medical Sciences (ethics code: IR.TUMS.DENTISTRY.REC.1400.190). Informed consent was obtained from the participants. It was conducted in accordance with the Declaration of Helsinki and the national guidelines and regulations

Using artificial intelligence (AI)

We would also like to acknowledge the use of ChatGPT-4 for paraphrasing sentences and checking grammar. After using this tool/service, the authors reviewed and edited the content as necessary and take full responsibility for the final content of the publication.

Author contribution

Hamid Mahmood Hashemi: Conceptualization, Investigation, Supervision, Writing - Original draft, Writing - Review & editing
Rasool Saeedi: Investigation, Formal analysis, Writing - Original draft, Writing - Review & editing
Zahra Sadat Modarresi: Conceptualization, Visuallization, Software, Formal analysis, Writing - Original draft, Writing - Review & editing
Farnoosh Razmara: Conceptualization, Supervision, Formal analysis, Project administration, Validation, Writing - Original draft, Writing - Review & editing

Conflict of interest

The authors declare no conflict of interest.

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