
The stability of occlusal plane rotation during orthognathic surgery

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Background: Considered rotation of the occlusal plane and the maxillomandibular complex during orthognathic surgery is an approach that enables optimisation of the functional and aesthetic outcomes of surgical-orthodontic treatment for the correction of a variety of dentofacial deformities.

Objectives: The objectives of this study are to: (1) retrospectively evaluate the stability of clockwise and anti-clockwise rotation of the occlusal plane during orthognathic surgery, and (2) compare the findings with the stability of orthognathic surgery in which no significant occlusal plane rotation occurs.

Aims and methods: Data were collected from a sample of 31 adult patients (22 females and nine males) treated by one orthodontist in private practice and at the University of Western Australia from 1992–2008. Patients received a Le Fort I osteotomy and BSSO to reposition the maxilla and mandible, respectively. The patients were separated into three groups defined by no occlusal plane rotation; clockwise occlusal plane rotation; or anti-clockwise occlusal plane rotation. Lateral cephalograms were taken at four time periods during treatment: T1 (pre-surgery), T2 (immediately post-surgery), T3 (six weeks post-surgery), and T4 (longest follow-up). The cephalograms were digitised and analysed using a customised cephalometric analysis (QuickCeph Studio, CA, USA) and landmarks were transferred via cranial base and maxillary superimpositions for each patient from T1 sequentially to T4.

Results: Clockwise rotation of the occlusal plane was highly stable one year following surgery and showed comparable results with cases treated without occlusal plane rotation. Anti-clockwise rotation of the occlusal plane was less stable and showed significant relapse of the occlusal plane angle towards the pre-surgical value during the post-surgical observation period.

Conclusion: Clockwise rotation of the occlusal plane during orthognathic surgery appears highly stable. Anti-clockwise occlusal plane rotation during orthognathic surgery appears less stable. Further studies are needed to evaluate the longer-term stability of clockwise and anti-clockwise rotation of the occlusal plane during surgical-orthodontic treatment.

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Introduction

Dentofacial deformities severe enough to require surgical intervention often require bimaxillary surgery to optimise the functional and aesthetic outcomes of treatment.¹⁻⁴ Depending on the patient's facial morphology, it is sometimes necessary and/or desirable to rotate the maxillomandibular complex (MMC) and occlusal plane (OP) during surgery. The benefits of performing this type of surgery are functional, such as reducing airway resistance and improving masticatory efficiency; and secondarily

aesthetic, related to the production of an angular taper to the facial form and a reduction in chin prominence of brachyfacial individuals (Figures 1–3); or increasing chin projection in severely retrognathic patients (Figure 4–6).⁵⁻⁷

Performing bimaxillary surgery without rotating the occlusal plane may produce undesirable aesthetic outcomes that are also potentially less stable over the long term. The rotation of the occlusal plane in a clockwise direction during orthognathic surgery was initially performed on patients with hypodivergent



Figure 1. Pre-surgical photographs and cephalogram exemplifying a patient treated by clockwise rotation of the occlusal plane during orthognathic surgery.



Figure 2. Pre-surgical and post-surgical cephalograms of a patient treated by clockwise rotation of the occlusal plane.



Figure 3. Post-surgical photographs and cephalogram of a patient treated by clockwise rotation of the occlusal plane.

Class II type of malocclusions because it enabled a reduction in chin prominence and improved stability.⁷ Clockwise rotation of the occlusal plane during surgery also produces a tapering of facial form that is aesthetically beneficial, particularly in brachyfacial female patients.⁸ However, it may be more advantageous to rotate the occlusal plane in an anti-clockwise direction during surgery to gain

improvements in airway volume and horizontal chin projection, especially in patients with severe chin retrusion. Whilst the potential functional and aesthetic advantages gained by surgery involving clockwise rotation of the occlusal plane are well documented, there is little literature supporting the long-term stability of anti-clockwise occlusal plane rotation during orthognathic surgery.^{9,10}



Figure 4. Pre-surgical photographs and cephalogram exemplifying a patient treated by anti-clockwise rotation of the occlusal plane during orthognathic surgery.

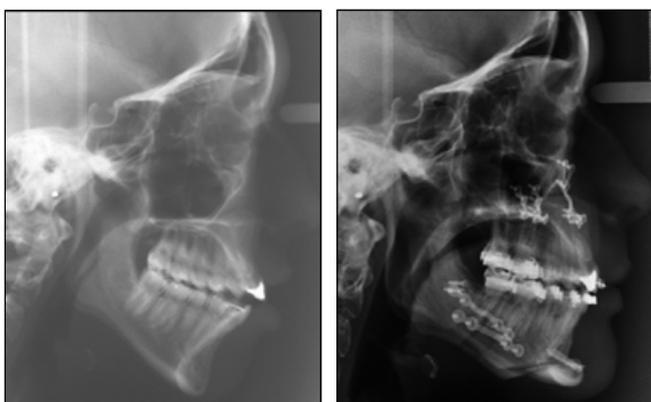


Figure 5. Pre-surgical and post-surgical cephalograms of a patient treated by anti-clockwise rotation of the occlusal plane.



Figure 6. Post-surgical photographs and cephalogram of a patient treated by anti-clockwise rotation of the occlusal plane.

The rotation of the occlusal plane is a consequence of rotation of the maxillomandibular complex and, depending on the functional and aesthetic goals of treatment, the MMC may be rotated downwards and backwards (clockwise) or upwards and forwards (anti-clockwise). (In order to be consistent with the literature relating to rotation of the MMC, cephalograms are viewed with the patient facing to the right; thus

clockwise rotation is downwards and backwards and anti-clockwise rotation is upwards and forwards). Following superior repositioning of the maxilla, the mandible autorotates about a point posterior and inferior to cephalometric-condylion, resulting in a variable amount of rotation of the occlusal plane, depending on the amount and direction of maxillary repositioning.^{13,14} Changes in the occlusal plane angle

of greater than 2° are considered to be clinically significant.¹¹ The key to occlusal plane rotation and MMC is the surgical rotation of the maxilla. Depending on the functional and aesthetic goals for treatment, the maxilla can be rotated clockwise or anti-clockwise to achieve the desired outcomes and so cephalometric studies aiming to assess surgical rotation must measure changes that are produced at both anterior and posterior maxillary cephalometric landmarks during surgery. Cephalometric analysis via superimposition is an accepted method by which to assess stability following surgical-orthodontic treatment, especially when maxillary surgery is performed.¹⁵⁻¹⁷

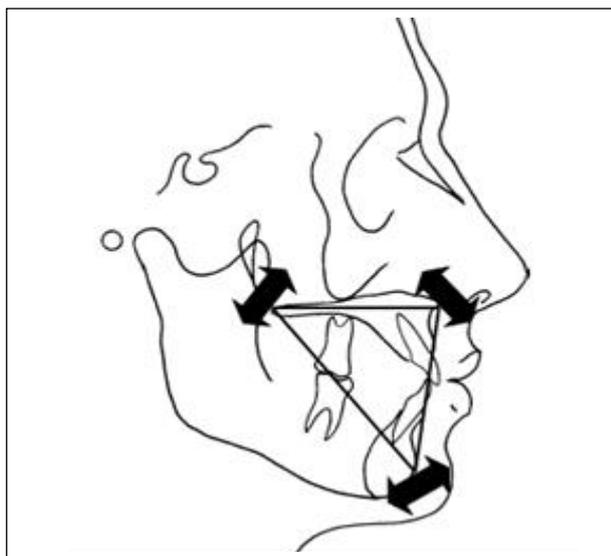


Figure 7.¹¹ Rotation of the maxillomandibular complex.

Previous studies appear to indicate that clockwise rotation of the occlusal plane is highly stable following bimaxillary surgery.^{10,11} In contrast, anti-clockwise rotation of the occlusal plane and MMC seems to be less stable. This may be attributed to factors related to the larger magnitude and direction of mandibular advancement produced by anti-clockwise rotation, the increased vertical dimension produced when the maxilla is inferiorly repositioned, and variations in osteotomy design and fixation techniques.^{6,9,11,18} The stability of orthognathic surgery involving anti-clockwise rotation of the occlusal plane may be improved by (1) planning maxillomandibular movements to ensure neuromuscular adaptation following surgery, (2) the utilisation of rigid fixation techniques, (3) the use of modern osteotomy design techniques (such as the Hanssuck modification), including detachment and incision of the

pterygo-masseteric sling when indicated, and (4) placement of grafting material, such as hydroxyapatite, into the osteotomy site.^{10,11} Further studies are needed to re-evaluate the stability of clockwise and anti-clockwise rotation of the occlusal plane and to compare the stability of orthognathic surgery without occlusal plane rotation in light of contemporary clinical advances.

Therefore, the objectives of the present study are to (1) evaluate the stability of clockwise and anti-clockwise rotation of the occlusal plane during orthognathic surgery, and (2) compare the findings with the stability of surgical treatment undertaken without occlusal plane rotation.

Materials and methods

Thirty-one non-syndromic, relatively facially-symmetrical, non-growing patients (22 females with a mean age of 24.5 years, and a standard deviation 9.1 years; and 9 males with a mean age of 22.8 years and a standard deviation 6.9 years) underwent surgical orthodontic treatment either at a private orthodontic clinic, or at the Orthodontic Department of the University of Western Australia. All patients were treated by the same orthodontist and the surgical procedures took place between 1992 and 2008. Four patients had a skeletal Class I malocclusion, 19 had Class II, and eight patients had a Class III skeletal pattern. Patients received a Le Fort I maxillary osteotomy and a BSSO to re-position the mandible. Twenty-four patients received a genioplasty. Rigid fixation techniques were applied in all cases and an interocclusal splint was utilised during surgery and maintained throughout the initial post-operative stage (<6-weeks post-surgery).

The cases were selected retrospectively on the basis that standard lateral cephalograms were taken in centric relation at four stages during treatment: T1 (pre-surgery: mean six weeks, range 1–18 weeks); T2 (immediate post-surgery: mean 8.5 days, range 2–20 days); T3 (six weeks post-surgery: mean 6.5 weeks, range 5–9 weeks); and T4 (longest follow-up with a minimum of six months post-surgery: mean 13.1 months, range 6–36 months).

The patients were grouped according to the following criteria:

Group 1: No occlusal plane rotation (NR). Nine patients (five female, four male) with a mean age of

22.7 years (range 13–31) received less than 2° occlusal plane rotation as a result of surgery. The average length of follow-up time was 10.9 months (range 6–15) after surgery.

Group 2: Clockwise rotation of the occlusal plane (CR). Twelve patients (9 female, 3 male) with a mean age of 27.6 years (range 15–44) received (>2°) clockwise rotation of the occlusal plane during surgery. The average follow-up time was 13.9 months (range 6–36) after surgery.

Group 3: Anti-clockwise rotation of the occlusal plane (CCR). Ten patients (8 female, 2 male) received (>2°) anti-clockwise rotation of the occlusal plane during surgery. The average follow-up time was 14.1 months (range 9–27) after surgery.

The pre-surgical radiographs were traced in a semi-dark room by one author onto clear overhead transparency sheets using a 0.5 mm fine permanent marker. The cranial base and maxillary regional tracings were used to transfer cephalometric landmarks from the pre-surgical radiograph to the subsequent post-surgical treatment radiographs to improve accuracy,

eliminate landmark identification errors and obviate inter-examiner assessment.^{15,16,19-22} Eight landmarks (Nasion, Sella, Horizontal Reference, Porion, Basion, Articulare, Pterygomaxillary, and Orbitale) were transferred via best-fit cranial base superimposition on the anterior wall of sella turcica and planum sphenoidale of the middle cranial fossa. Five landmarks (ANS, PNS, A-point, upper incisal edge, distal upper molar cusp) were transferred via best fit maxillary superimposition. The transfer of mandibular landmarks by superimposition was precluded due to the alteration in mandibular morphology following BSSO surgery and the inclusion of patients who underwent a concurrent genioplasty procedure. Measurement of the functional occlusal plane relative to the cranial base (SN-OP) was made in order to eliminate measurement errors due to infra- and over-erupted incisors.^{1,23}

Each radiograph (total = 124) was scanned and digitised using QuickCeph software (CA, USA) on an Apple Macintosh computer and analysed using a customised cephalometric analysis. The analysis

Table 1. Definition of cephalometric landmarks and variables.

Landmark/variable	Definition
Sella (S)	The geometric centre of the pituitary fossa by visual inspection
Nasion (Na)	The most anterior point on the frontonasal suture
Mx1	Upper incisor tip
ANS	Anterior point of the maxillary process at the inferior margin of the nasal aperture
A-point	Greatest point of concavity on the anterior surface of the maxilla near to the upper incisor root apex
PNS	The posterior spine of the palatine bone constituting the hard palate
Mx6	The most distal point of the upper first molar crown on a lateral cephalogram, measured perpendicular to the occlusal plane
Gonion (Go)	The point on the curvature of the angle of the mandible located by bisection of the lines tangent to the posterior ramus and inferior border of the mandible
B-point	Greatest point of concavity on the anterior surface of the mandible near to the lower incisor root apex
Pogonion (Pg)	The most anterior point on the mandibular symphysis
Menton (Me)	The most inferior point on the mandibular symphysis
Occlusal plane (OP)	Line through the occlusal surfaces of the posterior teeth
Mandibular plane (MP)	Line tangent to the inferior border of the mandible and Menton
SNA	Angle formed between the landmarks sella-nasion-Point A
SNB	Angle formed between the landmarks sella-nasion-Point B
SN-OP	Angle formed between the line sella-nasion and the occlusal plane
OP-MP	Angle formed between the occlusal plane and mandibular plane
Lower facial height LFH (%)	ANS-Menton/Nasion-Menton x 100% measured perpendicular to the X-axis

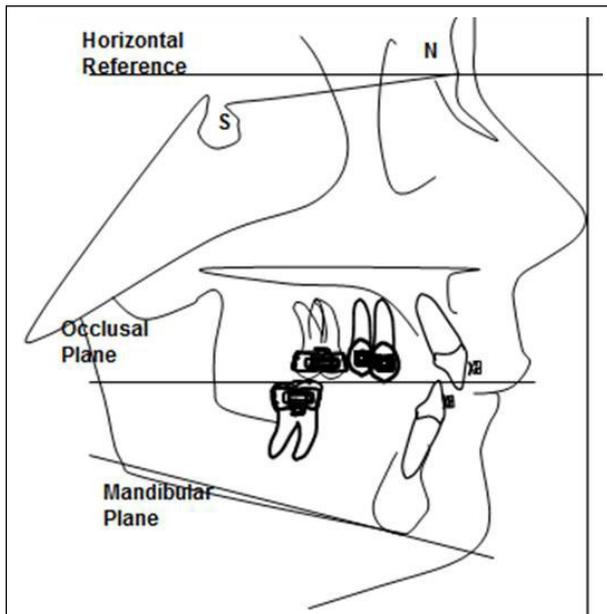


Figure 8. Angular measurements from the patient's horizontal reference line.

created an XY co-ordinate system that enabled measurement of linear distances from horizontal and vertical reference lines. The horizontal reference line passed through Nasion at right angles to the patient's True Vertical line, as assessed radiographically. The calculation of angular and linear measurements to the nearest 0.1° and 0.1 mm respectively was made using the software. Calibration of radiographs was performed using QuickCeph software to ensure uniform scaling of the measurements. The process of digitisation of each of the four radiographs taken during treatment was repeated blindly for a random selection of five patients (total = 20 radiographs), one month following the initial digitisation to assess intra-examiner reliability and ensure accuracy of the method using the intra-class correlation (ICC) test.^{21,22}

Results

Intra-Class Correlation (ICC) was used to evaluate the reliability of the data produced by the cephalometric superimposition and digitisation methods applied during the study. Each of the variables (linear measurements, angular measurements, and LFH%) that are presented in the following tables demonstrated an ICC of greater than 0.9, which is excellent, and indicates the data were very reliable.

Tables II–IV show the vertical, horizontal and angular changes that occurred in each of the three groups.

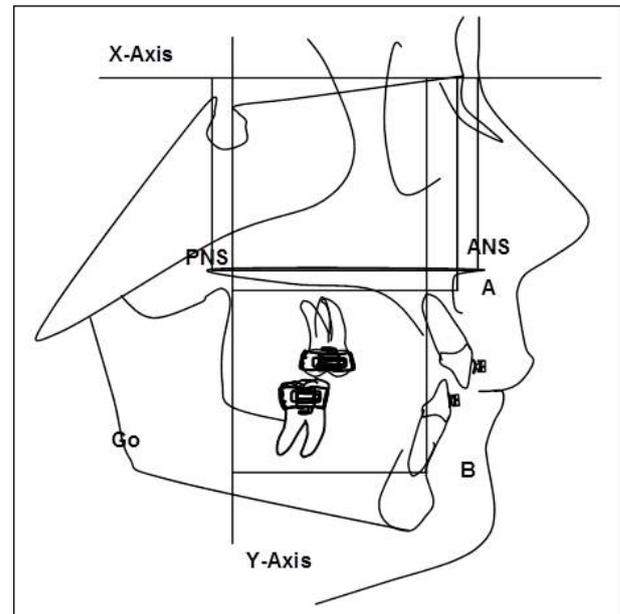


Figure 9. X-Y Coordinate system used in customised cephalometric analysis.

Linear measurements in the superior direction of the vertical plane were designated as negative (-), and linear measurements in the inferior direction of the vertical plane were positive. Linear measurements in the anterior direction of the horizontal plane were designated as positive, and linear measurements in the posterior direction of the horizontal plane were negative (-). The surgical changes were measured during the interval from T1–T2; post-surgical changes were measured during intervals T2–T3, T3–T4, and T2–T4; and the overall changes were measured during the interval T1–T4.

Group 1: No Rotation group

The No Rotation group was characterised by surgical changes involving significant measurable horizontal advancement of maxillary and mandibular cephalometric landmarks but no occlusal plane rotation during surgery. There was no significant measurable change in occlusal plane angle observed during any of the time intervals of the study.

The maxillomandibular complex tended towards superior repositioning as indicated by the negative values (Table II) from T1–T2 and T1–T4. Although these movements were not statistically significant, they represent: (1) a concomitant superior maxillary repositioning that accompanies horizontal advancement of the maxilla during surgery,

Table II. Group 1: No Rotation group.

	T1-T2	T2-T3	T3-T4	T2-T4	T1-T4
<i>Vertical changes</i>					
Mx1	-1.3778	0.3444	-0.1667	0.1778	-1.2
ANS	-1.5222	-0.07778	-0.04444	-0.1222	-1.5667
A-POINT	-1.5222	0.04444	-0.04444	0	-1.5222
PNS	-0.9222	-0.03333	-0.1222	-0.1556	-1.0778
Mx6	-1.2	0.3333	-0.07778	0.2556	-0.9444
Go	0.4	0.3556	-1.3889	-1.0333	-0.6333
B-POINT	-0.5889	-1.0222	-0.3333	-1.3556	-1.9444
POG	-2.3667	-0.3667	-0.3778	-0.7444	-3.111*
MENTON	-2.3444	-0.2333	-0.01111	-0.2444	-2.5889
<i>Horizontal changes</i>					
Mx1	2.2*	1.7556	-1.3111	0.4444	2.6444**
ANS	2.0333*	1.6778	-0.8778	0.8	2.8333**
A-POINT	2.1333*	1.6667	-0.9	0.7667	2.9**
PNS	2.5444**	0.8111	-0.5667	0.2444	2.7889**
Mx6	2.7444**	2.0222*	-1.0333	0.9889	3.7333**
Go	0.9556	1.8556	-1.0889	0.7667	1.7222
B-POINT	1.8444	2.9333*	-1.0222	1.9111	3.7556**
POG	4.2222**	2.8778	-0.8556	2.0222	6.2224***
MENTON	5.0111**	2.7333	-0.4889	2.24	7.2556***
<i>Angular changes</i>					
SNA	2.0556**	0.5	-0.3778	0.1222	2.1778**
SNB	1.0889	0.9667	-0.3556	0.6111	1.7*
SN-OP	0.1889	-0.6667	-0.3556	-1.0222	0.8333
OP-MP	3.9667**	0.00E+00	-1.2333	-1.2333	2.7333*
<i>Lower facial height</i>					
LFH%	0.4111	0.01111	-0.01111	0	0.4111

* denotes $p < 0.05$; **denotes $p < 0.01$; ***denotes $p < 0.001$

(2) mandibular autorotation during surgery, and (3) post-surgical change. Pogonion was the only variable to show significant change in the vertical plane, which was the result of genioplasty procedures. Overall from T1–T4, Pogonion moved superiorly by an average of 3.1 mm ($p < 0.001$). The initial surgical change at Pogonion from T1–T2 (average 2.3 mm) was not statistically significant, and the overall change was the result of surgical movement plus the accumulated post-surgical movement in the superior direction.

The maxillomandibular complex was advanced surgically in the horizontal direction, without rotation of the occlusal plane. A-point was advanced horizontally

by an average 2.1 mm ($p < 0.05$) during surgery. Throughout the post-surgical review, there was further anterior movement observed at A-point, and overall, the average of 2.9 mm ($p < 0.01$) advancement was measured at A-point from T1–T4. B-point was advanced horizontally by an average 1.84 mm during surgery; however, this change was not statistically significant. Following removal of the interocclusal splint, B-point moved anteriorly by an average of 2.9 mm ($p < 0.05$) as a result of the mandibular rotation. Overall, B-point advanced horizontally by an average of 3.7 mm ($p < 0.01$) from T1–T4. Menton moved forwards during surgery and overall by an average of 5.0 mm ($p < 0.01$) and 7.2 mm ($p < 0.001$),

Table III. Group 2: Clockwise Rotation group.

	T1-T2	T2-T3	T3-T4	T2-T4	T1-T4
<i>Vertical changes</i>					
Mx1	0.7667	0.05833	1.0667	1.125	1.8917*
ANS	0.6417	-0.075	0.25	0.175	0.8167
A-POINT	0.2417	-0.275	0.5417	0.2667	0.5083
PNS	-2.7167***	0.5167	-0.1167	0.4	-2.3167***
Mx6	-1.725**	0.2583	0.2833	0.5417	-1.1833
Go	-1.0667	-0.3083	-0.75	-1.0583	-2.125**
B-POINT	0.15	-0.9417	1.0333	0.09167	0.2417
POG	0.6667	-2.2083	2.5*	0.2917	0.9583
MENTON	1.0167	-1.7	2.0417	0.3417	1.3583
<i>Horizontal changes</i>					
Mx1	2.925***	0.6333	-0.1583	0.475	3.4***
ANS	5.2***	-0.6667	0.4333	-0.2333	4.9667***
A-POINT	4.6083***	-0.2917	0.05	-0.2417	4.3667***
PNS	5.4083***	-0.65	0.175	-0.475	4.9333***
Mx6	3.825***	0.025	0.06667	0.04167	3.8667***
Go	1.275	3.7167**	-3.0083*	0.7083	1.9833
B-POINT	2.2333*	1.1083	-0.9	0.2083	2.4417*
POG	3.2083*	0.9583	-1.175	-0.2167	2.9917*
MENTON	3.425*	1.35	-1.5083	-0.1583	3.2667*
<i>Angular changes</i>					
SNA	4.5***	-0.45	-0.125	-0.575	3.925***
SNB	1.4917**	0.3583	-0.3167	0.04167	1.533**
SN-OP	4.3583***	-0.9083	1.4083*	0.5	4.8583***
OP-MP	3.6833***	-0.8583	0.2583	-0.6	3.0833**
<i>Lower facial height</i>					
LFH%	-0.025	-0.5417	0.5	-0.04167	-0.06667

* denotes $p < 0.05$; **denotes $p < 0.01$; ***denotes $p < 0.001$

respectively. The greater magnitude of advancement measured at Menton compared with B-point was the result of mandibular autorotation following maxillary superior repositioning during surgery.

No significant change in lower facial height proportion was measured at any interval during the study.

The results indicate excellent stability of the maxillo-mandibular surgery as no significant relapse was measured at any of the variables examined during the post-surgical interval of T2–T4. The largest amount of post-surgical relapse of 2.2 mm anterior movement measured at Menton was not statistically significant, and the remaining linear variables showed ≤ 2 mm

post-surgical change. Furthermore, the changes produced during surgery at each of the variables tested remained statistically significant for the duration of the study over the interval of T1–T4.

Group 2: Clockwise Rotation group

Significant clockwise rotation of the occlusal plane was achieved during surgery (T1–T2) of 4.3° measured by SN-OP ($p < 0.001$), as presented in Table III. A further steepening of the occlusal plane by 0.5° (not statistically significant) was measured during the post-surgical observation period T2–T4, resulting in an overall steepening of the occlusal plane from T1–T4 by

an average of 4.8° ($p < 0.001$). Surgical rotation of the occlusal plane was produced by superior repositioning of the posterior maxilla during the interval T1–T2, measured at landmarks PNS and Mx6, by an average of 2.7 mm ($p < 0.001$) and 1.7 mm ($p < 0.001$), respectively. The surgical change at PNS remained significant overall, resulting in a superior repositioning at PNS of average 2.3 mm ($p < 0.001$) from T1–T4. No significant vertical change was measured at PNS during the post-surgical follow-up from T2–T4. In contrast, the surgical change at Mx6 did not remain statistically significant overall from T1–T4; however, an average 1.2 mm superior repositioning was measured. No significant vertical change was evident at Mx6 during the post-surgery interval from T2–T4. An overall inferior movement of average 1.9 mm ($p < 0.05$) was measured at Mx1 during the interval T1–T4. No significant vertical change was measured at the anterior maxillomandibular skeletal landmarks (A-point, B-point or Menton) during surgery from T1–T2; or post-surgery from T2–T4; or overall from T1–T4; however, there was a small amount of inferior movement of these structures consistent with clockwise rotation of the maxillomandibular complex and occlusal plane. An overall statistically significant superior movement was observed at Gonion (average 2.1 mm) ($p < 0.001$) from T1–T4, which is the result of surgical change (-1.1 mm, not significant) and post-surgical movement (-1.1 mm, not significant). The post-surgical movement from T2–T4 at Gonion was most likely the result of neuromuscular adaptation.

Significant horizontal advancement of the maxillomandibular complex during surgery was measured in the clockwise rotation group in the interval T1–T2. A-point was advanced by an average of 4.6 mm during surgery ($p < 0.001$), and B-point advanced by an average of 2.2 mm ($p < 0.05$). These changes remained significant for the overall observation period T1–T4, indicating excellent stability; and no significant post-surgical change was measured at either of these variables from T2–T4. Overall, A-point moved forwards by an average of 4.3 mm ($p < 0.001$), and B-point by an average of 2.4 mm ($p < 0.05$). Menton advanced horizontally by an average of 3.4 mm ($p < 0.05$) during surgery and by an average of 3.2 mm ($p < 0.05$) overall from T1–T4. No significant horizontal relapse was measured at any of the variables of the maxillomandibular complex during the post-surgical observation period (T2–T4). Although significant

horizontal changes were measured at Gonion in the immediate post-surgical observation periods T2–T3 and T3–T4, these changes were insignificant overall from T2–T4 and T1–T4, and most likely indicate the result of neuromuscular adaptation. Posteriorly, PNS advanced an average 5.4 mm ($p < 0.001$) during surgery from T1–T2, and by an average of 4.9 mm ($p < 0.001$) overall from T1–T4. There was a small amount of posterior relapse measured at PNS of 0.4 mm during the post-surgical observation period from T2–T4. Although this was not statistically significant, it suggests relapse possibly relating to neuromuscular adaptation. Mx6 advanced by an average of 3.8 mm ($p < 0.001$) during surgery and this change remained significant for the overall observation period T1–T4 (Mx6: 3.8 mm, $p < 0.001$). There were no cases of severe or measurable condylar resorption or bone remodelling identified in this group.

No significant change in lower facial height proportion was measured in the clockwise rotation group during any of the time intervals.

Group 3: Anti-clockwise Rotation group

A significant anti-clockwise rotation of the occlusal plane (SN-OP) averaging 4.6° ($p < 0.001$) during surgery was measured from T1–T2, as presented in Table IV. However, a significant amount of relapse of the occlusal plane angle was also measured during the post-surgical observation period T2–T4 of average 2.5° ($p < 0.001$). Overall from T1–T4, the occlusal plane was rotated significantly anti-clockwise by an average of 2.1° ($p < 0.01$).

An anti-clockwise rotation of the occlusal plane during surgery was produced by significant superior repositioning of the maxilla by a greater amount anteriorly compared with posteriorly. A-point was superiorly repositioned by an average 3.5 mm ($p < 0.001$) and PNS moved upwards by an average of 1.5 mm ($p < 0.05$). These skeletal changes remained significant for the overall observation period T1–T4 (A-point = 2.2 mm, $p < 0.01$; and PNS = 1.4 mm, $p < 0.05$), indicating acceptable stability of superior vertical maxillary repositioning. No significant vertical maxillary relapse was measured during the post-surgical interval T2–T4 (A-point = 1.3 mm, NS; PNS = 0.1 mm, NS); however, the relapse potential was suggested by the measured changes, especially at anterior skeletal maxillary landmarks. The level of significance of the vertical

Table IV. Group 3: Anti-clockwise Rotation group.

	T1-T2	T2-T3	T3-T4	T2-T4	T1-T4
<i>Vertical changes</i>					
Mx1	-3.71***	0.19	1.22	1.41	-2.3**
ANS	-3.84***	0.45	1.03	1.48	-2.36**
A-POINT	-3.57***	0.37	0.95	1.32	-2.25**
PNS	-1.5*	-0.14	0.24	0.1	-1.4*
Mx6	-1.43*	-0.33	0.74	0.41	-1.02
Go	-0.04	-1.07	-0.14	-1.21	-1.25
B-POINT	-1.8	-1.42	1.21	-0.21	-2.01
POG	-3.28*	-1.05	2.02	0.97	-2.31
MENTON	-1.64	-1.22	0.97	-0.25	-1.89
<i>Horizontal changes</i>					
Mx1	5.64***	0.09	-0.89	-0.8	4.84***
ANS	4.12***	0.35	-0.18	0.17	4.29***
A-POINT	4.55***	0.19	-0.34	-0.15	4.4***
PNS	4.29***	0.33	-0.35	-0.02	4.27***
Mx6	5.72***	-0.25	0.12	-0.13	5.59***
Go	2.96*	1.28	-0.59	0.69	3.65*
B-POINT	9.42***	1.22	-1.91	-0.69	8.73***
POG	14.75***	0.98	-2.29	-1.31	13.44***
MENTON	15.13***	0.81	-2.3	-1.49	13.64***
<i>Angular changes</i>					
SNA	4.21***	0.19	-0.52	-0.33	3.88***
SNB	5.06***	0.67	-1.1	-0.43	4.63***
SN-OP	-4.66***	1.49*	1.08	2.57***	-2.09**
OP-MP	1.15	1.62	-0.25	1.37	2.52*
<i>Lower facial height</i>					
LFH%	2.46***	-0.72	-0.48	-1.2*	1.26*

* denotes $p < 0.05$; **denotes $p < 0.01$; ***denotes $p < 0.001$

maxillary changes declined though the overall observation period T1–T4, which was also suggestive of relapse potential. Also, contributing to the occlusal plane, the Mx6 landmark was superiorly repositioned by an average 1.4 mm ($p < 0.05$) during surgery; however, the overall change in Mx6 was insignificant for the observation period T1–T4, measured as an average of 1.0 mm superior movement. The post-surgical change at Mx6 of an average 0.4 mm inferior movement from T2–T4 was not statistically significant and indicated settling of the posterior occlusion. Inferior movement was also detected at Mx1 by an average 1.4 mm during the interval from T2–T4; however, this was not statistically significant and likely indicated

settling of the anterior occlusion. The mandibular landmarks, B-point and Menton, were superiorly repositioned during surgery from T1–T2 (B-point = -1.8 mm, NS; Menton = -1.6 mm, NS) and these changes remained stable during the overall interval T1–T4 (B-point = -2.0; Menton = -1.9 mm), although they were not statistically significant. Pogonion was the only mandibular landmark that was significantly superiorly repositioned during surgery, as a result of genioplasty procedures; however, this change was not significant through the overall observation period T1–T4.

The maxillomandibular complex was significantly horizontally advanced during surgery in the Anti-clockwise Rotation group. A-point advanced by an

average 4.5 mm ($p < 0.001$) from T1–T2, and by an average 4.4 mm ($p < 0.001$) overall from T1–T4. B-point advanced by an average 9.4 mm ($p < 0.001$) during the surgical interval of T1–T2, and by an average 8.7 mm ($p < 0.001$) through the overall interval T1–T4. A greater amount of horizontal advancement was measured at Menton of average 15.1 mm ($p < 0.001$) from T1–T2, which remained significant from T1–T4 (Menton = 13.6 mm, $p < 0.001$). No significant horizontal relapse was measured for any of the variables during the post-surgical observation periods, indicating stability of the anterior horizontal movement of the MMC in this group. The largest amount of horizontal relapse during the interval from T2–T4 was measured at Menton (1.4 mm, NS).

A significant increase in lower facial height proportion during surgery was measured in the Anti-clockwise Rotation group (LFH% = 2.4, $p < 0.001$). Although this change remained significant for the overall observation period of T1–T4 (LFH% = 1.2, $p < 0.05$), a significant amount of negative change (relapse) of equal magnitude was also measured during the post-surgical observation period of T2–T4 for the lower facial height percentage (LFH% = -1.2, $p < 0.05$). No cases of severe or measurable condylar resorption or bone remodelling were identified in this group.

Figure 10 depicts the relapse of occlusal plane rotation in the anti-clockwise (CCR) group. The relapse in occlusal plane angle was statistically significant in the CCR group from T2–T3 and during the post-surgical observation period from T2–T4. By comparison, there was no significant change in occlusal plane angle in either the NR group or the CR group during the post-surgical observation period from T2–T4.

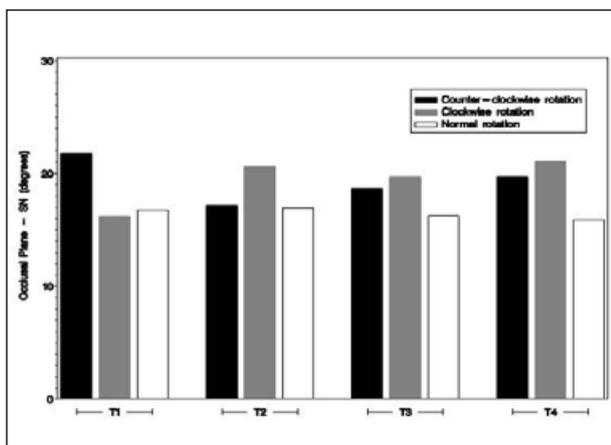


Figure 10. Occlusal Plane angle by time and treatment.

Discussion

The present study utilised similar methods of cephalometric superimposition and digitisation to previous studies on surgical-orthodontic treatment to ensure accuracy, reproducibility, and reliability of the data.^{10,11,15-17,25} Cephalometric tracing, superimposition and digitisation was performed by the same person and the intra-examiner reliability was tested using the ICC, according to accepted statistical testing methods for medical research.^{21,22} The value of over 0.9 calculated for the ICC of each of the cephalometric variables measured indicated an excellent agreement and reliability of measured data.

In the context of post-treatment stability relating to surgical-orthodontic care, it is important to establish how stability is reported in the scientific literature. Studies of post-treatment stability describe post-surgical changes using various methods, including: (1) the percentage post-surgical change of a variable that was observed for a given period of follow-up time; (2) the percentage of patients who experience post-surgical change of a certain variable; and finally, (3) in terms of the absolute amount of post-surgical change measured at a certain variable.^{9-11,17,25-29} Each of these methods has provided valuable knowledge in the field of orthognathic surgery, and has contributed to the development of a hierarchy of stability.^{9,27} A detailed discussion of stability is beyond the scope of this article; however, as a guide, orthognathic surgery involving maxillary superior repositioning, mandibular advancement (<10 mm), and maxillary advancements (<8 mm) is considered stable (i.e. approximately 20% chance of 2–4 mm post-surgical change) when moderate in magnitude. In contrast, surgery resulting in maxillary inferior repositioning is categorised as problematic, defined by an approximately 40–50% chance of 2–4 mm post-surgical change and a significant chance of >4 mm change.²⁷ Furthermore, several principles for post-surgical stability have been proposed: (1) stability is greatest when the soft tissues are relaxed during surgery and least when they are stretched, (2) excellent stability requires neuromuscular adaptation, and (3) neuromuscular adaptation affects muscular length, not muscular orientation.⁹

No significant occlusal plane rotation was produced during orthognathic surgery or overall in the No Rotation group. The maxillomandibular complex was advanced horizontally during surgery without

occlusal plane rotation. A measurable, although statistically insignificant, amount of superior maxillary repositioning and mandibular autorotation during surgery was evident. The possible explanation for superior maxillary repositioning is twofold: (1) to maintain incisal display and adjust for upper-lip soft-tissue shortening following maxillary advancement, and (2) the removal of bony interferences from the posterior maxilla during surgery.^{30,31} Mandibular autorotation follows as a consequence of maxillary superior repositioning during surgery.^{13,14} Overall, the maxilla advanced horizontally at A-point by an average of 2.9 mm ($p < 0.01$); and the mandible advanced by an average of 3.7 mm ($p < 0.01$) and 7.2 mm ($p < 0.001$) at B-point and Menton, respectively. A larger amount of advancement at Menton compared with B-point was the effect of mandibular autorotation during surgery. No significant changes were measured in any of the cephalometric variables during the post-surgical observation period from T2–T4, and a ≤ 2 mm change in vertical and horizontal linear measurements was recorded for each of the variables (except Menton = 2.2 mm, NS), indicating excellent post-surgical stability. Furthermore, the changes produced during surgery at each of the variables tested remained statistically significant for the duration of the study over the interval from T1–T4, also indicating excellent treatment stability. These results are comparable to previous studies that have demonstrated the high stability and predictability of orthognathic surgery without occlusal plane rotation.^{9,11,27,29,32}

The Clockwise Rotation group was characterised by clockwise rotation and horizontal advancement of the maxillomandibular complex. The occlusal plane steepened by an average of 4.3° during surgery. A further 0.5° steepening was measured during the post-surgical interval, producing an overall clockwise rotation by 4.8° . Steepening of the occlusal plane during surgery was produced by superior repositioning and horizontal advancement of the posterior maxilla (measured at PNS and Mx6). During surgery, PNS was repositioned superiorly by an average of 2.7 mm and advanced horizontally by average 5.4 mm. Overall, PNS was superiorly repositioned by an average of 2.3 mm and horizontally advanced by an average of 4.9 mm. There was no significant post-surgical change measured at PNS. By contrast, there was a measurable amount of post-surgical movement in the inferior direction at dental landmarks Mx1 and

Mx6, such that, for the overall observation period from T1–T4, the vertical change produced during surgery at Mx6 was no longer significant (Mx6 = -1.2 mm, NS) and significant inferior movement at Mx1 was evident (Mx1 = 1.9 mm, $p < 0.05$), which was not produced during surgery from T1–T2. These post-surgical changes indicate likely settling of the occlusion.^{9,10} The overall superior movement from T1–T4 at Gonion of an average of 2.1 mm was the result of surgical change and post-surgical neuromuscular adaptation. No significant vertical changes were observed at anterior skeletal landmarks during surgery or for the overall time interval T1–T4, indicating successful surgical treatment and excellent stability of the results. A significant amount of horizontal maxillary and mandibular advancement was produced during surgery at anterior regions (A-point = 4.61 mm; B-point = 2.2 mm and Menton = 3.4 mm). These changes remained stable throughout the overall observation period of the study from T1–T4 (A-point = 4.3 mm; B-point = 2.4 mm and Menton = 3.2 mm). No significant horizontal or vertical relapse was measured at any of the variables of the maxillomandibular complex during the post-surgical observation period (T2–T4); and < 2 mm post-surgical change was measured for each of the linear variables in the horizontal and vertical direction, indicating excellent stability. These results compare favourably with the no-rotation group and confirm the findings of previous studies.^{9-11,27} Clockwise rotation of the occlusal plane and maxillomandibular complex during orthognathic surgery is an effective and stable treatment to correct a variety of dentofacial deformities, especially those characterised by mandibular retrognathism and deep overbite.^{5,7,10,11}

A decrease in the occlusal plane angle was achieved during orthognathic surgery and remained significant throughout the observation period in the Anti-clockwise Rotation group. The occlusal plane angle decreased by an average of 4.6° during the interval from T1–T2. However, during the post-surgical review, significant relapse (increase) in the occlusal plane angle was measured (2.5°). Overall, from T1–T4, a significant decrease in the occlusal plane angle of 2.1° was observed throughout the study, which was clinically significant.¹¹ Anti-clockwise rotation of the occlusal plane was produced by significant differential superior repositioning of the maxilla by a relatively larger amount anteriorly. The mandible was

surgically repositioned to match the maxilla; however, the superior repositioning of the mandible was not statistically significant, and resulted in a proportional increase in lower facial height from T1–T2 by an average of 2.4%. The significant relapse in occlusal plane angle measured during the post-surgical interval from T2–T4 may be attributed to vertical changes at maxillary landmarks (dental and skeletal), and was likely the result of settling of the occlusion.^{9,10} The significant proportional decrease in lower facial height measured during the post-surgical interval T2–T4 was the result of a greater amount of vertical relapse of the anterior maxilla (A-point) compared with a vertical change at the anterior mandibular landmark, Menton. Although the vertical changes at A-point and Menton were not significant from T2–T4, the absolute difference was an average of 1.5 mm, which was significant enough to alter the LFH% value. Overall, the change in lower facial height proportion was stable throughout the study, and measured an average increase of 1.2%. The maxillomandibular complex advanced horizontally during surgery in the anti-clockwise group by an average of 4.5 mm at A-point, 9.4 mm at B-point, and 15.1 mm at Menton. These changes were statistically significant and remained significant for the overall duration of the study from T1–T4 (A-point = 4.4 mm, B-point = 8.7 mm, and Menton = 13.6 mm), indicating excellent treatment stability, comparable with the findings of previous studies in this field.^{9–11,27} Post-surgical relapse in the horizontal direction was not significant and measured a maximum average of 1.5 mm at Menton from T2–T4. As expected, a far greater amount of mandibular advancement was produced in the Anti-clockwise Rotation group compared with the Clockwise Rotation group and the No Rotation group for a similar magnitude of horizontal maxillary movement.^{5,6,11}

The present results indicate that a significant degree of relapse may follow an anti-clockwise rotation of the occlusal plane during surgical-orthodontic treatment, which is the possible result of post-surgical changes related to settling of the occlusion.^{9,10} However, overall, the results also demonstrate excellent stability of the maxillomandibular complex in the vertical and horizontal planes, indicating that anti-clockwise rotation of the occlusal plane during orthognathic surgery is a viable treatment alternative for the correction of certain forms of dentofacial deformity, particularly those characterised by severe

chin retrusion and airway compromise.^{10,33} In these circumstances, the stability of occlusal plane rotation during orthognathic surgery may be improved by (1) ensuring maximal superior repositioning of the MMC, (2) maintaining or decreasing the patient's facial height and lower facial height proportion during surgery to promote neuromuscular adaptation, and (3) optimising surgical techniques, including the use of rigid fixation, and appropriate osteotomy design.^{9,10,18,28,34,35} Inferior repositioning of the maxilla during orthognathic surgery is considered one of the least stable orthognathic procedures and is categorised as problematic.²⁷ Therefore, practitioners should aim to reposition the anterior maxilla superiorly to achieve occlusal plane rotation during surgery and negate the potential for relapse that would otherwise have been introduced by inferior repositioning of the posterior maxilla to produce anti-clockwise rotation. Care must also be taken during surgical planning to consider the desired aesthetic and functional goals for each patient, whilst also 'setting' the occlusal plane to the desired angulation to produce anti-clockwise occlusal rotation. These measures will ensure a balanced approach to achieving a harmonious dentofacial outcome, guided by the principles of post-surgical stability.^{9,36}

Although the present findings compare favourably with previous studies on the stability of orthognathic surgery with and without occlusal plane rotation, further studies with a longer follow-up and larger sample size are needed. The duration of follow-up for the present study was an average of 13 months for the three groups, with a range of 6–36 months. A longer follow-up time would be beneficial for comparison with studies demonstrating long-term stability and reporting on the influence of condylar resorption following orthognathic surgery.^{10,25,27,29,37} A larger sample size may also increase the statistical power and conclusiveness of the study. However, the authors of a recent systematic review stated that the greatest difficulty encountered in their study was the scarcity of literature on the topic of occlusal plane (MMC) rotation. It was suggested that the use of randomised clinical trials (RCTs) was warranted to ensure that the quality and standard of further scientific evidence on this topic is acceptable.³⁸

Conclusions

The findings of the present study indicate that a clockwise rotation of the occlusal plane during

orthognathic surgery is highly stable in the year following surgery, and demonstrates comparable stability with cases in which no occlusal plane rotation was performed. Anti-clockwise rotation of the occlusal plane is less stable and a significant degree of post-surgical relapse may be expected. However, the relapse in occlusal plane angle is a result of occlusal settling and likely neuromuscular adaptation following surgery, and, overall, the results of anti-clockwise rotation and moderate advancement of the maxillomandibular complex demonstrate excellent stability for the medium term.

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Conflict of interest

The author has no conflict of interest to declare.

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