JOHAN P. REYNEKE

Rotation of the Maxillomandibular Complex

An Alternative Treatment Design in Orthognathic Surgery

ACADEMIC DISSERTATION
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Abstract

Conventional treatment planning for the correction of dentofacial deformities does not always achieve optimal aesthetic outcomes, especially in the treatment of high or low occlusal and mandibular plane angle cases. Rotation of the maxillomandibular complex or altering the occlusal plane angle, independent of the existing occlusal plane, during the surgical correction of the occlusion in these cases, can often result in an improved aesthetic outcome.

A maxillomandibular complex triangle constructed between anterior nasal spine, posterior nasal spine and pogonion on a cephalometric tracing, facilitates visualization of the soft and hard tissue changes that can be achieved by either clockwise or counter-clockwise rotation of the maxillomandibular complex. The variation of soft tissue changes that can be obtained by changing the rotation point is simplified by the concept of a maxillomandibular triangle. Formulas were developed for the basic prediction of soft tissue changes. These formulas can be utilized to indicate the required direction of rotation as well as selection for the most favorable point of rotation of the maxillomandibular complex for the treatment of specific deformities.

The method for the development of a surgical visual treatment objective for maxillomandibular complex rotation differs from the development of a visual treatment objective for conventional treatment. A method for the development of a cephalometric visual prediction tracing was designed and the soft tissue effects that can be expected following clockwise and counter-clockwise rotation of the maxillomandibular complex around various points demonstrated.

A total of 89 patients who had undergone double jaw surgery for the correction of dentofacial deformities were divided into three groups: Group 1 consisted of 22 patients with correction by means of conventional treatment planning methods all involving mandibular advancement procedures; Group 2 consisted of 26 patients who had clockwise rotation of the maxillomandibular complex while Group 3 consisted of 41 patient where the maxillomandibular complex was rotated in a counter-clockwise direction. Long-term post-operative skeletal stability comparing the three groups was studied. The skeletal stability of the groups was found to be, not only comparable with each other, but also with the skeletal stability following two jaw surgeries reported in the literature.

The clinical outcomes of all the cases in the study were evaluated and compared. The results compared well with no significant difference between the groups. In general the aesthetic outcomes were relatively high.

Keywords:

Rotation of the maxillomandibular complex
Clockwise rotation
Conventional treatment
Counter-clockwise rotation
Occlusal plane alteration

Acknowledgements

This work was carried out under the auspices of the Institute for Regenerative Medicine and Medical School, University of Tampere, Tampere, Finland. Although the surgical design was developed in the early 1990's the refinement of the concept and surgical technique took many years. The research was carried out spanning the years 2003-2005.

I wish to express my gratitude and thanks to my supervisor, Riitta Suuronen, Professor and head at the Institute of Regenerative Medicine and Medical School, University of Tampere, Tampere, for; firstly, encouraging me to undertake this project and secondly, for providing me with expert guidance and valuable comments. Her enthusiasm and support certainly made this work possible. I was fortunate to have such a renowned researcher as supervisor. The advice of Leena Ylikontiola and Pekka Laine is greatly appreciated.

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Professor Chris Snijman, former Head of the Department of Maxillofacial and Oral Surgery, Faculty of Dentistry, University of Pretoria, and later Dean of the Faculty of Dentistry, University of Pretoria, passed away several years ago. One of the regrets in my life is that I will not be able to present him with a copy of this thesis. He was certainly one of the fathers of our profession in South Africa and my role model. I thank him for his inspiration and teaching, especially instilling in me, as a surgeon, to have the utmost respect for hard and soft tissues at all times.

I express my sincerest thanks to my dear friends and Orthodontic colleagues; Professor Tony Mc Collum, Department of Orthodontics, Division of Dentistry, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg and Professor Bill Evans former Head of the Department of Orthodontics, Division of Dentistry, Faculty of Health Sciences and now acting Dean of Division of Dentistry at the same university, for their confidence, help and support and co-authoring some of the publications on which this thesis was based. I also thank them for making me think like an Orthodontist…sometimes! I offer my sincerest appreciation and thanks to the co-authors of the other publication that formed an integral part of this research, Professor Riitta Suuronen, Institute for Regenerative Medicine, University of Tampere, Tampere, Finland and Dr. Richard Bryant, former resident, Department of Maxillofacial and Oral Surgery, Division of Dentistry, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg as well as Dr Piet Becker.

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Orthognathic surgery demands a team approach in which the orthodontist plays an important role in the treatment of patients with dentofacial deformities. In this respect, I would like thank my many orthodontic colleagues that I had the privilege and honor to work with over the past three decades.

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Johannesburg, October 2005. Johan P Reyneke.

Abbreviations

A	A point
ANB	A point : Nasion :B point angle
ANS	Anterior Nasal Spine
AO	A point : Occlusal plane line
B	B point
Ba	Basion
BaN	Basion : Nasion plane
BO	B point : Occlusal plane line
CT	Conventional treatment
CR	Clockwise rotation
CCR	Counter-clockwise rotation
FH	Frankfort horizontal plane
G’	Soft tissue glabella
MMC	Maxillomandibular Complex
MMCT	Maxillomandibular Complex Tracing
MP	Mandibular Plane
N	Nasion
NA	Nasion : A point plane
O	Orbitale
OM	Occlusal : Mandibular plane angle
OP	Occlusal Plane
OT	Original Tracing
PNS	Posterior Nasal Spine
Pog	Skeletal Pogonion
Pog’	Soft tissue Pogonion
PP	Palatal Plane
S	Sella
Sn	Subnasale
SN	Sella :Nasion plane (anterior cranial base)
SNA	Sella : Nasion : A point angle
SNB	Sella : Nasion : B point angle
VME	Vertical Maxillary Excess
VTO	Visual Treatment Objective

Glossary of terms

Anterior nasal spine (ANS): The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

Basion (Ba): The lowest point on the anterior rim of the foramen magnum.

Conventional orthognathic treatment (CT): The surgical correction of vertical dentofacial deformities are considered *conventional* if the occlusal plane alteration (rotation) takes place around a point at (or just behind) the mandibular condyle.

Frankfort plane (FH): The plane extending from porion to orbitale.

Glabella (G): The most anterior point on the frontal bone.

Glabella (G'): The most anterior point on the soft tissue of the forehead.

Mandibular plane (MP): A line tangent to the lower border of the mandible and the lowest point of the symphysis (Menton).

Maxillomandibular complex (MMC)*:* The maxilla below the le Fort I osteotomy and the distal part of the mandible anterior to the vertical osteotomy on the body of the mandible forms the *maxillomandibular complex* once the teeth had been placed in the planned occlusion.

Maxillomandibular complex tracing (MMCT): The tracing (on a separate piece of paper) of the maxilla below the le Fort I osteotomy line and the distal part of the mandible anterior of the vertical osteotomy line with the teeth in the desired occlusal relationship.

Nasion (N): The most anterior point on the frontonasal suture in the midsagittal plane.

Occlusal plane (OP): A line bisecting the overlapping cusps of the molars and the incisor overbite (Downs).

Orbitale (O): To locate orbitale, place one end of a ruler tangent to the top edge of ear rod (mechanical porion) and move the other end upwards until it first touches the infra orbital rim of the orbit; this point is orbitale.

Original tracing (OT): The tracing of the dental, skeletal and soft tissues of the face on a lateral cephalometric radiograph.

Pogonion (Pog): The most anterior point on the bony chin

Porion (Po): The most superiorly positioned point of the external auditory meatus located by using the ear rods of the cephalostat (mechanical porion).

Posterior nasal spine (PNS): The posterior spine of the palatal bone constituting the hard palate.

Sella (S): Geometric center of the pituitary fossa located by visual inspection.

Soft tissue pogonion (Pog'): The most anterior point on the soft tissue of the chin.

Subspinale (A point): The most posterior midline point in the concavity between the anterior nasal spine and the prosthion (the most inferior point on the alveolar bone overlying the maxillary incisor teeth).

Supramentale (B point): The most posterior midline point in the concavity of the mandible between the most superior point on the alveolar bone overlying the lower incisor (infradentale) and pogonion.

Visual Treatment Objective (VTO): A prediction of the dental, skeletal and soft tissue treatment objectives developed from a cephalometric radiograph tracing.

List of original papers

This thesis is based on the following original articles which are referred to in the text:

1. McCollum AG, Reyneke JP & Wolford LM (1989). *An alternative for the correction of the Class II low mandibular plane angle.* Oral Surg Oral Med Oral Pathol 67(3): 231-241.

2. Reyneke JP (1990). *Surgical manipulation of the occlusal plane.* Int J Adult Orthod Orthognathic Surg 5(2): 99-110.

3. Reyneke JP (1998). *Surgical manipulation of the occlusal plane: new concepts in geometry.* Int J Adult Orthod Orthognathic Surg 13(4): 307-316.

4. Reyneke JP (1999). *Surgical cephalometric prediction tracing for the alteration of the occlusal plane by means of rotation of the maxillomandibular complex.* Int J Adult Orthod Orthognath Surg 14: 55-64.

5. Reyneke JP, Bryant RS, Suuronen R, Becker PJ (2006). *Post-operative skeletal stability following clockwise and counter-clockwise rotation of the maxillomandibular complex compared to conventional orthognathic treatment* (accepted for publication, British Journal of Oral and Maxillofacial Surgery).

Reprints were made with permission of the relevant journals.

1 Introduction

The treatment of dentofacial deformities through mobilization of both upper and lower jaws was first described by Mohnac (1965). Mohnac (1966) also introduced various surgical approaches involving simultaneous segmental procedures to the upper and lower jaws. Finn, Throckmorton, Bell & Legan (1980) introduced more sophisticated orthognathic surgical procedures combined with orthodontic treatment involving simultaneous surgery to both jaws. The indications of double jaw surgery were established by Epker, Turvey & Fish (1982) while the treatment planning for these procedures described by Turvey, Hall, Fish & Epker (1982). The possibility of repositioning the maxilla, mandible and chin in one surgical procedure not only placed greater demands on the clinician in treatment planning, but also involved increased risk for complications and increased the operating time. However, most importantly they offered real patient benefit. Simultaneous mobilization of the maxilla, mandible and the chin now allowed the clinician to plan and correct multiple dentofacial deformities concurrently (Turvey, Hall, Fish & Epker 1982).

Tremendous advances in the science and art of surgical correction of jaw deformities have been seen in the last three decades (Betts & Turvey 2000). Improved understanding of the treatment planning, accurate prediction of hard and soft tissue results as well as technological advances in fixation methods has made it possible to treat most patients with dentofacial deformities successfully (Kinnibrew, Hoffmann & Carlton 1983, Kallela et al 1998, Wolford & Fields 2000, Dohl, Reyneke, Thompson & Sandor 2006).

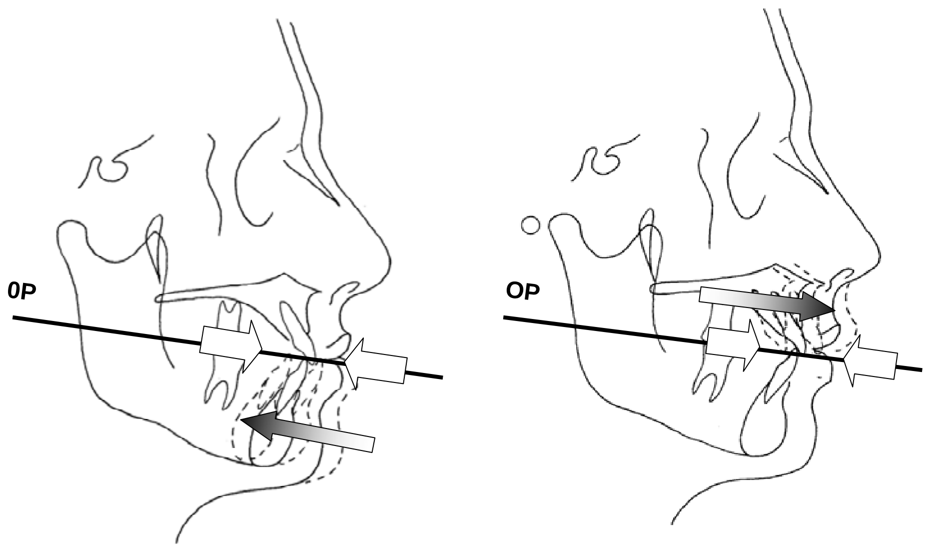
Many dentofacial deformities require surgery to both the maxilla and the mandible to optimized the occlusal function and facial aesthetics and the surgical planning guidelines have been developed (LaBlanc, Turvey & Epker 1982, Epker, Turvey & Fish 1982, Turvey, Phillips, Zayton & Proffit 1988). Conventional management in double jaw surgery, regardless of the steepness of the pre-surgical OP angle, either maintains the pre-surgical OP angulation or alters it by rotation of the mandible following vertical repositioning of the maxilla (usually in an upward and forward direction) (Epker, Fish & Stella 1995). Although treatment according to these methods may achieve an acceptable relationship of the teeth in centric relation, they may not always provide the best aesthetic result.

The “limitation” of adhering to the existing OP, with or without rotation at the condyle, can however be overcome (Wolford, Chemallo, Hilliard, 1993). Two jaw surgery allows the surgeon to alter the OP to enhance the aesthetic outcome. It was felt that this relatively new and alternative treatment design in orthognathic surgery required formalization regarding indications for this method of treatment design, principles and concepts for treatment planning, expected soft tissue changes, creation of a specific method for the development of a surgical visual treatment objective and a study of the long term stability of results.

2 Background and literature review

2.1 Conventional treatment planning

The correction of most dentofacial deformities requires single jaw surgery whereby either the mandible or the maxilla is repositioned. Repositioning the mandible may involve advancement or setback of the jaw and this horizontal movement should take place along the OP of the maxilla (the unoperated jaw) (Jacobson & Sadowsky 1980, Wolford, Hilliard & Dugan 1985) (Fig.1).



a b

Figure 1. Any antero-posterior movements of the mandible or maxilla should take place along the existing mandibular occlusal plane. (a) the mandible is advanced/set back and (b), the maxilla advanced /set back along the existing mandibular occlusal plane (OP).

Maxillary repositioning, either anteriorly or posteriorly (albeit seldom) will also take place along the existing OP. The maxilla however, may also be repositioned superiorly, for the treatment of vertical maxillary excess (VME), or inferiorly, down grafted for the correction of maxillary vertical deficiency (Epker & Fish 1995). A change in anterior facial height has a significant effect on the horizontal relationship of the jaws, and when the maxilla is vertically repositioned an additional dimension is added to the surgical design (Schendel, Eisenfeld, Bell & Epker 1978). A change in the height of the maxilla will necessitate the mandible to rotate, either counter-clockwise (after superior repositioning of the maxilla) or clockwise (after inferior repositioning of the maxilla). The mandible will rotate around a point at or just posterior of the mandibular condyle (Nattestad & Vedlofte 1992, Cottrell et al 1997), and as a consequence of the rotation of the mandible, the OP angle will also change (Fig. 2).

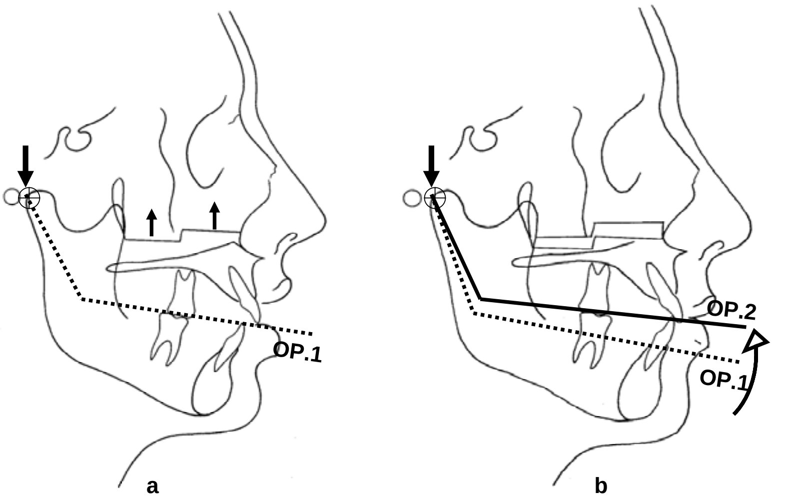


Figure 2a, Following superior repositioning of the maxilla the mandible will autorotate around a point at or just behind the condyle (arrow). b, as a consequence of the CCR of the mandible, the OP will change from OP.1 (dotted line) to OP.2 (solid line). (When the maxilla is down grafted, the mandible will conversely, rotate clockwise and the OP plane angle will increase).

The final OP will therefore be determined by the mandibular OP after autorotation. Any antero-posterior movements of the maxilla and/or mandible should now take place along the "new" OP (Wolford, Hilliard & Dugan 1985) (Fig. 3).

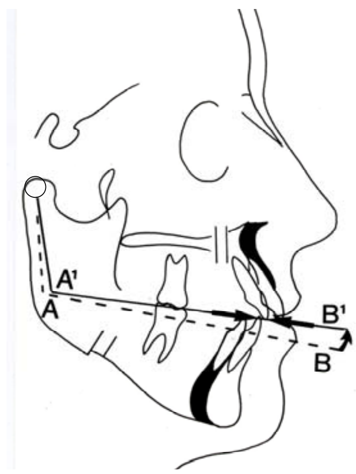


Figure 3. The OP has changed from A-B to A1-B1 and antero-posterior repositioning of the maxilla and/or mandible should now take place along this "new" OP (A1-B1).

During the correction of anterior open bite deformities the posterior maxilla will be superiorly repositioned to "conform" to the mandibular OP after CCR of the mandible, closing the open bite (Bell 1971, Proffit & Bell 1980). This will often require greater superior repositioning of the posterior maxilla than in non open bite cases where the maxilla needs to be superiorly repositioned (Epker & Fish 1978). The variation in the amount of superior repositioning of the anterior and posterior maxilla to allow the maxillary OP to "conform" to the mandibular OP is well demonstrated by the changing pattern of bone that has to be removed for maxillary repositioning. This is evident when comparing the difference in the pattern of bone removal at the le Fort one osteotomy for correcting an anterior open bite malocclusion and correction of a purely vertical maxillary excess dentofacial deformity (Fig. 4).

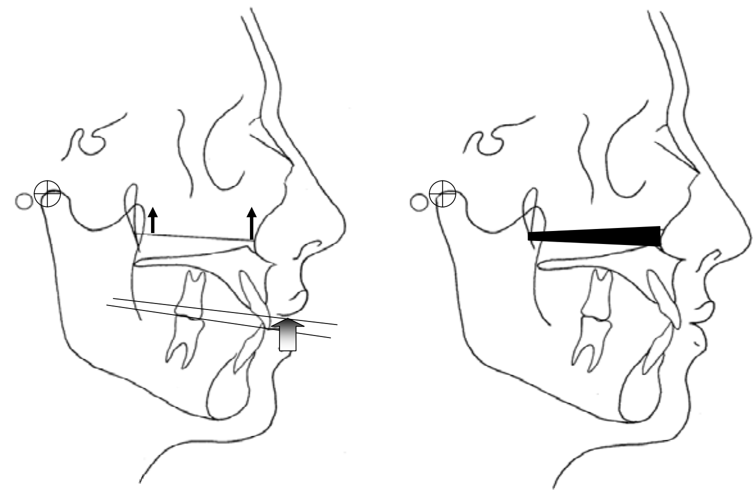


Figure 4a. Due to the arc formed by the mandible with rotation around the condyle the superior movement closer to the point of rotation will be less than further away from the center of rotation (left). Therefore, the amount of superior movement of the posterior maxilla will be less than the superior repositioning at the anterior maxilla (right).

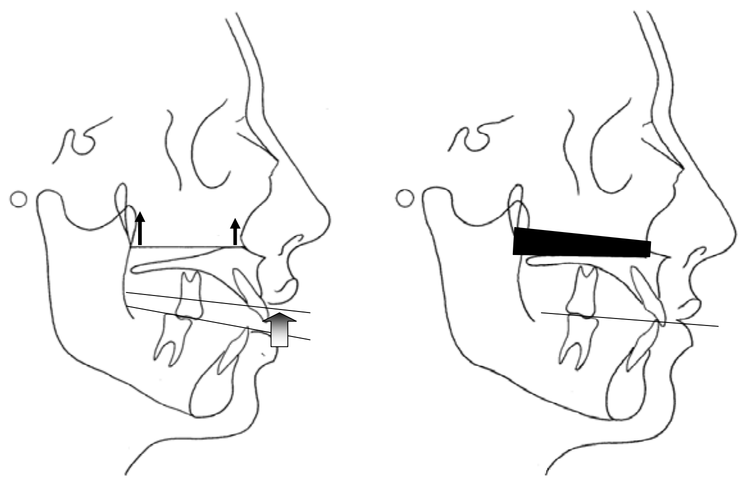


Figure 4b. In anterior open bite cases where the occlusal planes of the maxilla and mandible differ, the posterior maxilla needs more superior repositioning to allow the mandible to autorotate while the maxillary OP conforms to the OP of the mandible.

2.2 Cephalometric analyses relevant for cases requiring rotation of the MMC

Cephalometry can greatly enhance orthodontic and surgical diagnosis and treatment planning, however, has several limitations (Delaire, Schendel, & Tulasne 1981, Weems 1995). It must be recognized that with cephalometrics a two dimensional radiograph represents a three dimensional object (Butow & van der Walt 1984). Other difficulties are standardizing head posture, soft tissue position and occlusal relationship when taking the radiograph (Preston, Todres, Evans, Murphy 1995, Wylie, Fish & Epker 1987). The difficulty in identifying cephalometric landmarks as well as the reproducibility of the landmarks is also a potential limitation, especially when measuring and comparing hard and soft tissue changes on pre- and post-operative radiographs (Chen et al 2004, Schulze, Gloede & Doll 2002). It should also be kept in mind that when using cephalometric analyses, an individual tracing is compared to an average facial pattern and the difference between them often requires considerable interpretation (Saltzmann 1962).

2.2.1 Hard tissue cephalometric aspects:

The OP plane and its angle in relation to other facial planes i.e. the anterior cranial base (SN) and the Frankfort horizontal plane (FH) has traditionally played a significant role in the cephalometric analyses of patients needing orthodontic treatment and/or orthognathic surgery (Tweed 1953, Steiner 1960, Woodside 1975, Schudy 1992, Sadowsky 1995).

Definition of the functional occlusal plane (natural occlusal plane): The level of the OP is located 0.5 mm inferior to the mesiobuccal cusp of the maxillary first molar. An OP constructed at this level will go through the tips of the maxillary premolars and bisecting the incisor overbite. This definition of the OP is also called the *natural occlusal plane* (Peterson 1992) and it is found that the long axis of the premolar teeth is approximately perpendicular to this plane (Fig. 5).

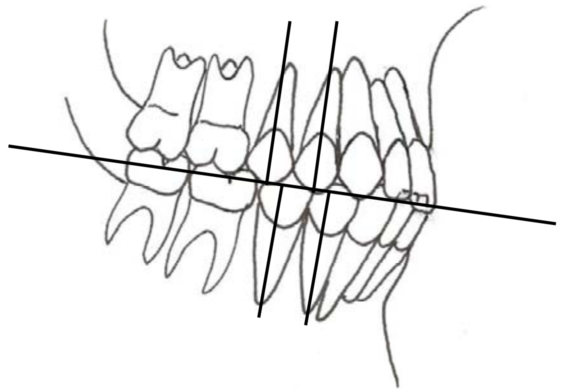


Figure 5. The functional or natural occlusal plane is constructed by a line 0,5mm inferior to the mesiobuccal cusp of the first maxillary molar, through the tips of the maxillary premolar cusps and bisecting the incisor overbite.

In malocclusions, such as open bites and deep bites it is common to find two occlusal planes, a mandibular and a maxillary OP. In open bite cases the occlusal planes will be divergent while in deep bites the planes will be convergent (Fig. 6).

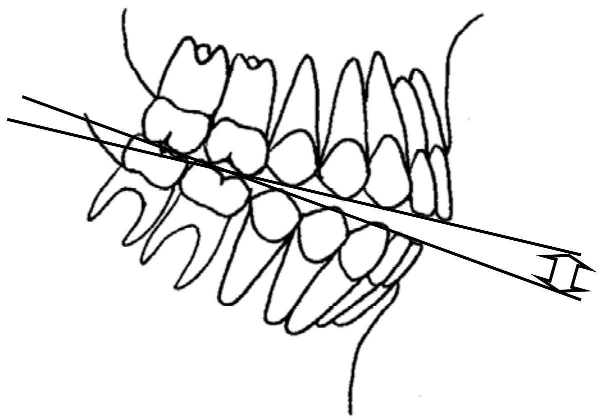


Figure 6a. The occlusal planes of the maxilla and the mandible are divergent in open bite occlusions.

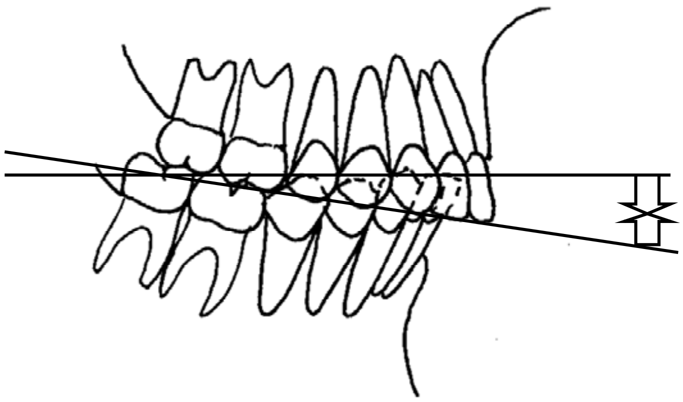


Figure 6b. Due to the deep bite the maxillary and mandibular occlusal planes are convergent.

As far back as 1955, Jenkins realized some shortcomings regarding measuring the antero-posterior jaw position in relation to the skull base by means of the ANB angle according to Steiner 1953. He suggested that the jaws should rather be related to the functional occlusal plane.

Downs definition of the occlusal plane: The OP is constructed by drawing a line bisecting the overlapping cusps of the first molars and the incisal overbite (Downs 1956) (Fig. 7).

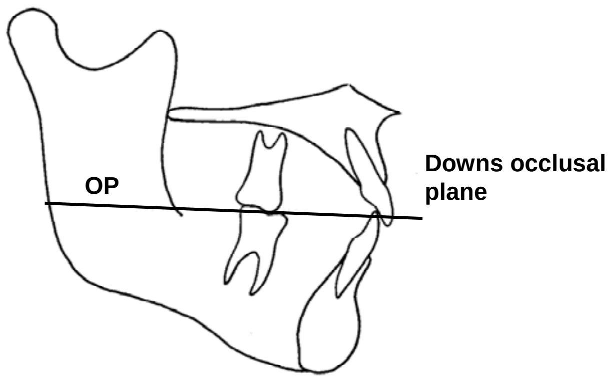


Figure 7. Downs's OP is constructed by a line drawn through the mesiobuccal cusp of the first maxillary molar and bisecting the incisor overbite.

Steiner's definition of the occlusal plane: The OP is constructed by drawing a line through the region of the overlapping of the first molars and the first premolars (Steiner 1953) (Fig. 8).

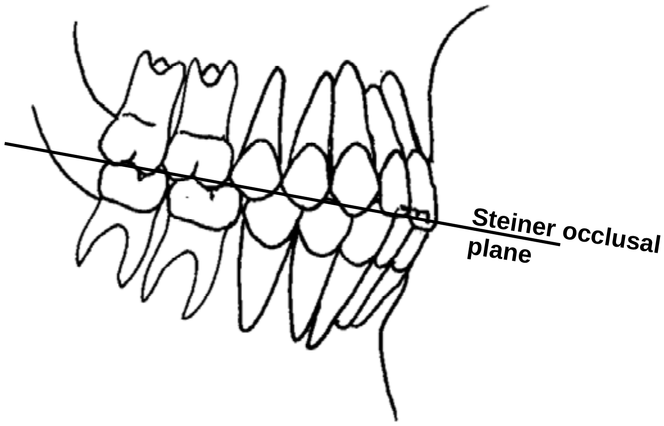


Figure 8. Steiner's OP bisects the overlapping of the first molars and premolars.

Divergence of horizontal facial planes: In most cephalometric analyses, the OP is measured relative to the anterior cranial base (sella – nasion (SN)) and the Frankfort horizontal plane (porion – orbitale (FH)). In the average Caucasian face, the OP is approximately 14 degrees to the SN plane and approximately 9 degrees to the FH plane (Fig. 9).

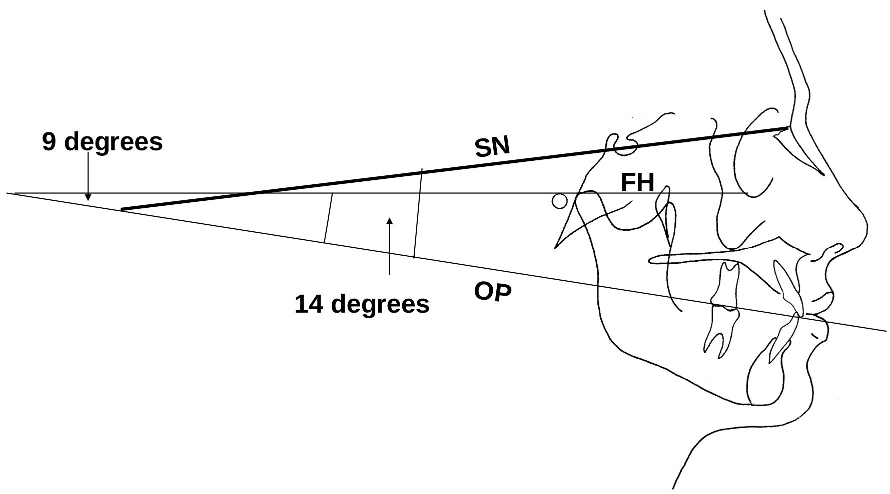


Figure 9. The OP and its relationship to SN (14 degrees) and to the FH (9 degrees).

On a lateral cephalometric radiograph the SN plane, OP, palatal plane (PP) and mandibular plane (MP) are often used as guides to hypodivergency or hyperdivergency of the facial planes. Since these planes always diverge anteriorly, the degree of divergency from an idealized divergency in a normal facial pattern is referred to as hyperdivergency or hypodivergency (Schudy 1992). In the orthodontic and orthognathic literature hyperdivergency is also referred to as high angle, while hypodivergency referred to as low angle. Hyperdivergent skeletal problems are also referred to as "long face syndrome" (leptoprosopic face) and are associated with VME, while hypodivergent skeletal patterns are referred to as "short face syndrome" (euryprosopic face) with vertical maxillary deficiency associated (Schendel, Eisenfeld, Bell & Epker 1976, Bell 1977). The degree of divergency often gives a clue to the direction of growth and to the degree of difficulty to be encountered in problems with post-treatment retention (Moorees, Efstratiadis & Kent 1995)
The occlusomandibular (OM) plane angle is another method of evaluating skeletal divergency and is expressed as the MP angle minus the OP angle (Schudy 1992). An OM angle of 21 degrees would indicate a hyperdivergency while an OM angle of 9 degrees would indicate a more hypodivergent skeletal pattern of the mandible.

The Wits Appraisal:

One way to evaluate the relative antero-posterior relationship between the maxilla and the mandible (discrepancy of the anterior apical bony base region of the jaws) is by means of the Wits analyses. The relative antero-posterior relationship between the maxilla and mandible is measured by comparing A point (maxilla) and B point (mandible) to each other in relation to the OP. Lines are drawn perpendicular to the OP from A point and B point and the AO – BO discrepancy measured (Fig. 10).

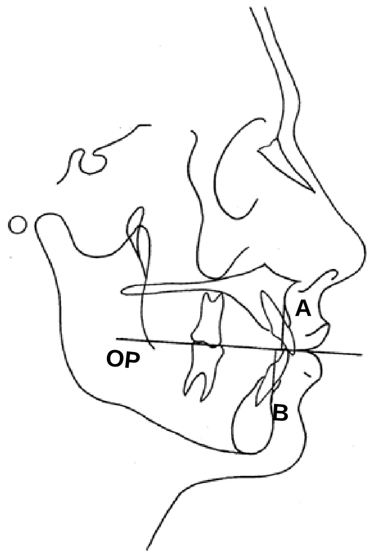


Figure 10. Lines are constructed perpendicular to the OP from A point and B point. The discrepancy between the AO and BO points is measured and gives an indication of the relative antero-posterior relationship of the maxilla and the mandible to each other (normal: AO and BO coincides in females, while AO is 1.0mm behind BO in males).

A discrepancy of 0mm is considered normal in Caucasian females and point AO should be 1.0mm behind point OB in normal Caucasian males (Jacobson 1975). When the mandible is positioned anterior to the maxilla the discrepancy is noted as positive while the difference is noted as negative when the mandible is positioned posterior to the maxilla (Jacobson 1988). The Wits analysis is influenced by the teeth both horizontally and vertically. Horizontally because points A and B are somewhat influenced by the dentition and vertically, because the OP is determined by the vertical position of the teeth. It is therefore important that when the Wits analysis is used that the functional OP is drawn (a line along the maximum intercuspation of the posterior teeth) rather than a plane determined by the vertical position of the incisor teeth.

This approach however tends not to distinguish between discrepancies caused by skeletal problems and those caused by the dentition (Proffit & Fields 1986). The relationship of the jaws to the cranium is also not reflected with the WITS analysis.

The Steiner analysis:

Another way of measuring the relative antero-posterior relationship between the maxilla and the mandible is by relating the jaws to the anterior cranial base on a lateral cephalometric radiograph (Steiner 1959). By subtracting the Sella – Nasion - B point (SNB) angle (normal 80 degrees) from the Sella : Nasion : A point (SNA) angle (normal 82 degrees) the antero-posterior relationship between the maxilla and mandible can be established and the angle is called the A point : Nasion : B point (ANB) angle (normal 2 degrees) (Fig. 11). The Steiner analysis thus relates the relative position of the jaws to the cranium.

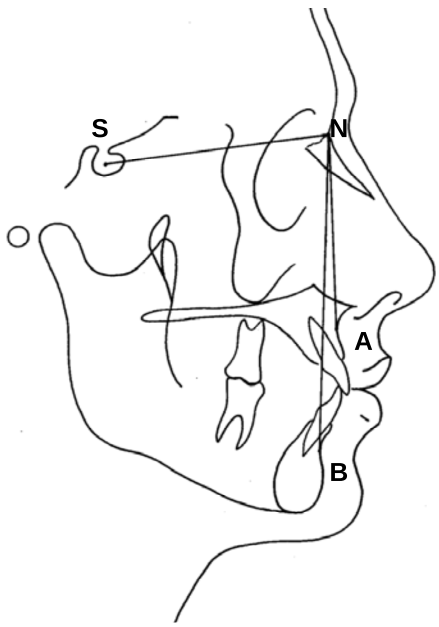


Figure 11. The normal value for the SNA angle is 82 degrees and the SNB angle is 80 degrees. The difference between SNA and SNB angles indicates the antero-posterior discrepancy between the maxilla (A point) and the mandible (B point) relative to the cranial base (SN). The normal ANB angle is 2 degrees.

This method of antero-posterior spatial relationship of the jaws relative to Nasion (N) is influenced by the anterior cranial base length, the steepness of the cranial base as well as the OP angle (Fig 12) (Jacobson 1995).

Several authors investigated the relationship between the ANB angle (Steiner 1959) and the Wits analysis (Jacobson 1975) as well as the effect that any rotation of the jaws may have on the relationship of the apical bony base of the maxilla and the mandible to the skull base as well as to each other (Bishara, Fahl & Peterson 1983, Rothberg et al.1980, Roth 1982, Rushston, Linney & Cohen 1991, Millet & Gravely 1991.) The angle of the OP has a profound effect on the antero-posterior position of the bony apical base of both jaws and therefore ultimately the facial appearance. With the above in mind, the OP should be an important consideration in orthognathic diagnosis and treatment planning.

When comparing measurements of various cephalometric analyses it is often found that they are contradictory. This is also true when comparing the Wits analysis with the Steiner analysis. Due to the rotational effect of the jaws, the variation of the OP angle as well as the variation of the vertical alveolar dimensions of the jaws, quite different observations may be made comparing the Steiner, and the Wits analyses (Roth 1982, Martina et al 1982). In figure 12 the contradiction between two cephalometric analyses is demonstrated in a Class III case with high mandibular and OP angles. The Steiner analysis in this case indicates a mild Class III relationship with an ANB angle of 0 degrees. The Wits analysis however, indicates a severe Class III discrepancy between the maxilla and the mandible with AO 12mm behind BO. This case is a good example of the profound effect that the vertical dimension of dentofacial deformities has on the antero-posterior relationship between the dentition, jaws and soft tissue. Increased vertical development of the maxilla will result in an increased OP angle (high OP angle, hyperdivergency or long face syndrome) (Schendel et al 1976). The downward and backward rotation of the mandible improves the antero-posterior relationship between the jaws and the anterior cranial base (Sn). The antero-posterior relationship between the maxilla and mandible, relative to the OP however, reveals a large Class III discrepancy.

Low mandibular plane angle cases with short anterior lower facial heights, also some times called short face syndrome, will have the opposite effect on the antero-posterior relationship of the jaws, to each other, as well as the anterior cranial base (Freihofer 1981).

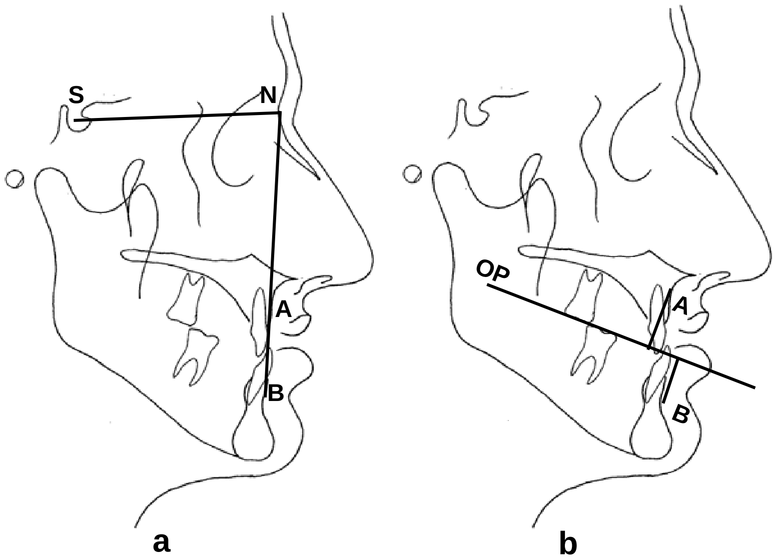


Figure 12a, a Steiner cephalometric analysis of a patient with a Class III occlusion, high mandibular and OP angle and vertical maxillary excess. The ANB angle of 0-degrees (Steiner) indicates a mild Class III discrepancy between the maxilla and mandible. The relationship is measured relative to the anterior cranial base and any further CR due to vertical maxillary growth (increase in lower facial height), could even result in an increased ANB angle, which would then indicate a normal antero-posterior relationship. b, a Wits cephalometric analysis of the same patient in figure 12a. The Wits analysis expresses the relative position of the maxilla to the mandible to the OP indicating a severe Class III relationship. Vertical increase in maxillary height will have little effect on the antero-posterior measurement according to the Wits analysis.

2.2.2 Soft tissue Cephalometric aspects

For the Orthognathic surgeon the aesthetic objectives depend largely on the harmonious relationship between the hard and soft tissue structures of the face (Powell & Humphreys 1984). The soft tissue profile is not only influenced by the inter-relationship between the maxilla, mandible, chin and dentition, but also the relationship of these structures to the anterior cranial base (Park & Burstone 1986). The soft tissue profiles are profoundly influenced by the position and relationship of the underlying hard tissue structures e.g.: The antero-posterior position of anterior nasal spine directly influences the position of soft tissue Subnasale (Sn), while hard tissue Pogonion (Pog) directly influences the position of soft tissue Pogonion (Pog') (Rosen 1988, Ewing & Ross 1992). Likewise, the position and angulation of the incisor teeth influences the upper and lower lip position (Epker, Stella & Fish 1995).
Facial aesthetics may often be the primary concern for many patients. The aesthetic desires of the individual patient should therefore form part of the eventual aesthetic treatment goals. The preoperative orthodontic mechanics should be aimed to allow optimal aesthetics following surgery. There are, in the literature, however, a myriad of clinical facial parameters (Peck & Peck 1970, Powell & Humphreys 1984, Arnett & Bergman (1) 1993, Arnett & Bergman (2) 1993) and cephalometric guidelines (Legan & Burstone 1980, Fish & Epker 1980, Holdaway 1983, Holdaway 1984, Wylie, Fish & Epker 1987) constituting ideal facial harmony and pleasing aesthetics. Two valuable cephalometric soft tissue guidelines used for diagnosis and treatment planning are the facial contour angle and Holdaway's H-line angle.

The Facial Contour Angle:

A line connecting Sn and Pog' forms the lower facial contour plane while the upper facial contour plane is formed by a line joining soft tissue glabella (G') and Sn. The facial contour angle is measured between the lower and the upper facial contour planes above Sn. An angle ahead of the upper facial plane is recorded as negative, while an angle behind the upper facial plane is recorded as positive. A facial contour angle of -11 to -14 degrees is considered to be normal for Caucasian females and -10 to -13 degrees normal for Caucasian males (Epker & Fish 1985). The facial contour angle is an important indicator of the convexity (or concavity) of the soft tissue profile in the context of orthognathic analyses. G' should be considered as a fixed point. G' can usually only be changed by means of craniofacial surgery and any change is mostly indicated in syndromic patients. Sn and Pog' are however, both cephalometric landmarks that can be altered by means of orthognathic surgery. For example, by surgically advancing the maxilla, Sn would be advanced and by so doing the facial contour angle will increase. In addition surgical advancement of the mandible, Pog' will be advanced and in turn the facial contour angle will decrease (Fig. 13).

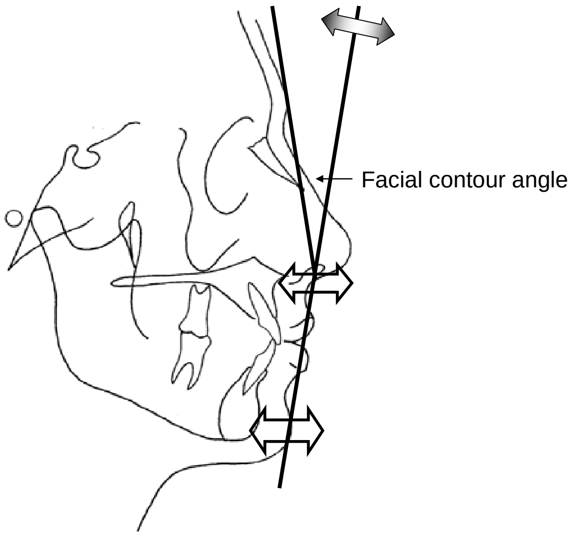


Figure 13. By changing the antero-posterior relationship between Sn and Pog' the facial contour will change.

Holdaway's H-line angle:

The H-line angle is formed by the intersection of soft tissue Nasion´-Pog´ line and a line tangent to Pog´ and the upper lip. The latter angle measures either the degree of upper lip prominence or the degree of retognathism or prognathism of the soft tissue chin (Holdaway 1983, Holdaway 1984). This angle is also a valuable guideline regarding the indication for genioplasty and, more specific, the amount of chin advancement or reduction that will be required for an aesthetic relationship between the chin, mental sulcus, lower- and upper lip. An acceptable angular range for the H-line angle is 7 to 15 degrees (Fig. 14). Chin shape is more important than chin position (antero-posterior position of Pog´). Although Pog´ may be in the ideal antero-posterior position, a deep labio-mental sulcus (labio-mental fold) will make the chin appear knobby, while a shallow sulcus will make the chin appear flat. Helpful guides to evaluate the shape of the chin are: 1. lower lip relation to the H-line. The lower lip to H-line distance is measured from the most prominent outline of the lower lip. 2. The labio-mental sulcus depth is measured at the point of deepest curvature between the lower lip and the chin to the H–line and should be 5mm.

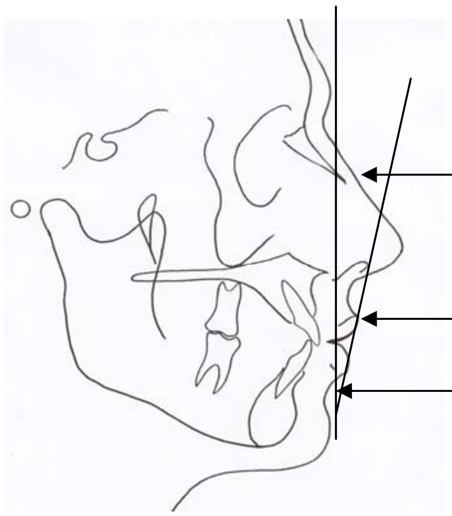


Figure 14. Holdaway's H-angle is formed by the intersection between N'-Pog' line and line tangent to Pog' and the upper lip vermilion. A negative reading indicates that the lower lip is behind the H-line and a positive angle indicates that the lip is ahead of the H-line. A range of -1 to +2mm is regarded to be normal. The mental sulcus depth should be 5mm.

2.3 The relationship between malocclusions, dentofacial deformities, and the facial contour angle

Skeletal Class III malocclusions may be caused by maxillary antero-posterior deficiency, mandibular antero-posterior excess or a combination of the two. This type of jaw malrelationship will result in a less negative facial contour angle (straight or concave profile). Skeletal Class II malocclusions on the other hand may be caused by mandibular antero-posterior deficiency, maxillary protrusion or a combination of the two and will in turn result in a more negative facial contour angle (convex profile). The face is, however, a complex three dimensional structure and the vertical relationship of the jaws will also play an important role in influencing the antero-posterior dimension (profile). For instance, any change in the height of the maxilla will result in a change in the antero-posterior position of the chin due to the rotation (clockwise or counter-clockwise) of the mandible. The clinician should keep this important principle in mind when interpreting the facial contour angle during cephalometric analysis and radiographic diagnosis (Arnett & Bergman (1) 1993, Arnett & Bergman (2) 1993). Figure 15 demonstrates how different dentofacial deformities may have the same facial contour angle.

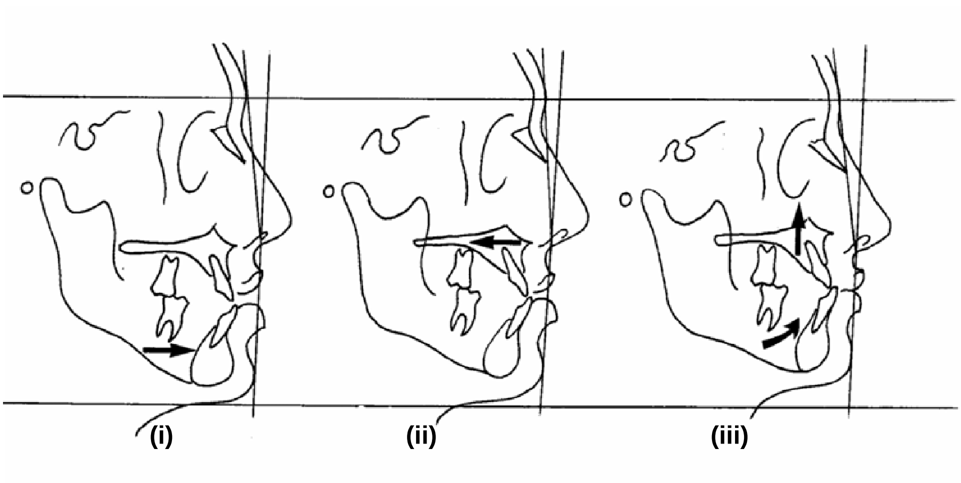


Fig 15a. The same but less negative facial contour angle (concave profile) in these cases is caused by skeletal mandibular antero-posterior excess (i), maxillary antero-posterior deficiency (ii) and vertical maxillary deficiency (iii).

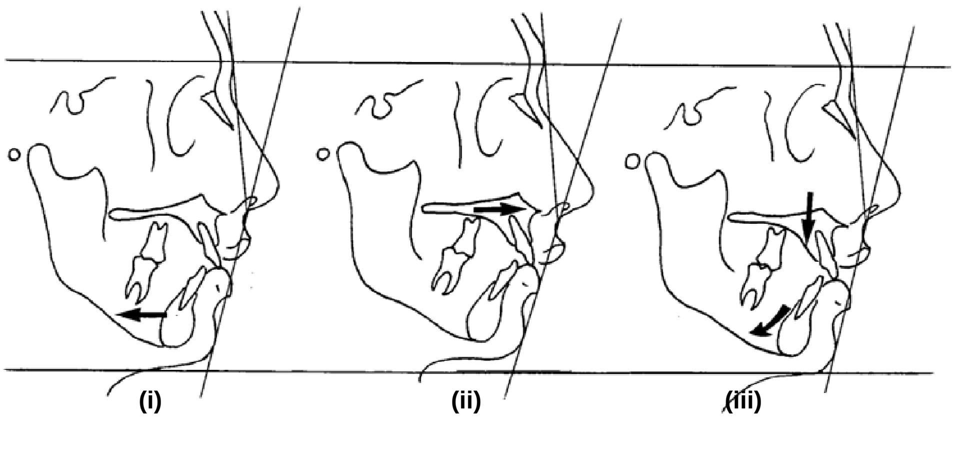


Fig 15b. A more negative facial contour angle in these cases is caused by skeletal mandibular antero-posterior deficiency (i), maxillary antero-posterior excess (ii) and vertical maxillary excess (iii).

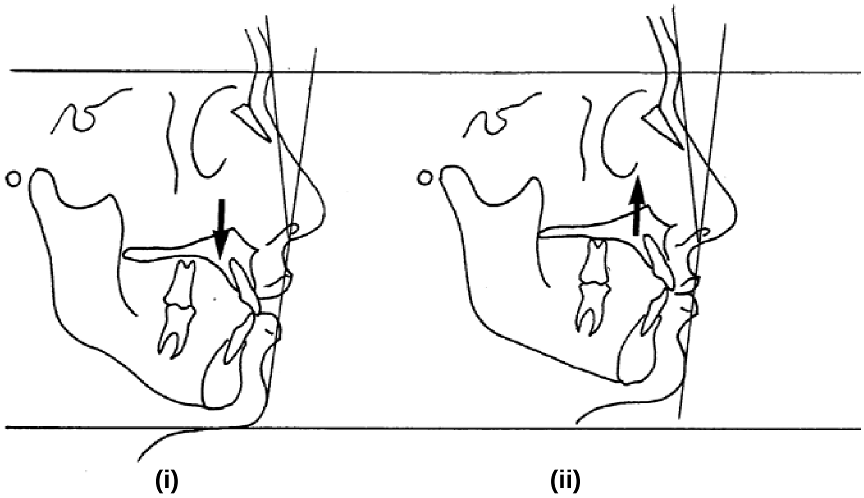


Fig 15c. Both these cases have the same facial contour angle (normal - 12 degrees), however, one has vertical maxillary excess (i) and the other vertical maxillary deficiency (ii).

The inter-relationship between the horizontal and the anterior and posterior vertical dimensions of the face is an important aspect of facial harmony and should be carefully considered when planning the surgical and orthodontic treatment for patients with dentofacial deformities.

2.4 The role of the occlusal plane in diagnosis and treatment planning

The pre-treatment occlusion (malocclusion) and OP represents what the patient starts with, before orthodontic and/or surgical intervention and is often the consequence of a skeletal deformity. The pre-treatment OP of each jaw, the curve of the OP and the OP angle are not only important factors when making a diagnosis, but also play an important role during the development of a treatment plan (Schudy 1992).

The OP was originally defined by Downs (1956) as that line bisecting the overlapping cusps of the first molars and the incisor overbite. In cases in which the incisors are grossly malpositioned the line should be drawn through the region of the overlapping cusps of the first bicuspids and first molars (functional OP). Although in most cephalometric analysis, the OP angle is measured relative to the SN line, Downs defined the OP angle as a measure of the slope of the OP to the FH plane. The angle would be positive when the anterior part of the plane is lower than the posterior.

The occlusal, palatal and mandibular planes always diverge anteriorly. It is, however, prudent when assessing the above planes to SN, or for that matter to any anatomic plane e.g. basion-nasion (BaN) or the FH, to also evaluate the upper – and lower anterior facial heights as well as posterior facial heights.
The degree or divergency from an idealized divergency in a normal facial pattern is referred to as hyperdivergent or hypodivergent (Sadowsky 1995). The degree of divergency of the OP is often an indication of the direction of facial growth and also to the degree of difficulty to be encountered in the successful treatment of the dentofacial deformity. It is often difficult to achieve optimal aesthetic results following the correction of patients with extremely high (hyperdivergent) or low (hypodivergent) OP plane angles. It is in these cases that rotation of the MMC (alteration or manipulation of the occlusal plane angle) should be considered as an alternative treatment plan design (Wolford, Chemallo & Hilliard 1993, Wolford, Chemallo & Hilliard 1994, Chemallo, Wolford & Buchang 1994).

Figure 16 illustrates the extremes of facial pattern divergency comparing a hyperdivergent Class II anterior open bite malocclusion with a vertically excessive maxillary pattern to a hypodivergent Class II division 2 malocclusion with a vertically deficient maxillary pattern. High and low OP facial patterns do, of course, also occur in Class I and III malocclusions and skeletal deformities. The antero-posterior discrepancy between the maxilla and mandible in relation to the OP (according to the WITS analysis) give the clinician another helpful perspective in these cases.

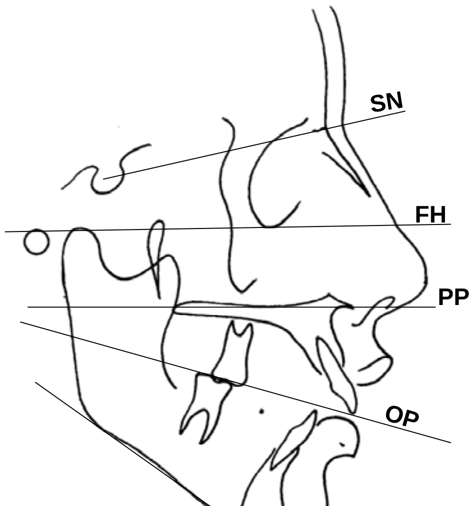


Figure 16a. The cephalometric tracing of a patient with vertical maxillary excess, mandibular antero-posterior deficiency and a Class II division 1 occlusion. The hyperdivergency of the SN plane, the PP, the OP and MP is illustrated.

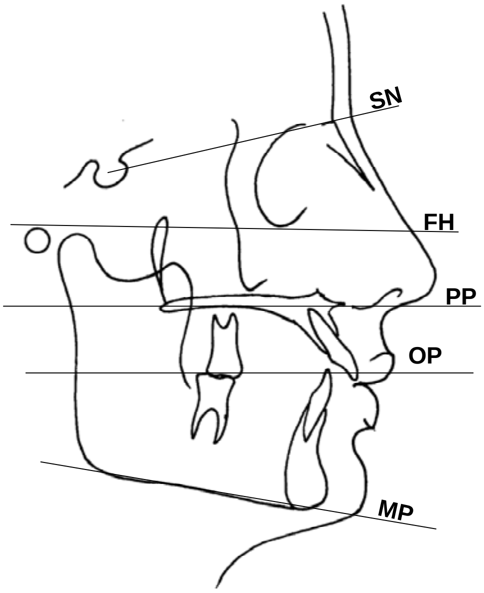


Figure 16b. The cephalometric tracing of a patient with vertical maxillary deficiency and a Class II occlusion illustrates the hypodivergency of the SN plane, the PP plane, OP plane and MP.

Finally the face and MMC should always be considered as a three dimensional anatomical structure. Lateral cephalometric analysis is performed in a sagittal plane, however, the transverse cant of the OP should also always be considered during treatment planning, especially in patients with dentofacial asymmetry (Epker, Stella & Fish 1995).

3 Aims of the study

The purpose of this research project was to formalize the concept of the rotation of the MMC as a treatment method for dentofacial deformities and to give the surgical design a scientific basis. This will enable the surgeon to visualise treatment possibilities and to accurately plan treatment through a structured understanding of the concept of rotating the MMC. The specific aims of the study were:

1. To evaluate the utilisation of a triangle constructed between ANS, PNS and Pog to visualize treatment possibilities:
   a. to develop formulae for expected dental, skeletal and soft tissue outcomes.
   b. to identify specific points on the MMCT, which would allow the surgeon to achieve certain aesthetic results following rotation of the MMC around these points.

2. To develop a specific surgical cephalometric treatment objective method for the concept of rotation of the MMC.

3. To evaluate the skeletal stability following rotation of the MMC in a clockwise direction in one group of patients with the skeletal stability in a group of patients following counter-clockwise rotation of the MMC. Then to compare the above results to skeletal stability in a group of patients following conventional orthognathic treatment involving two jaw surgery and rotation of the mandible around a point at or just behind the condyle.

4. To assess the clinical outcomes of patients in all three groups (CT, the CR and CCR group) and to investigate any correlation between clinical outcome, skeletal stability and the amount of OP rotation.

4 Materials and methods

4.1 Evaluation of the efficacy of the MMC complex triangle

When planning and performing two jaw surgery the final horizontal and vertical relationship between ANS, the maxillary incisor edge and Pog are determining factors in the aesthetic outcome.

The horizontal inter-relationship between ANS, upper incisor tip and Pog is a consequence of the horizontal dental and skeletal relationships e.g. Class I, Class II or Class III (Fig 17a). At the same time the vertical relationship between ANS, upper incisor tip and Pog are influenced by the vertical skeletal and dental pattern e.g. vertical maxillary deficiency, vertical maxillary excess, deep or open bite etc. (Fig 17b).

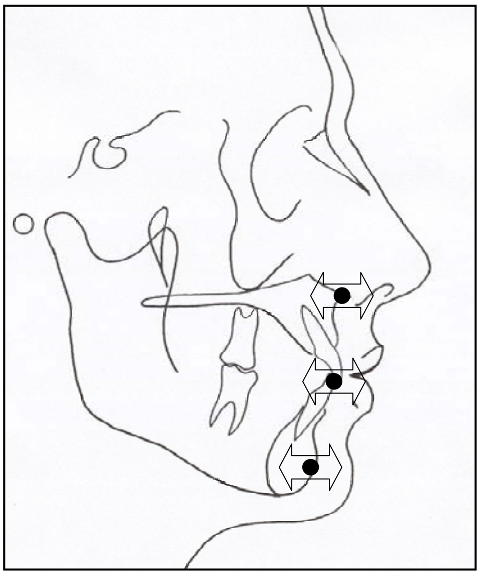


Figure 17a. The antero-posterior inter-relationship of: a) ANS e.g. maxillary antero-posterior deficiency, b) incisor-lip relationship e.g. dental protrusion, dental retrusion, reverse overjet, an increased overjet and c) Pog e.g. microgenia, macrogenia, mandibular antero-posterior excess or deficiency influences the facial harmony.

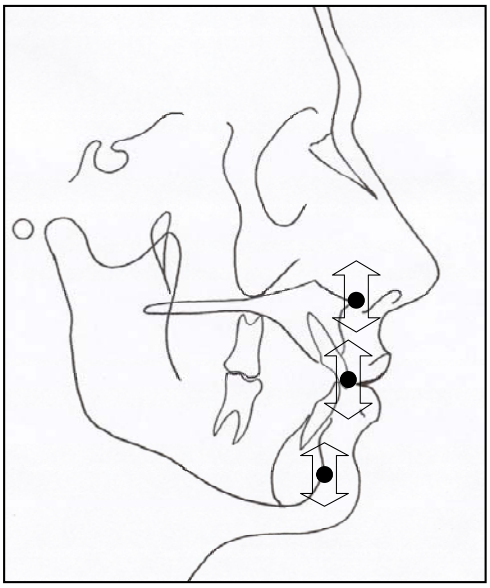


Figure 17b. Vertical facial harmony is influenced by the inter-relationship of: a) ANS e.g. vertical maxillary excess or deficiency, b) incisor-lip relationship e.g. deep bite, open bite and c) Pog e.g. vertical mandibular excess or deficiency.

The inter-relationship of important soft tissue landmarks such as Subnasale (Sn), upper lip position (and its relationship to maxillary incisor) and Pog' are directly dependant on the position of underlying skeletal and dental structures (ANS, upper incisor and Pog respectfully) (Fig 17c and d).

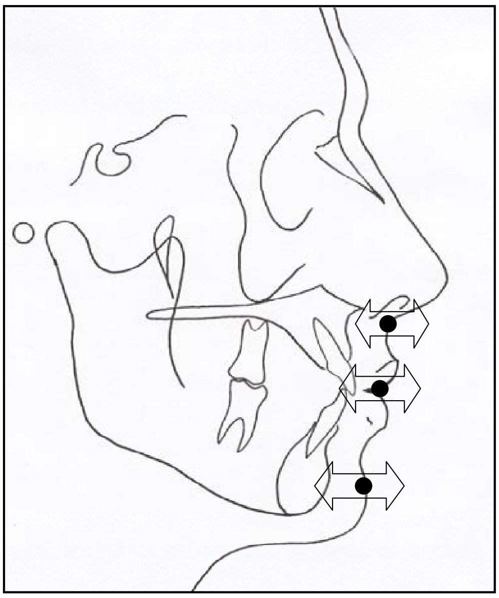


Figure 17c. The underlying horizontal skeletal and dental relationships influence the horizontal inter-relationship between Sn, the lips and Pog' and may result in a concave, straight or convex profile.

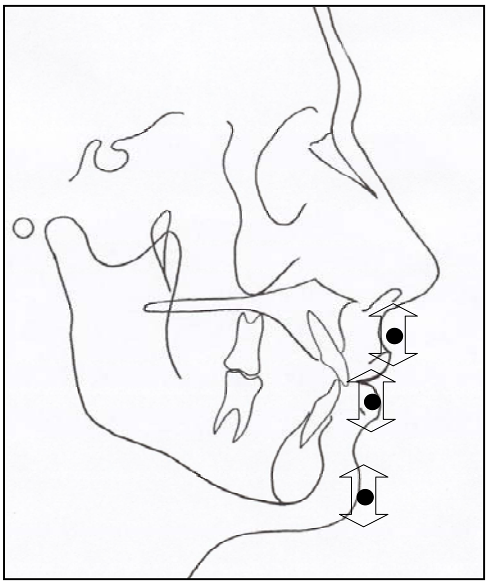


Figure 17d. The lower facial height is influenced by the vertical relationship between Sn, the lips and Pog'. The soft tissue relationship depends on the underlying hard tissue relationships, which will result in a long, short or normal anterior facial height.

Surgical orthodontic correction of skeletal, dental and soft tissue deformities can in most cases position the facial structures in harmonious relationships achieving good aesthetic and functional outcomes. In some hyperdivergent and hypodivergent cases it may be found that the abnormally high or low OP angle limits the achievement of optimal facial aesthetics. In the above instances hard tissue landmarks ANS, incisor tip and Pog may be well related to each other, however, the patient may still have an excessively convex or concave profile (Fig. 17e).

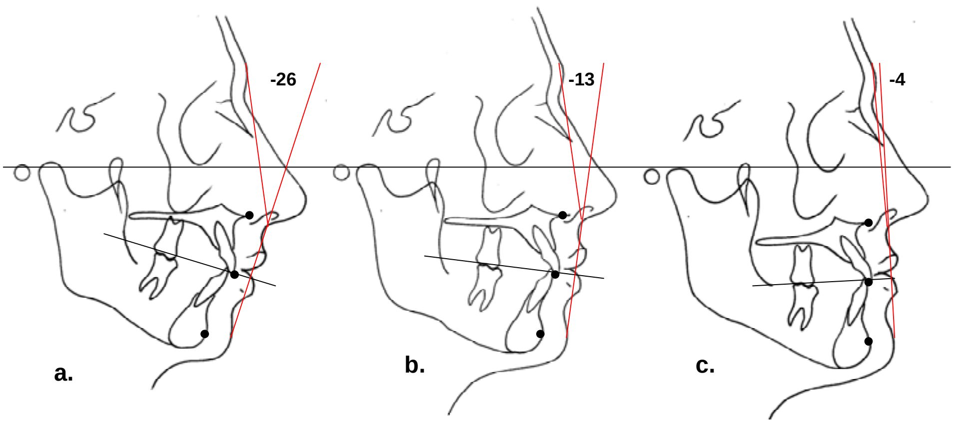


Figure 17e. In all three the cases the inter-relationship between ANS, incisor tip and Pog is the same, however, (a) due to the high OP angle the profile is convex with a facial contour angle of -26 degrees, (b) the facial contour angle is normal (-13 degrees) with normal OP angle and (c) a concave profile with low OP angle and facial contour angle of -4 degrees.

To investigate and to visualize treatment possibilities and expected hard and soft tissue changes as a result of surgical repositioning of the maxilla and mandible *independent* of the existing OP (“manipulation of the OP”), a cephalometric tracing of a patient with relatively normal soft tissue and skeletal relationship and a Class I occlusion was used. A triangle, called the MMC, was constructed on the cephalometric tracing by connecting ANS, PNS and Pog (Fig. 18).

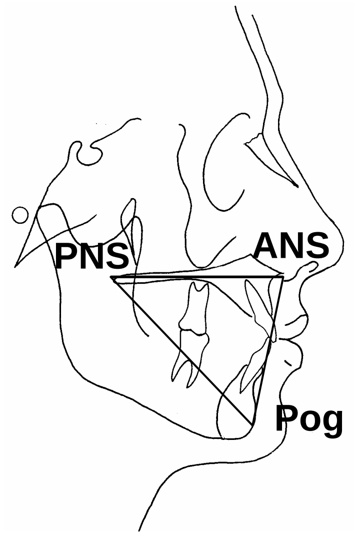


Figure 18. The MMC is represented by a triangle connecting ANS, PNS and Pog.

The same cephalometric tracing (with the constructed MMC triangle) was used to investigate various soft tissue and hard tissue changes that can be expected by rotating the MMC in a clockwise direction (increasing the OP angle), as well as rotation in a counter-clockwise direction (decreasing the OP angle). In addition, the variation in soft tissue, skeletal and dental changes by rotating the MMC around different points were investigated and clinical cases, where this concept was utilized, are used to demonstrate the concept.

The relative linear dimensions between PNS-ANS and ANS-Pog.

Horizontal and vertical measurements were performed on 30 adult dry skulls (15 male and 15 female) to establish relative dimensions of the maxillary length (PNS-ANS) and the skeletal anterior facial height (ANS-Pog) (Fig. 19). The maxillary length forms the superior leg of the MMC triangle, while the anterior facial height forms the anterior leg. The knowledge of the average lengths of these two legs would enable the clinician to calculate the “gearing” that will take place during rotation of the MMC triangle.

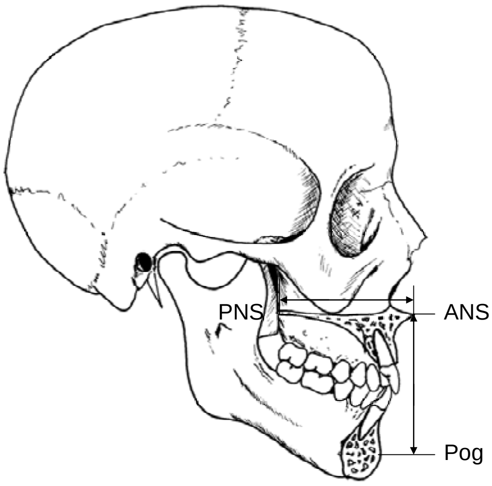


Figure 19. Thirty dry skulls of adult human Caucasians were used to obtain an average measurement for the anterior facial height (ANS-Pog) and maxillary length (ANS-PNS).

4.2 The development of a cephalometric visual treatment objective method.

Careful analysis of the lateral cephalometric radiograph forms an important part of the examination, diagnosis and treatment planning in orthognathic surgery. The cephalometric tracing is used to develop a VTO predicting the dental, skeletal and soft tissue results using pencil and tracing paper. *The cephalometric treatment objective required to plan the surgical treatment involving rotation of the MMC, differs from conventional orthognathic treatment planning.*

The cephalometric tracings and analysis of two patients with dentofacial deformities which would typically require surgical correction utilizing rotation of the MMC were selected. For each of the patients a VTO was developed according to CT methods. A VTO utilizing the concept of rotating the MMC was then developed and described in a step by step fashion. The important role of the constructed MMCT is demonstrated during the detailed description. Using the information obtained from the "MMCT concept", the skeletal, dental and soft tissue changes that can be expected by either clockwise or counter-clockwise rotation of the MMC as well as the importance of the selection of a rotation point around which the MMC should be rotated is demonstrated. The principle of reconciling the cephalometric rotation point with the actual surgical rotation point on the le Fort I osteotomy line is demonstrated and explained.

4.3 Post-operative skeletal stability

Eighty eight patients (19 male and 69 female patients) who underwent orthognathic surgery for the correction of dentofacial deformities were included in this retrospective study. Consecutive patients that qualified regarding surgical design, available records and sufficient follow up time for each group were included in the study. Each patient had surgery consisting of a le Fort I maxillary osteotomy (one- or multi- piece) fixated with two 1.5mm titanium plates (two screws above and two screws below the osteotomy line) in the anterior maxilla and two interosseous wires in the posterior maxilla (multi piece maxillae received four plates); and bilateral sagittal split mandibular ramus osteotomies fixated with 2mm bicortical titanium screws (three screws on each side), (*W.Lorenz Surgical, Jacksonville, U.S.A). Patients who also underwent a sliding genioplasty procedure as part of the surgical correction were included in the study. It is for this reason that B point was selected as reference point as this area of the mandible is not influenced by the genioplasty procedure. All patients had the surgery performed by the same surgeon (JR).

All patients had light training elastics for approximately four to six weeks after surgery. Although surgical splints were used as intermediate splints during surgery, none of the patients had an inter-occlusal splint present in the post-operative phase.

The patients were divided into three groups:

Group CT: Twenty two patients, (17 females and 5 males) with a mean age of 21.9 years (13-48) who had corrective surgery according to conventional orthognathic treatment planning principles. Antero-posterior as well as vertical changes were dictated by the OP of the mandible after autorotation where the rotation point was just posterior to the condyle. The mean follow up time was 14.1 (6-60) months after surgery.

Group CR: Twenty five patients, (19 females and 6 males) with a mean age of 25.5 years (14-50) who had surgical correction involving both jaws with CR of the MMC. The mean follow up time was 13.3 (6-29) months after surgery.

Group CCR: Forty one patients (33 females and 8 males) with a mean age of 20.6 (13-41) who had surgical correction involving both jaws with CCR of the MMC. The mean follow up time was 14 (6-46) months after surgery. The greater superior repositioning of the anterior maxilla than the posterior maxilla had the effect of decreasing the OP more than in the CT group and therefore allowed greater advancement of the mandible than in the CT group. In cases where this was not possible due to aesthetic concerns (maxillary incisor/lip relationship), the posterior maxilla was down grafted enhancing the rotation. In these cases bone grafts were placed in the posterior maxilla and stabilized with 2.0mm bone plates.

The three groups were well matched in terms of mean age and gender. The minimum follow up period for all patients was 6 months with a mean follow up time of 13.9 (6-60) months.

Lateral cephalometric radiographs were obtained in centric relation for each patient, 1 week before surgery (T^1), 1 week after surgery (T^2) and the longest follow-up period after surgery

(T^3) with a minimum of six months. All radiographs were taken by the same radiographer in natural head posture with the patient positioned in a cephalometric head holder on the same x-ray machine (Planmeca proscan PM 2OO2 CC*). The visual axis of the patient, rather than the Frankfort horizontal plane was used to standardize the patients head posture. Patients with vertical maxillary deficiency had a second radiograph taken with the teeth separated until the lips just parted to establish maxillary incisor upper lip relationship. The radiographer ensured that the patient's lips were in repose and teeth in centric relation. All cephalometric radiographs were traced and digitized by the same person using the Viewbox version 3.1.1 digitizer* (dHal Software, Copyright 2004, D. Halazontis) and the following skeletal cephalometric landmarks were identified and digitized: Sella (S), Nasion (N), A point, B point, PNS, G and M. To evaluate surgical and long-term skeletal changes the following planes were constructed: The anterior cranial base or SN plane, true horizontal plane (7 degrees to Sn), PP, the OP, the MP (Gonion-Menton). The true horizontal plane was used as the Y-axis for vertical measurements while the X- axis was constructed perpendicular to the Y-axis through Sella and used to measure horizontal changes. The landmarks and reference planes utilized to make all linear measurements are demonstrated in figure 20.

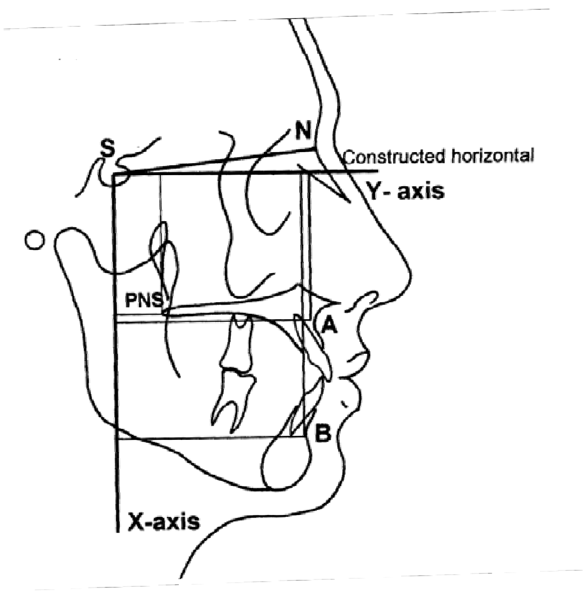


Figure 20. Vertical measurements were made from A point, B point and PNS to the constructed horizontal plane (7 degrees from SN), the Y-axis. Horizontal measurements were made using a perpendicular line through sella as the X-axis.

To assess antero-posterior changes of the maxilla and the mandible the linear distances were measured in millimeters from the constructed vertical plane (X-axis) to A point (ax), B point (bx) and PNS (pnsx) respectively, while vertical changes were assessed by measuring the distance from A point (ay), B point (by) and PNS (pnsy) to the constructed true horizontal plane (Y-axis). The OP was defined and constructed by drawing a line bisecting the overlapping cusps of the first molars and the incisal overbite. The change in the OP and MP were measured in relation to the constructed true horizontal plane (Fig. 21).

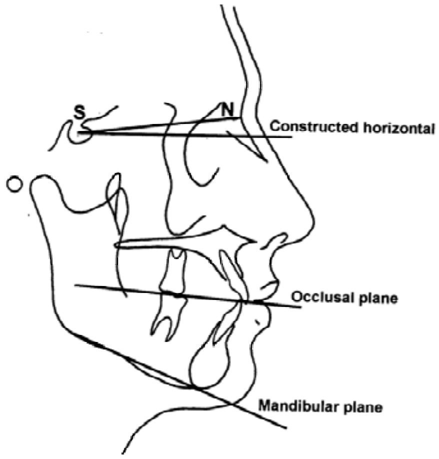


Figure 21. Angular changes of the OP and MP were measured to a constructed horizontal plane (7 degrees to SN).

It is inevitable that the OP angle will be altered after vertical repositioning of the maxilla due to rotation of the mandible around a point at the condyle. To establish the relative angular changes that can be expected after vertical repositioning of the maxilla, an OP was constructed on a cephalometric tracing of a patient with normal OP angle (11 degrees). The maxilla was then superiorly repositioned by 10 millimeters and the change in OP angle measured (Fig. 22). In orthognathic surgical terms, a 10 millimeter vertical repositioning of the maxilla can be considered as a large movement and is seldom indicated. A change of 1 degree in the OP angle was recorded after a 10 millimeter vertical repositioning of the maxilla. With the above in mind, cases with an OP change of more than +2 degrees were considered to be significant enough to be considered as CR cases while cases with an OP change of -2 degrees and more negative were classified as CCR cases. All cases with OP changes of between +2 and -2 degrees were deemed as to have been treated according to CT planning methods.

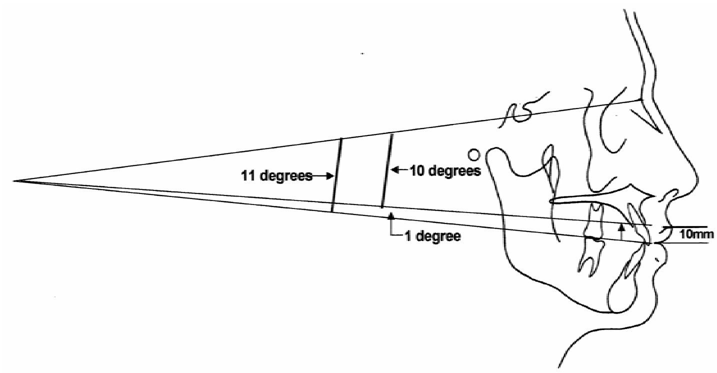


Figure 22. Superior repositioning of the maxilla by 10mm would result in a 1 degree change of the OP in a patient with and 11 degree OP angle.

Ten radiographs were randomly selected, redigitized and remeasured after two weeks to ensure intra-examiner accuracy while twenty randomly selected radiographs were digitized and measured by an independent examiner to ensure inter-examiner accuracy. Post-operative antero-posterior, vertical and angular changes were deemed negative if relapse was opposite to the direction of the surgical movement and positive when in the same direction as the movement.

4.4 Post surgical clinical assessment.

The aesthetic and functional outcomes were evaluated at the longest post operative follow up. The aesthetic outcomes were assessed using the post operative clinical evaluation described by Turvey et al (1988) as guideline. Good facial appearance, a Class I occlusion and closed bite was classified as excellent. The result was satisfactory if good facial appearance was present, the bite was closed and the canine relationship was not worse than canine end-on and the overjet not more than 4mm. The result was considered poor if the post operative bite was open, the canine relationship was Class II, and/or the overjet was more than 4mm.

The above clinical assessment was correlated with the cephalometric stability at B point (bx 3-2) of each group as well as the amount of rotation (in degrees) of the OP (clockwise or counter clockwise). B point was chosen as the antero-posterior position of the mandible plays a major role in the final aesthetic outcome of cases.
In cosmetic surgery, various scales have been used to assess outcomes (Bass NM 1991, Liang et al 1991, Al Yami, Kuijpers-Jagtman & Van't Hof 1998, Ching et al 2003).Unfortunately none has achieved wide spread use. Outcome research examines the end results of medical interventions and should also take into account patient experience, preferences and values. Patient satisfaction is however, the predominant factor in determining success.
In the pre surgical clinical assessment of the cases in the study the facial contour angle and Holdaway's H- line angle played important roles. In an attempt to simplify and standardize the aesthetic assessment these two parameters were used to assist in the assessment of the aesthetic outcomes and was performed by the same clinician. Post surgical facial contour angles of between 11-15 degrees were considered excellent, within 2 degrees more or less than 11-15 degrees as satisfactory, and more than 2 degrees above or below 11-15 degrees as poor. The soft tissue outcome in relation to the H-line angle as well as the lip position and chin contour in relation to the H-line were assessed and assisted in post- operative aesthetic evaluation.
The angular change of the OP played a pivotal role in the aesthetic planning of all the cases in the study. The amount of OP change in relation to clinical outcome was therefore deemed important to investigate.
The skeletal stability was considered stable and classified as excellent, if the relapse at B point was less than 1.0mm, satisfactory when relapse was less than 2.0mm, but more than 1.0mm and classified as poor in cases where B point moved by more than 2.0mm long term post-operatively.

The average rotation of the OP, (clockwise or counter clockwise) was calculated for each group and category.

Although many studies have reported disruption of the masticatory function and temporomandibular disease in patients with malocclusions the exact mechanism for specific types of disruption has not yet been understood well enough to be used for diagnosis. Some studies found little or no improvement of masticatory performance after orthognathic surgery (Kobayyashi, Katshuhiko & Nakajima 1993, Zarrinkelk, Throckmorton, Ellis et al. 1995). No data regarding the functional consequences such as masticatory force and masticatory performance, following MMC rotation is available and this aspect needs further research in future, however this large subject falls beyond the scope of this thesis.

An OP angle approaching the steepness of the articular eminence of the temporomandibular joint fossa, have certain functional implications: firstly, loss of canine guidance; secondly, loss of incisal guidance and finally, development of functional working and non-working interferences. In contrast low OP angulation with a deep bite e.g. Class II division 2 occlusions, may also have implications for temporomandibular joint function, due to the locking of the canine and reduced incisor guidance. The incidence of temporomandibular joint dysfunction appears to vary among different dentofacial deformities. White and Dolwick (1992) found that temporomandibular joint dysfunction was more prevalent in patients with Class II skeletal deformity (60.8%) as compared with patient with Class III deformity (14.3%). Although no adverse effects on the Temporomandibular joints were found in any of the groups following surgery, this important subject needs further research.

5 Results

5.1 *Evaluation of the efficacy of a triangle representing the MMC for treatment planning in orthognathic surgery.*

5.1.1 *Geography of the treatment design using the constructed triangle:*

By using a constructed triangle including ANS, PNS and Pog, representing the MMC, it was found that the treatment design increase treatment options for the correction of dentofacial deformities. This is due to the fact that the MMC can be rotated *independently* of the condylar rotation point. Rotation of the MMC may take place: (1) in a clockwise or counter-clockwise direction, and (2) around various selected points.

The correction of Class III dentofacial deformities requiring surgery to both jaws will involve maxillary advancement combined with mandibular setback. Rotation of the MMC in a clockwise direction will however, increase the facial contour angle, while counter clockwise rotation will decrease the facial contour angle (figure 23a and b).

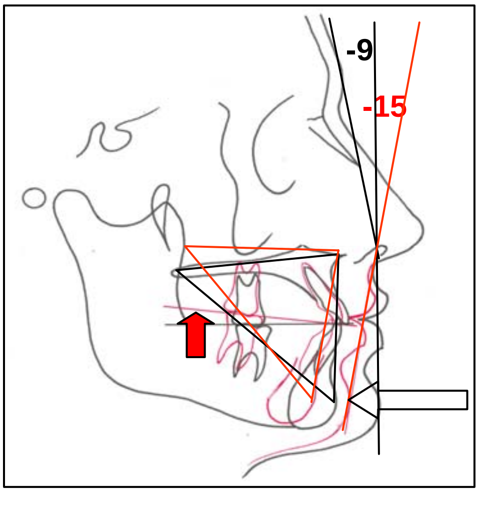


Figure 23a. A cephalometric tracing of a patient with a Class I occlusion and a straight profile (facial contour angle = -9degrees). By rotating the MMC triangle clockwise and increasing the OP angle a more convex profile is obtained (facial contour angle = -15 degrees).

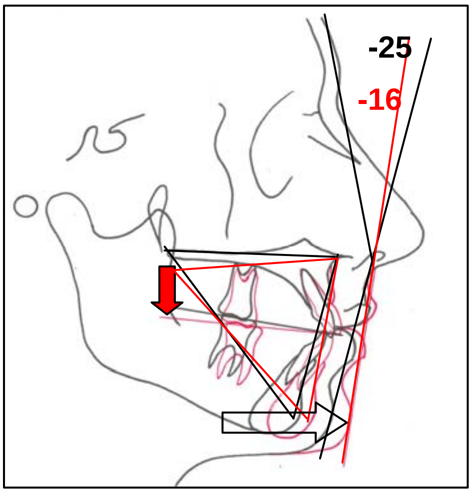


Figure 23b. A cephalometric tracing of a patient with a convex profile (facial contour angle = -25 degrees) and a Class I occlusion. The MMC triangle is rotated in a counter-clockwise direction decreasing the OP angle to establish a less convex profile (facial contour angle = -16 degrees).

The center of rotation around which the inclination of the maxilla can be adjusted may be located at the ANS, at the tip of the maxillary incisor tooth, PNS, the zygomatic buttress or at Pog. The selection of the direction of the rotation as well as the point around which the MMC should be rotated is primarily dictated by the aesthetic requirements of each case.

The following text, tables and figures illustrate the basic skeletal, dental and soft tissue changes that can be expected with CR and CCR of the MMC as well as the subtle differences in results that can be achieved by changing the point around which the MMC is rotated.

5.1.2 Clockwise rotation of the MMC

5.12.1 Center of rotation at ANS

Surgical superior repositioning of the posterior maxilla as a result of rotation around ANS will result in the changes illustrated in figure 24 and summarized in Table 1.

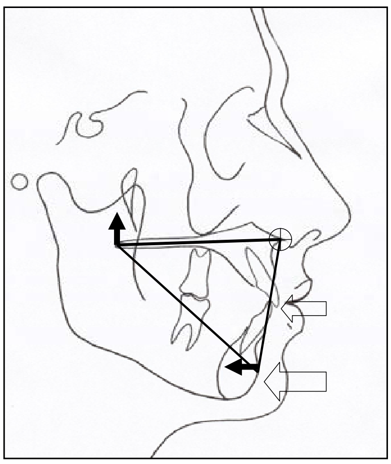


Figure 24. The constructed triangle simplifying and demonstrating the rotation of the MMC around ANS. The hard- and soft tissue changes associated with rotation around ANS are demonstrated.

Table 1

Clockwise rotation of the MMC with rotation point at ANS

Hard tissue changes		Soft tissue changes	
OP angle	increase	Subnasale	no change
Maxillary incisor tip	retraction	Upper lip support	decrease
Pog position	setback	Facial convexity (contour)	increase
Upper incisor angle	decrease	Mandibular prominence	decrease
Maxilla at ANS	no change	Para nasal fullness	no change
MP angle	increase	Nasolabial angle	increase
Posterior maxillary height	decrease	Anterior facial height	no change
		Chin throat length	decrease

Table 1. A summery of the expected hard and soft tissue changes following clockwise rotation of the MMC which can be visualized in figure 24.

The extent of posterior repositioning of Pog is greater than the amount of superior repositioning of the posterior maxilla due to the fact that the anterior height of the MMC (ANS – Pog) is greater than the antero-posterior length of the maxilla (ANS – PNS) (Fig. 25).

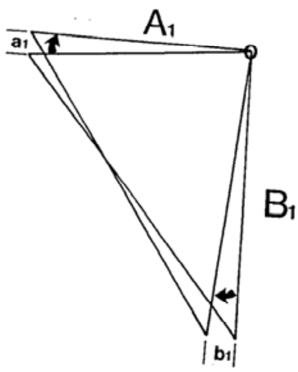


Figure 25. Note that due to the fact that the maxillary length (A1) is shorter than the anterior facial height (B1) the rotation of the triangle around ANS will lead to a larger setback of the chin (b1) than the amount of superior repositioning of the posterior maxilla (a1).

The ratio of the movements can be expressed as follows (Fig. 25):

$$\frac{A_1}{B_1} = \frac{a_1}{b_1}$$

Case 1 (G.M.)

In this case the rotation of the MMC in a clockwise direction around ANS is demonstrated. The cephalometric analysis reveals a Class III malocclusion, skeletal mandibular antero-posterior excess, maxillary antero-posterior deficiency and concave profile (Fig 26a).

The surgical VTO performed according to CT design shows that a maxillary advancement of 5mm and mandibular setback of 5.5mm is required to achieve a Class I dental relationship (a total surgical movement of 10.5mm). However, figure 26b indicates that the predicted profile is still very straight (facial contour angle of -1 degrees). A surgical VTO with rotation of the MMC in a clockwise direction, around ANS shows that a more favorable convex profile (facial contour angle of -9 degrees) can be achieved (Fig. 26c).
The cephalometric analysis, VTO and treatment results are demonstrated in figure 26d to k.

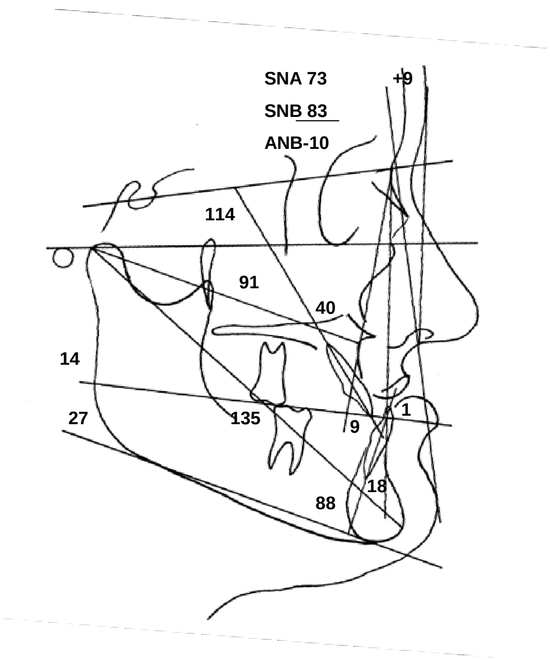
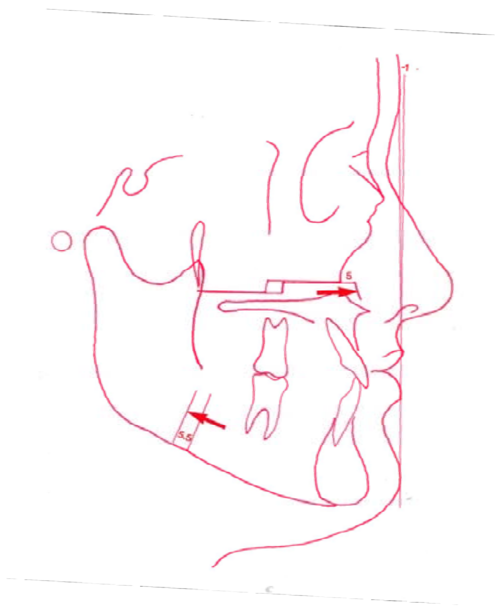
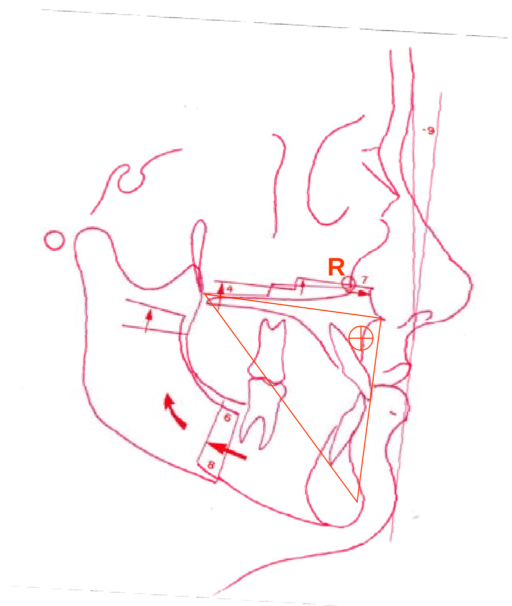


Figure 26a. Case 1 G.M. Pre-surgical cephalometric analysis. Maxillary antero-posterior deficiency: SNA = 73 degrees; mandibular antero-posterior excess: SNB = 83 degrees; Class III skeletal relationship ANB: -10 degrees; concave profile: facial contour angle = +9 degrees.



Conventional treatment planning

Figure 26b. Case 1 G.M. Pre-surgical VTO. The facial contour still appears concave and the mandible prominent (facial contour angle = -1 degree). CT planning does not render an aesthetically pleasing profile.



Clockwise rotation of the MMC

Figure 26c. Case 1 G.M. CR of the MMC at A point allows for a larger amount of mandibular setback, a greater amount of maxillary advancement and a more pleasing profile and a facial contour angle of -9 degrees.

Figure 26. Case 1 G.M. Pre-surgical frontal view (d), profile view (e), thee-quarter view (f). Post-treatment results are demonstrated in the frontal view (g), profile view (h), three-quarter view (i). Pre-surgical occlusion (j) and post-treatment occlusion (k).

5.1.2.2 Center of rotation at the maxillary incisor tip

Surgical superior repositioning of the posterior maxilla as a result of CR of the maxilla around the maxillary incisor tip will result in the changes illustrated in figure 27 and summarized in Table 2.

Table 2.
Clockwise rotation of the MMC with rotation point at the incisor tip

Hard tissue changes		**Soft tissue changes**	
OP angle	increase	Subnasale	advance
Maxillary incisor tip	no change	Upper lip support	no change
Pog position	setback	Facial convexity (contour)	increase
Upper incisor angle	decrease	Mandibular prominence	decrease
Maxilla at ANS	advance	Para nasal fullness	increase
MP angle	increase	Nasolabial angle	increase
Posterior maxillary height	decrease	Anterior facial height	no change
		Chin throat length	decrease

Table 2. The hard and soft tissue changes that may be expected, following the rotation of the MMC in a clockwise direction around the tip of the maxillary incisor tooth, is summarized in the columns and illustrated in figure 27.

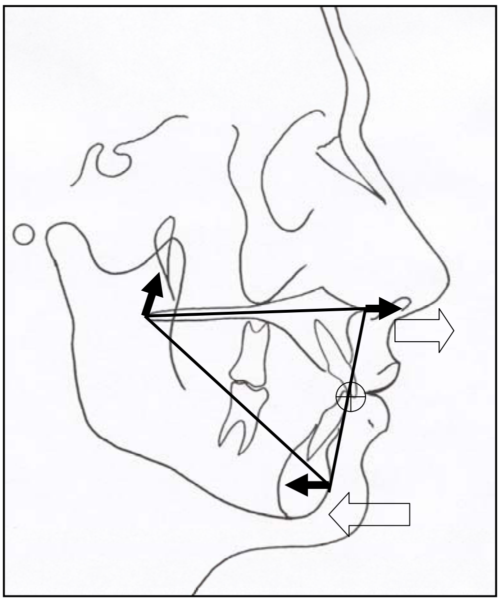


Figure 27. The geography of rotation of the MMC around maxillary incisor tip with expected soft and hard tissue changes illustrated.

The ratio of the extent of the anterior movement of ANS to the posterior movement of Pog is the same as the ratio between the distance from ANS to the tip of the maxillary central incisor and the distance from the tip of the incisor to Pog (Fig. 28). This ratio can be expressed as:

$$\frac{b_2}{c_2} = \frac{B_2}{C_2}$$

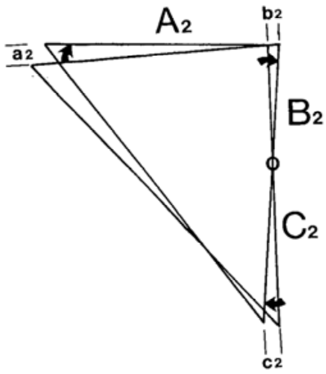


Figure 28. The maxillary advancement (b2) and mandibular setback (c2) in relation to the amount of superior repositioning of the posterior maxilla (a2) is demonstrated.

The ratio of movements can be expressed as follows: $\frac{A_2}{B_2 + C_2} = \frac{a_2}{b_2 + c_2}$

Case 2(B.T.)

The case demonstrates how an enhanced aesthetic result can be achieved by CR of the MMC around a point at the incisor tip. The cephalometric analysis reveals a Class II division I, deep bite malocclusion and short lower third facial height (Fig 29). The treatment is complicated by the fact that the patient's dentist removed her first maxillary bicuspids at an early age in an attempt to correct her malocclusion by means of a removable orthodontic appliance.
Note the chin prominence and relatively straight profile (facial contour angle -8 degrees) on the surgical VTO in figure 29b performed according to CT planning. Further reduction of the chin by means of a reduction genioplasty will obliterate the labio-mental fold resulting in poor chin aesthetics. An improved predicted aesthetic outcome is demonstrated on the surgical VTO in figure 29c. This modified treatment design involves CR of the MMC around the incisor tip resulting in a more favorable convex profile (facial contour angle -14 degrees).
The planning and treatment results are demonstrated in figure 29a-j.

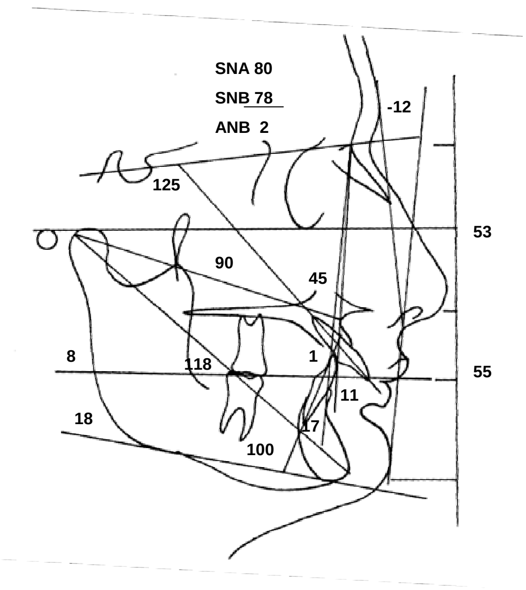
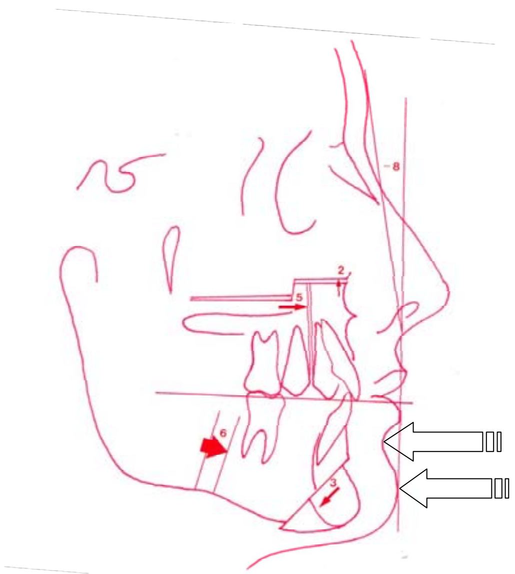
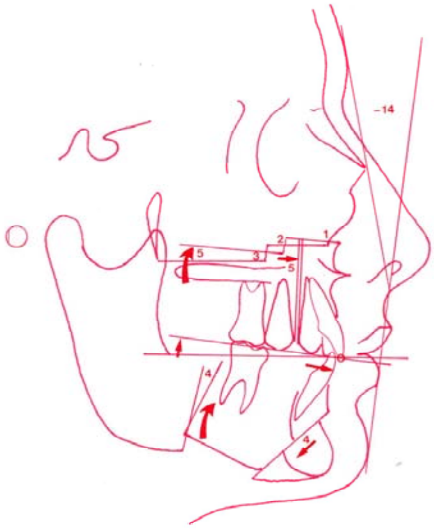


Figure 29a. Case 2 B.T. Pre-treatment cephalometric analysis. The pre-surgical orthodontic treatment consisted of aligning the maxilla in three segments, improving the angulation of the maxillary incisors and coordinating the dental arches.



Conventional treatment planning

Figure 29b. Case 2 B.T. Surgical prediction tracing performed according to conventional planning i.e. small superior repositioning of the maxilla, mandibular advancement and reduction genioplasty with slight vertical increase. Note the chin appears prominent and the profile is now still straight (facial contour angle -8 degrees). Further reduction of the chin will however obliterate the labio-mental fold (arrow).



Clockwise rotation of the MMC

Figure 29c. Case 2 B.T. The MMC is rotated around the incisor tip: (1) superior repositioning of the posterior maxilla, (2) rotation of the mandible (the dentition is advanced more than the chin) and (3) reduction genioplasty.

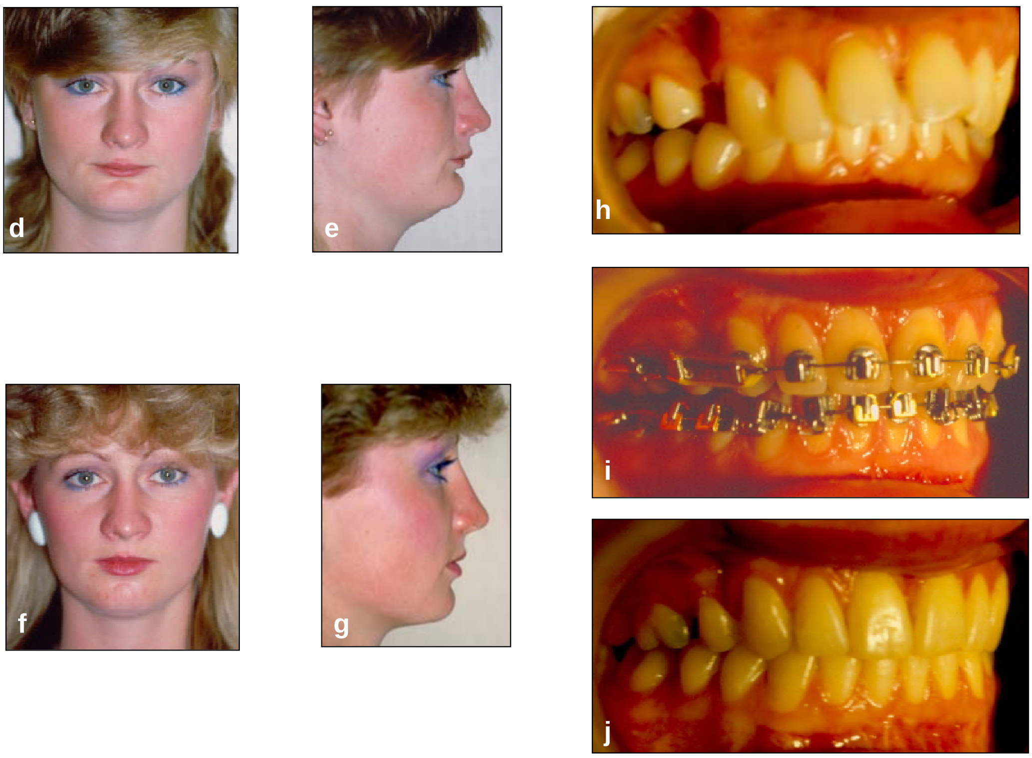


Figure 29. Case 2 B.T. Pre-treatment: frontal view (d), profile view (e). Post- treatment: frontal view (f), profile view (g)). Pre-treatment occlusion (h), pre-surgical occlusion (i) and post-treatment occlusion (j).

5.1.2.3 Center of rotation at Pogonion

Clockwise rotation of the MMC around Pog will result in the hard and soft tissue changes illustrated in figure 30 and summarized in Table 3.

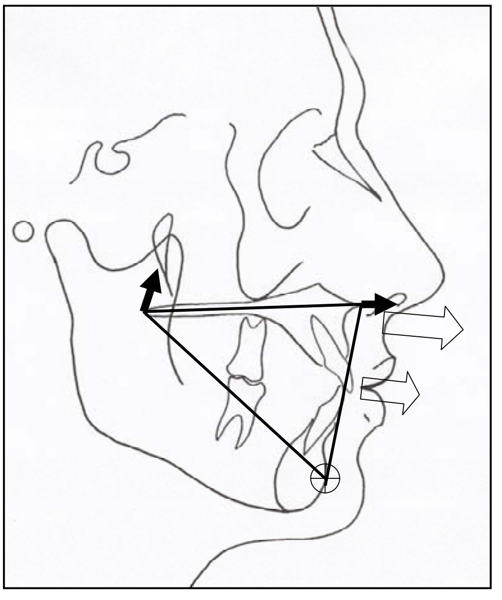


Figure 30. When rotating the MMC around Pog the chin position is maintained, while the posterior maxilla is superiorly repositioned and the anterior maxilla and incisors advanced. Note the slight inferior movement of ANS and maxillary incisor.

Table 3.

Clockwise rotation of the MMC with rotation point at Pogonion

Hard tissue changes		Soft tissue changes	
OP angle	increase	Subnasale	advance
Maxillary incisor tip	advance	Upper lip support	increase
Pog position	no change	Facial convexity (contour)	increase
Upper incisor angle	decrease	Mandibular prominence	no change
Maxilla at ANS	advance	Para nasal fullness	increase
MP angle	increase	Nasolabial angle	increase
Posterior maxillary height	decease	Anterior facial height	no change
		Chin throat length	decrease

Table 3. A summary of the hard tissue and profile changes that can be expected following clockwise rotation of the MMC around Pog. The surgical changes can also be visualized in figure 30.

The ratio of movements can be expressed as follows (Fig. 31):

$$\frac{B_1}{A_1} = \frac{b_1}{a_1}$$

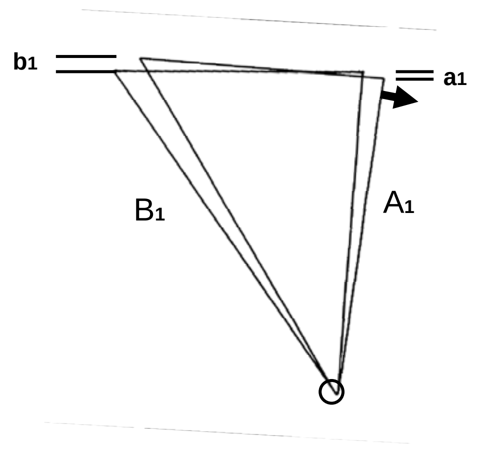


Figure 31. Due to the superior repositioning of the posterior maxilla and rotation around Pog, the anterior maxilla is advanced and moved slightly downward.

The above soft-tissue changes are all greater than when the rotation point is superior to Pog and even more accentuated than with CT planning principles. The selection of the rotation point is dictated by the aesthetic requirements of each case. For those patients who require more upper lip support and paranasal fullness and less mandibular setback, the rotation point should be at Pog. While patients that require less maxillary advancement but more mandibular setback, the rotation point should be at ANS. By selecting a point between ANS and Pog, i.e. maxillary incisor tip, the above effects are approximately halved. For other nuances in aesthetic requirements the rotation point may be varied and placed anywhere between ANS and Pog.

5.1.2.4 Center of rotation at zygomatic buttress

Clockwise rotation of the MMC around point posterior to ANS will tend to increase the anterior facial height and increase maxillary tooth exposure under the upper lip. The hard and soft tissue changes illustrated in figure 32 is summarized in Table 4.

Table 4.
Clockwise rotation of the MMC with rotation point at the zygomatic buttress

Hard tissue changes		Soft tissue changes	
OP angle	increase	Subnasale	no change
Maxillary incisor tip	inferior + slight retraction	Upper lip support	slightly decreased
Pog position	inferior + slight setback	Facial convexity (contour)	increase
Upper incisor angle	decrease	Mandibular prominence	decrease
Maxilla at ANS	inferior	Para nasal fullness	no change
MP angle	increase	Nasolabial angle	increase
Posterior maxillary height	decrease	Anterior facial height	increase
		Chin throat length	decrease

Table 4. A summary of expected skeletal and soft tissue changes as a result of clockwise rotation of the MMC around a point at the zygomatic buttress. The surgical changes are also illustrated in figure 32.

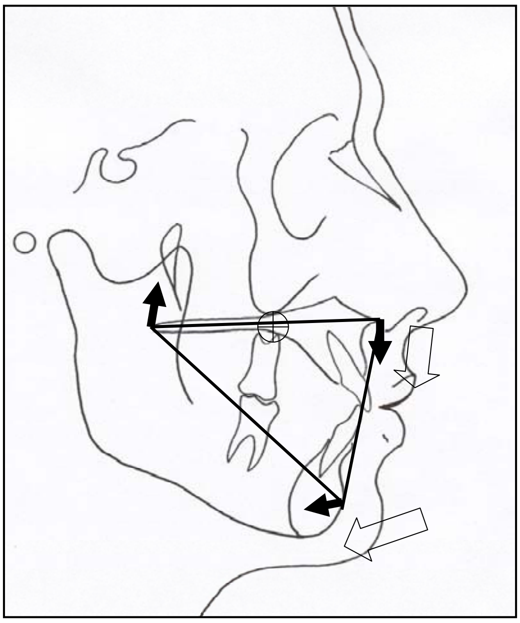


Figure 32. The posterior maxilla is superiorly repositioned, the anterior maxilla (and upper incisor) moves downward while Pog rotates posteriorly.

The ratio or surgical movements can be expressed as follows (Fig 33):

$$\frac{C+B}{A} = \frac{c+b}{a}$$

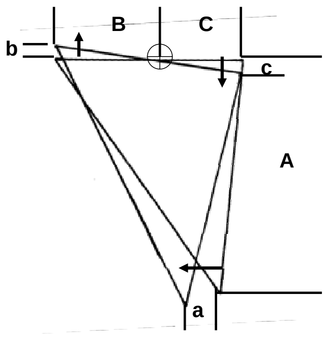


Figure 33. Small skeletal movements of the maxilla (posterior maxilla upwards and the anterior maxilla downwards) lead to a substantial posterior movement of the mandible.

Case 3 (E.H.)

The aesthetic aims in this case were to reduce the chin prominence and at the same time increase the anterior facial height (Fig. 34a). CT design could not achieve these goals as seen on the surgical VTO (Fig. 34b). However by using the Zygomatic buttress as rotation point and rotating the MMC clockwise, an improved aesthetic result could be predicted (Fig. 34c). The treatment results are demonstrated in figure 34d-k.

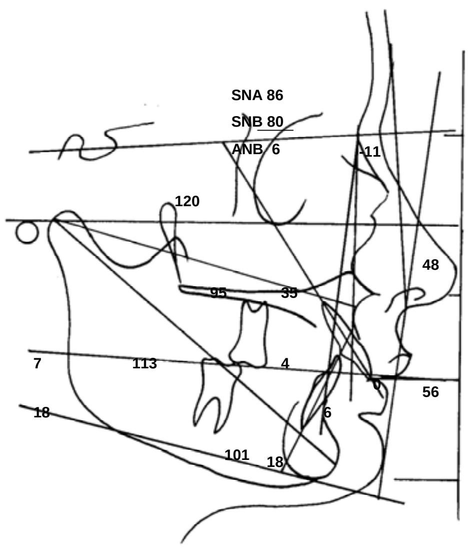
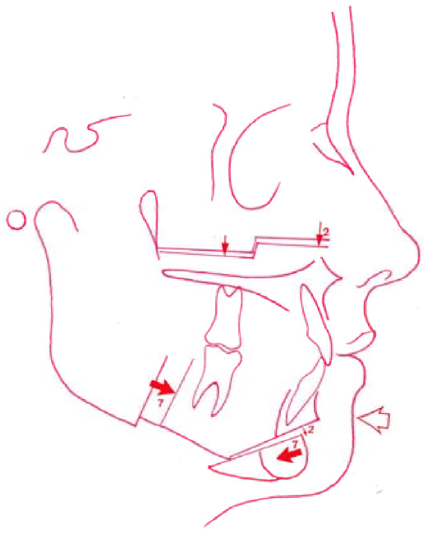
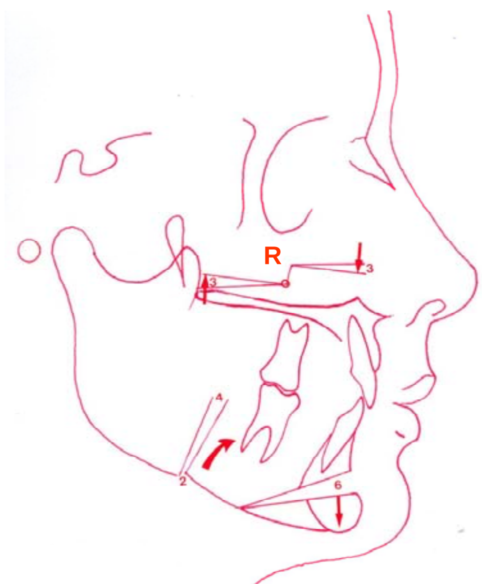


Figure 34a. Case 3 E.H. Pre-treatment cephalometric analysis.



Conventional treatment planning

Figure 34b. Case 3 E.H. CT planning results in a too prominent mandible and straight profile. If the chin is reduced further, an even more obtuse labiomental sulcus will be created (arrow).



Counter clockwise rotation of the MMC

Figure 34c. Case 3 E.H. The MMC is rotated around a point at the zygomatic buttress (R). Note the difference between the predicted profiles in (b) and (c).

Figure 34d. Case 3 E.H. Pre-treatment: frontal view (d); profile view (e) and three-quarter view (f). Treatment results: frontal view (g); profile view (h) and three quarter view (i). Pre-treatment occlusion (j), and post-treatment occlusion (k).

5.1.3 Counter-clockwise rotation of the MMC

Certain dentofacial deformities can be treated by rotation of the MMC in a counter-clockwise direction. These rotational movements of the MMC are usually beneficial for the treatment of patients with excessively convex profiles and high MP and OP angles.

5.1.3.1 Center of rotation at ANS

Surgical down-grafting of the posterior maxilla following rotation of the MMC around a point at ANS will result in the hard and soft tissue changes illustrated in figure 35 and summarized in Table 5:

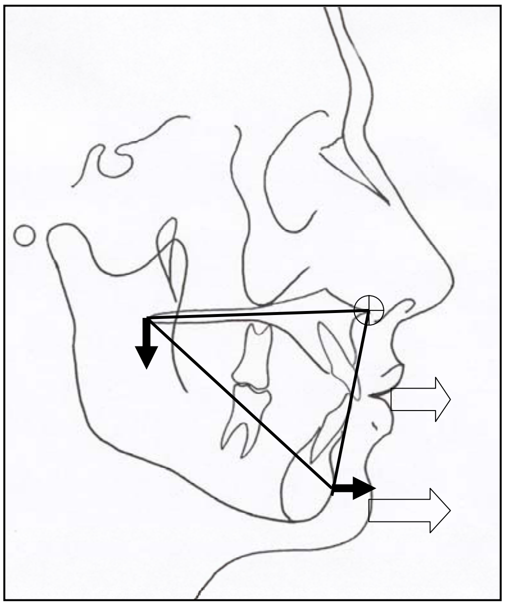


Figure 35. The chin (Pog) is advanced by down grafting the posterior maxilla and rotating the MMC around ANS.

Table 5.
Counter clockwise rotation of the MMC with rotation point at ANS

Hard tissue changes		**Soft tissue changes**	
OP angle	decrease	Subnasale	no change
Maxillary incisor tip	advance	Upper lip support	increase
Pog position	advance	Facial convexity (contour)	decrease
Maxillary incisor angle	increase	Mandibular prominence	increase
Maxilla at ANS	no change	Para nasal fullness	no change
MP angle	decrease	Nasolabial angle	decrease
Posterior maxillary height	increase	Anterior facial height	no change
		Chin throat length	increase

Table 5. Rotation of the MMC around ANS will result in the hard and soft tissue changes summarized in this table. The expected surgical changes are also demonstrated in figure 35.

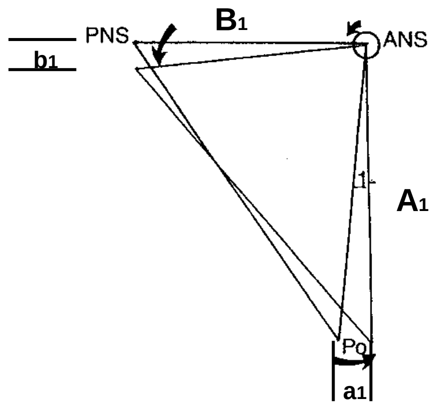


Figure 36. Due to the fact that the anterior facial height (A1) is longer than the maxillary length (B1) the amount of advancement of the chin at Pog (a1) will be greater than the amount of down graft at PNS (b1).

The ratio of the amount of inferior repositioning of the maxilla (at PNS) to the advancement of Pog can be expressed as follows (Fig. 36):

$$\frac{B_1}{A_1} = \frac{b_1}{a_1}$$

Case 4 (N.A.)

The fact that this patient's dentition was orthodontically compensated for her skeletal Class II relationship made improvement of her profile by means of orthognathic surgery virtually impossible. Her four first bicuspids were removed preceding her orthodontic treatment and upper incisor teeth then retracted to achieve a Class I occlusion. The profile is convex and nasolabial angle obtuse (Fig. 37a and e). The possibility of decompensating the occlusion to facilitate mandibular advancement is limited.

CCR of the MMC around the anterior maxilla and maintaining the existing occlusion would solve most of the aesthetic problems in this case (Fig. 37b). The treatment results are demonstrated in figure 37c-k.

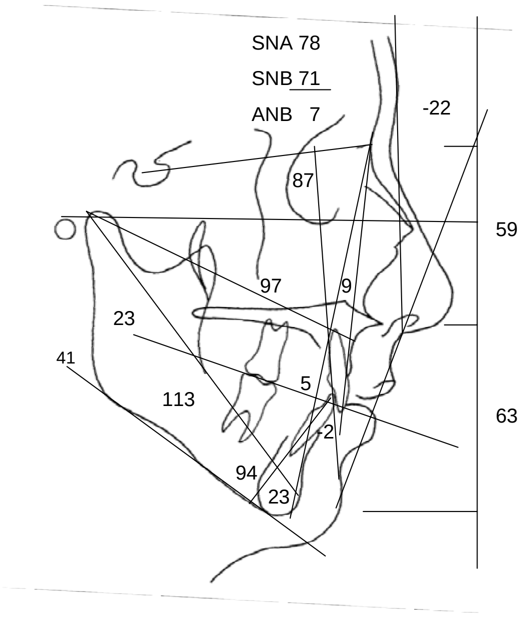
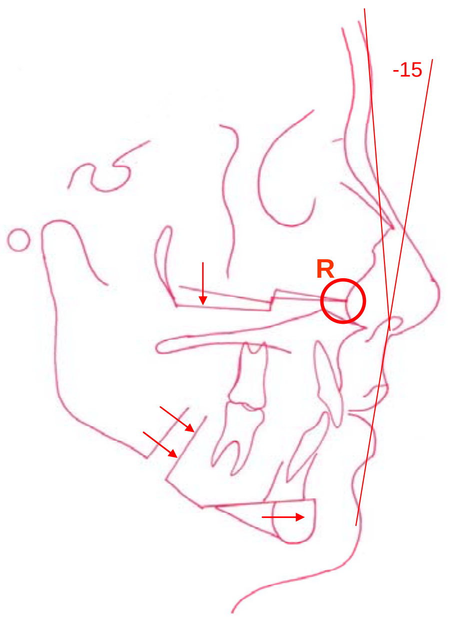


Figure 37a. Case 4 N.A. The compensated dentition for skeletal mandibular deficiency is evident: ANB = 78 degrees; upper incisor – SN = 87 degrees; facial contour angle = -22 degrees; nasolabial angle = 115 degrees.



Counter-clockwise rotation of the MMC

Figure 37b. Case 4 N.A. By maintaining the existing occlusion and downgrafting the posterior maxilla, using the anterior maxilla as rotation point ("R"), the lower facial third is advanced. A less convex profile (facial contour angle -15 degrees) is predicted on the VTO.

Figure 37. Case 4 N.A. Pre-treatment: frontal view (c); three-quarter view (d) and profile view (e). Post-treatment: frontal view (f); three-quarter view (g) and profile view (h). Pre- and post-operative occlusion (i) and (j).

5.1.3.2 Center of rotation at the zygomatic buttress

With the rotation point at the zygomatic buttress (about midway between PNS and ANS), the posterior maxilla will be inferiorly repositioned, while the anterior maxilla moved superiorly. The hard and soft tissue changes can be expected is illustrated in figure 38 and summarized in Table 6.

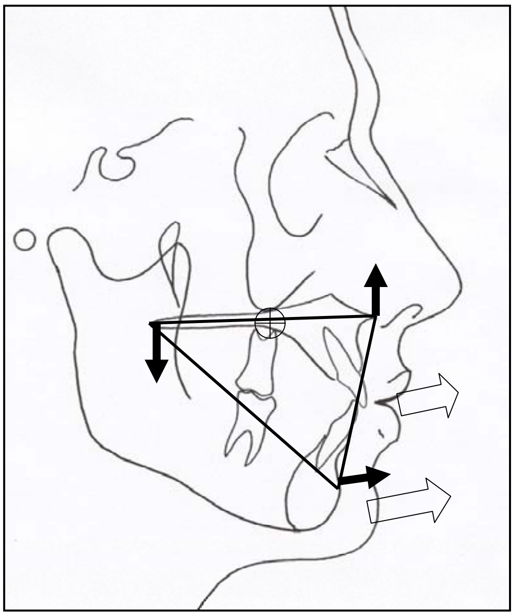


Figure 38. Rotating the MMC at the zygomatic buttress results in the chin (Pog) and dentition to advance, the anterior maxilla to shorten in relation to the upper lip and posterior maxilla to be down grafted.

Table 6.

Counter clockwise rotation of the MMC with rotation point at the zygomatic buttress

Hard tissue changes		Soft tissue changes	
OP angle	decrease	Subnasale	advance
Maxillary incisor tip	advance + superior	Upper lip support	increase
Pog position	advance + superior	Facial convexity (contour)	decrease
Maxillary incisor angle	increase	Mandibular prominence	increase
Maxilla at ANS	superior	Para nasal fullness	increase
MP angle	decrease	Nasolabial angle	decrease
Posterior maxillary height	increase	Anterior facial height	decrease
		Chin throat length	increase

Table 6. A summary of surgical changes, to be expected following counter clockwise rotation of the MMC with the rotation point at the zygomatic buttress. The changes are illustrated in figure 38.

The ratio of vertical to horizontal changes can be expressed by the following formula (Fig 39):

$$\frac{C_1}{c_1} = \frac{B_1}{b_1} \quad \text{or} \quad \frac{c_1 + b_2}{C_1 + B_1} = \frac{a_1}{A_1}$$

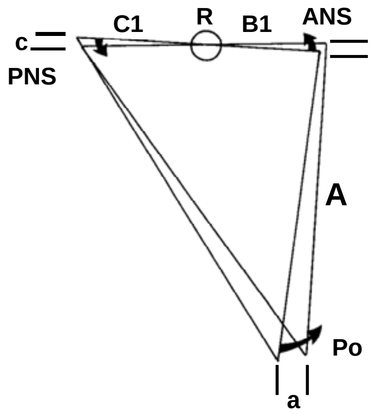


Figure 39. The MMC triangles illustrate the ratios of maxillary superior repositioning and mandibular advancement following CCR around PNS.

5.1.3.3 Center of rotation at PNS

To rotate the MMC in a counter-clockwise direction around a point at PNS the anterior maxilla must be superiorly repositioned, while the height of the posterior maxilla is maintained. The maxillary movement will then be followed by the mandible. The hard and soft tissue changes that can be expected as a result of the above-mentioned surgical movements is illustrated in figure 40 and summarized in Table 7:

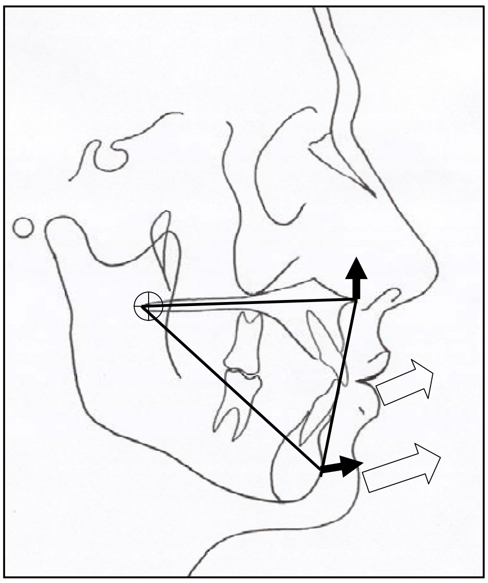


Figure 40. By using PNS as rotation point and superior repositioning the anterior maxilla the amount of mandibular advancement is enhanced.

Table 7.
Counter clockwise rotation of the MMC with rotation point at PNS

Hard tissue changes		Soft tissue changes	
OP angle	decrease	Subnasale	advance
Maxillary incisor tip	advance + superior	Upper lip support	increase
Pog position	advance + superior	Facial convexity (contour)	decrease
Maxillary incisor angle	increase	Mandibular prominence	increase
Maxilla at ANS	superior	Para nasal fullness	increase
MP angle	decrease	Nasolabial angle	decrease
Posterior maxillary height	no change	Anterior facial height	decrease
		Chin throat length	increase

Table 7. A summary of the expected skeletal, dental and profile changes following counter clockwise rotation of the MMC around PNS. Figure 40 illustrates the expected changes.

The ratio of horizontal to vertical changes can be expressed as follows (Fig. 41):

$$\frac{A_1}{a_1} = \frac{B_1}{b_1}$$

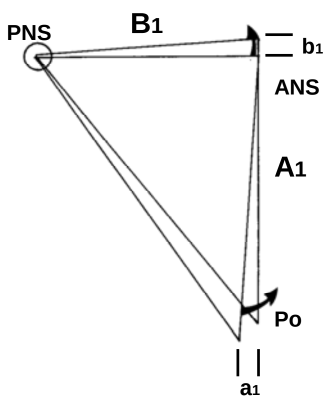


Figure 41. The ratios resulting from CCR of the MMC around PNS and surgical repositioning of ANS and PNS are illustrated.

Case 5 (CB).

This patient's diagnosis is: Class II malocclusion, vertical maxillary excess, mandibular antero-posterior deficiency and a convex profile (Fig. 42a). To establish a Class I occlusion and soft tissue harmony the following surgical procedures are indicated: maxillary superior repositioning, mandibular advancement and advancement genioplasty. The surgical advancement of the mandible is however limited by the fact that the incisor teeth are compensated (upper incisors retroclined and lower incisors proclined). CT planning on the surgical VTO shows the small amount of mandibular advancement possible while the facial contour angle is still increased (-21 degrees), (Fig. 42b). A much greater mandibular advancement can be achieved by rotating the MMC counter-clockwise direction around PNS (Fig. 42c). Note the improved profile (facial contour = -13 degrees).

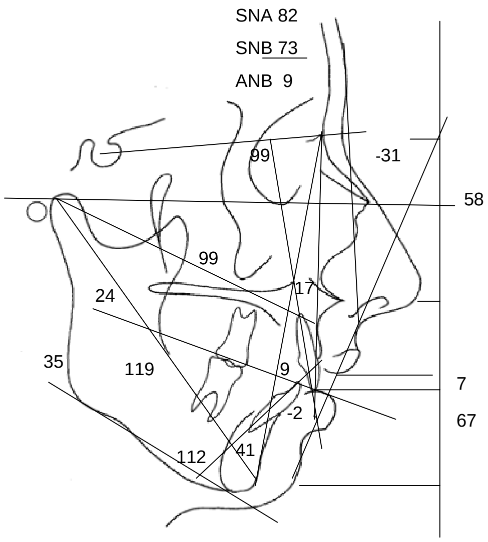


Figure 42a. Case 5 C.B. Pre-surgical cephalometric analysis. Note: the Class II occlusion, upright maxillary incisors (upper incisor-SN = 99 degrees), proclined lower incisors (lower incisor-MP = 112 degrees), mandibular antero-posterior deficiency (ANB = 9 degrees), vertical maxillary excess (7mm tooth exposure), convex profile (facial contour angle = -21 degrees).

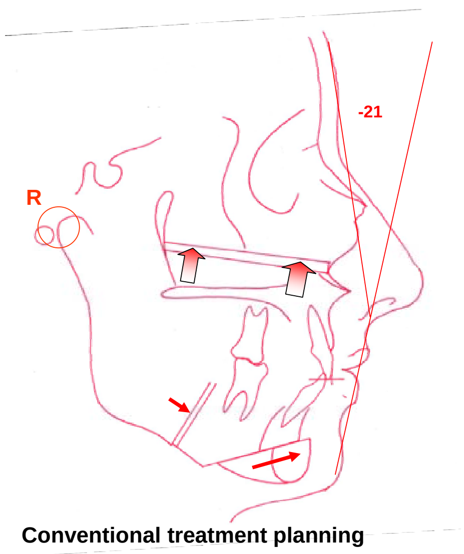
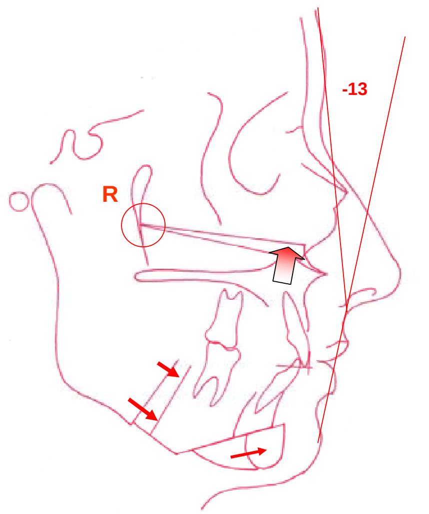


Figure 42b. Case 5 C.B. Conventional VTO renders less than satisfactory aesthetic results with still a convex profile (facial contour angle = -21 degrees). Further advancement of the chin will lead to a "knobby" appearance.



Counterclockwise rotation of the MMC

Figure 42c. Case 5 C.B. A less convex profile is achieved by rotation of the MMC around PNS in a counter-clockwise direction. This rotation enables the surgeon to advance the mandible further and by so doing achieve a straighter profile (facial contour angle= -13 degrees).

Figure 42. Case 5 C.B. Pre-surgical: frontal view (d) profile view (e) and occlusion (f). Post-operative results: frontal view (g) profile view (h) and occlusion (i).

5.1.4 Relative horizontal and vertical facial skeletal dimensions

The data in Table 8 represents the horizontal and vertical measurements of 30 adult dry skulls. These measurements of the maxillary length (PNS-ANS) and skeletal anterior facial height (ANS-Po) were performed to calculate the linear relationship between the two facial dimensions:

Table 8

Number	Height	Length	Age	Sex
1	80,5	48	43	M
2	75,5	53	47	M
3	79,5	61	36	M
4	71,5	53	67	M
5	78	51	57	M
6	70,5	53	56	M
7	67,5	53	60	M
8	71,5	52	91	M
9	60,5	49	31	M
10	74	50	77	M
11	63	50,5	78	M
12	73	51,5	89	M
13	67	51	68	M
14	75	52	49	M
15	70	48	43	M
Average	68,1	51,7	59,5	
16	59	48,5	55	F
17	68	58	65	F
18	63	48,5	46	F
19	68	53	65	F
20	72,5	51	72	F
21	73	50	60	F
22	63	49	70	F
23	61	51,5	70	F
24	58,5	51	50	F
25	62	46,5	49	F
26	68,5	56	59	F
27	54	51	63	F
28	74,5	51	58	F
29	65	48	45	F
30	65	46,5	56	F
Average	65	50,6	58,9	
Average	66,5	47,6	59,2	

To establish realistic values for the skeletal dimensions, thirty dry human Caucasian skulls with relatively normal occlusions and skeletal facial structures were obtained from the Department of Anatomy, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg. Fifteen male and fifteen female skulls were studied. The length of the maxilla, from ANS to PNS was measured using a Vernier caliper. The skeletal anterior facial height, from anterior nasal spine (ANS) to the most prominent point on the mandibles (Pogonion) was also measured.
Average values for the above were calculated for both groups. The average age of the males at the time of death was 59,5 years (range 31-91 years) and for the female group 58,9 years (range 43-72 years) The average anterior facial height (ANS-Pog) for males was 68,1mm (range 60,5-80,5mm) and females 65mm (range 54-74,5mm). The average maxillary lengths measured as follows: males, 51,7mm (range 48-61mm) and females 50,6mm (range 46-58mm) (Fig. 43). The differences in the measurements between the two groups were statistically insignificant and average values for the whole group were calculated. Average values for the thirty skulls were (table3):

1. Lower facial height - 66,5mm
2. Maxillary length - 47,6mm
3. Age at time of death - 59,2 years

The anterior facial height was 28, 4% longer than the maxillary length.

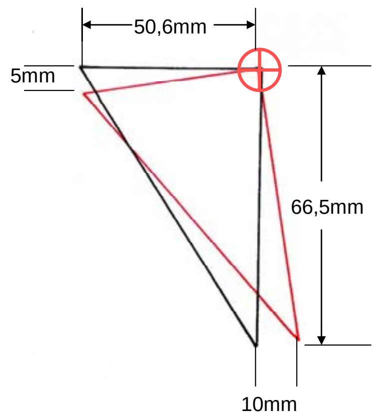


Figure 43. Using the average values for anterior facial height (66,5mm) and maxillary length (47,6mm) a triangle is constructed. The triangle is then rotated in a counter-clockwise direction around the antero-superior tip (representing ANS) downwards by 5mm at the postero-superior tip (representing PNS). The rotation results in an advancement of 10mm at the inferior tip (representing Pog) (twice the distance at ANS).

5.2. The development of a method for a cephalometric visual treatment objective utilizing the concept of rotation of the MMC.

The surgical cephalometric prediction tracings involving surgery to both jaws and rotation of the MMC differs from the conventional prediction tracing for double jaw surgery. In contrast to CT planning where the final OP is dictated by the mandibular OP after clockwise or CCR the OP is now altered independently of the mandibular OP to improve aesthetic results. Rotation of the MMC is only considered in cases where an acceptable aesthetic result cannot be achieved by CT methods and a conventional VTO should be developed for every patient before contemplating rotation of the MMC.

The clinician should be thoroughly familiar with conventional techniques for the prediction of results for the correction of dentofacial deformities as well as have a good understanding of the relation between hard tissue changes and the expected facial soft tissue changes following surgery. While an abundance of data is available in the literature regarding the expected soft tissue changes that may occur after repositioning of the facial skeleton, the author believes, however, that soft tissue changes are surgeon-specific, due to the difference in individual surgical techniques as well as soft tissue handling. Each surgeon should, therefore, be able to predict his or her individual surgical result accurately.

5.2.1 The step by step development of a Surgical Prediction Tracing or VTO utilizing the principle of the rotation of the MMC

To illustrate the method of developing a VTO involving the rotation of the MMC, several dentofacial deformities, which typically would require this method of treatment, will be used as examples. Various cases will be used to illustrate the principle of choosing (1) the direction of rotation of the MMC, (2) the ideal point around which the MMC should be rotated.

5.2.1.1 Surgical prediction tracing involving CR of the MMC

CASE 1:

The pre-surgical cephalometric analysis of Case 1 is demonstrated in figure 44. The basic diagnosis for this patient is:

- Class II occlusion.
- Maxillary antero-posterior deficiency.
- Macrogenia.
- Mandibular alveolar antero-posterior deficiency.

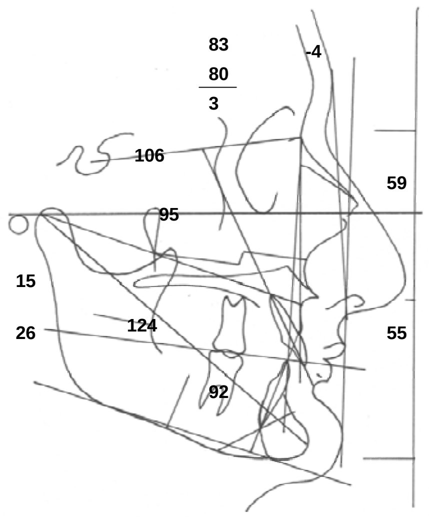


Figure 44. A cephalometric tracing of a patient requiring orthognathic surgery for the correction of a Class II dentofacial deformity.

5.2.1.1.1 Surgical prediction tracing according to conventional treatment principles

Figure 45 illustrates conventional surgical prediction involving maxillary advancement, mandibular advancement and reduction genioplasty. It is not possible to achieve an aesthetic chin contour and at the same time acceptable antero-posterior chin position by means of a reduction genioplasty. An alternative treatment design utilizing the rotation of the MMC is tested by means of a surgical cephalometric prediction.

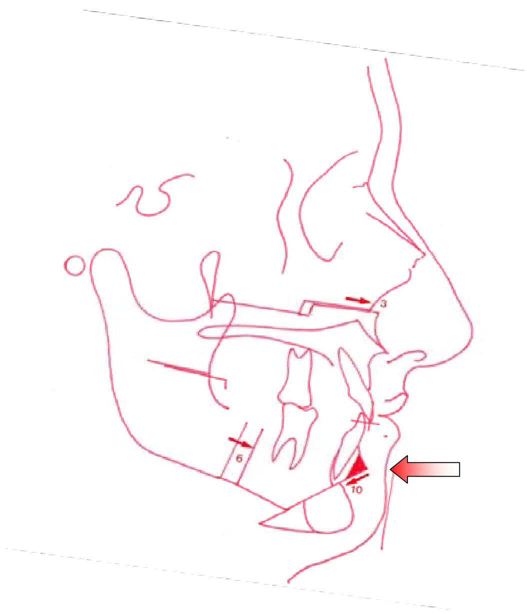


Figure 45. The maxilla as well as the mandible is advanced while the chin is antero-posteriorly reduced. Although the chin is in an acceptable antero-posterior position, the labiomental fold is obliterated in an attempt to position Pog' in harmonious relation to other facial structures resulting in poor aesthetics.

5.2.1.1.2 Surgical prediction tracing involving clockwise rotation of the MMC

STEP 1 (Fig.46).

A cephalometric tracing is done on the immediate pre-operative radiograph. This tracing will be called the original tracing (OT). Draw lines representing the intended osteotomies on the maxilla, mandible and symphysis. When no vertical change of the chin is indicated the osteotomy line is drawn more horizontally keeping the mental nerve and root apices of the mandibular teeth in mind. In this case, however, vertical increase as well as antero-posterior reduction is required. The osteotomy line should therefore be angulated downwards. All osteotomy lines should be drawn as close as possible to the anatomical position where the actual osteotomies will be performed for accurate measurement.

The proposed horizontal position of the soft tissue chin (Pog') should be indicated by a vertical line in the chin area. Handy guidelines to indicate the horizontal chin position are the facial contour angle (upper to lower facial planes: females -13 (±2) degrees and males -11 (±2) degrees) and the 0-degree meridian (a line perpendicular to FH drawn through soft tissue nasion: Pog' should be 0-2mm behind the line).

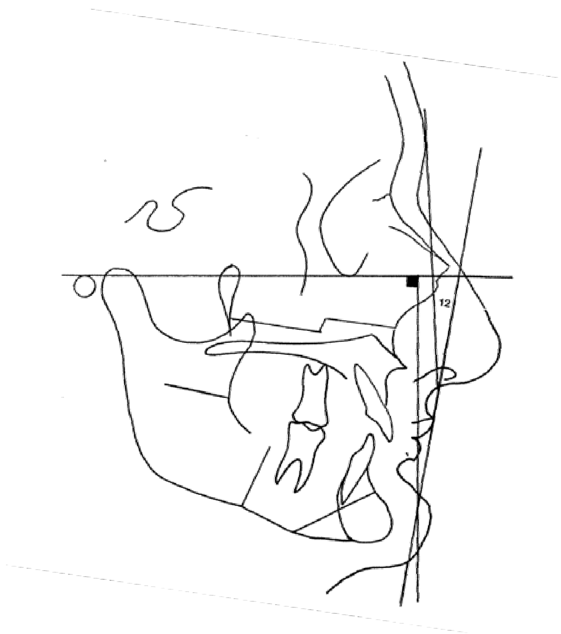


Figure 46. The OT with the le Fort I, bilateral sagittal split and genioplasty osteotomy lines drawn at the appropriate anatomical areas. The constructed facial contour angle (-12 degrees) and 0-degree meridian indicate the proposed chin position (Pog').

STEP 2 (Fig.47):

Lay a clean piece of acetate paper over the OT and trace all the structures that will not be altered by the surgery. That means all the skeletal structures above the le Fort I osteotomy line and mandibular structures behind the vertical sagittal split line. The soft tissue of the forehead and nose is traced to just above the tip of the nose. This tracing will be called the prediction tracing

(PT) (Fig. 47a). The ideal position of the maxillary incisor edge should be indicated on the PT by two lines. The horizontal line indicates the ideal vertical position of the incisor tip and the vertical line the ideal antero-posterior position of the anterior tooth surface. The antero-posterior position of the chin should also be indicated by a vertical line. Helpful guidelines in determining this line include the angle of facial convexity, the O-degree meridian as well as the clinician's judgment (Fig. 47b).

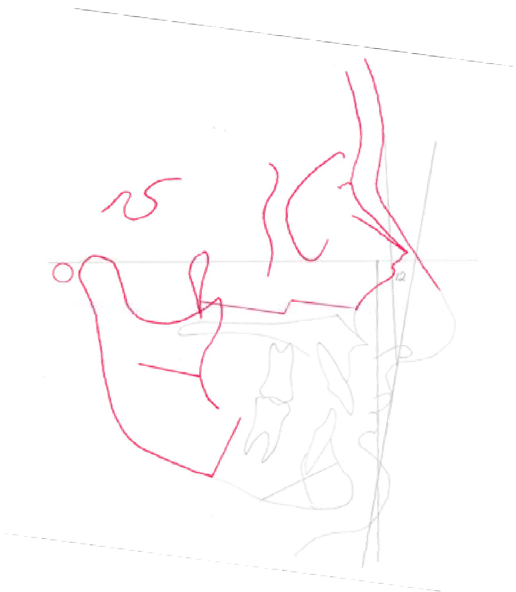


Figure 47a, All the skeletal structures above the le Fort I osteotomy line and mandibular structures behind the vertical sagittal split line are traced. The soft tissue of the forehead and nose to above the tip of the nose are traced. This tracing will be called the prediction tracing (PT).

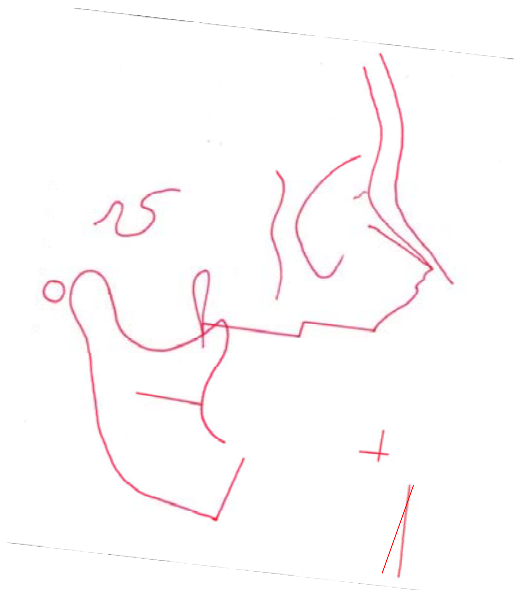


Figure 47b, Trace the desired antero-posterior position of the chin (Pog) in the chin area and the ideal maxillary incisor edge position from the OT (horizontal and vertical line).

STEP 3 (Fig.48):

Tracing of the MMC:
Remove the PT from the OT and lay a new acetate paper over the OT. Trace the le Fort I osteotomy line and the maxillary structures below. Move the acetate paper (to the left in this case) to achieve the optimal occlusal relationship between the traced maxillary teeth and the mandibular teeth on the OT and trace the mandibular teeth and the distal part of the mandible anterior and including the vertical osteotomy line (Fig. 47a). Retrace the osteotomy line for the genioplasty at the symphysis. This tracing is called the maxillomandibular complex tracing (MMCT) and is kept in this position on the OT. The MMCT is demonstrated in figure 48b.

Figure 48a. The MMCT. The mandible has been advanced to obtain the best possible occlusion and the skeletal structures traced on a separate piece of acetate paper. The maxilla below and including the le Fort I osteotomy line and the mandible in front of and including the vertical sagittal split osteotomy line are traced.

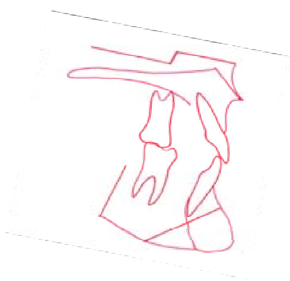


Figure 48b. The MMCT consists of the skeletal and dental structures below the le Fort I osteotomy line and the distal part of the mandible anterior to the vertical osteotomy line with the teeth in the planned relationship. The line for the genioplasty osteotomy is also drawn on the mandible, however, the chin below the line is not traced as a reduction genioplasty is contemplated.

STEP 4 (Fig. 49):

Overlay the PT on the OT. The MMCT can now be moved between the OT and PT.
The principles to generate the VTO discussed previously can now be applied to determine: (1) the direction of rotation of the MMC and (2) the most favourable point of rotation. In this case the tracing is rotated in a clockwise direction advancing the maxilla and rotating the mandible posteriorly using the "box" for the maxillary incisor tip and the vertical line for the chin as guidelines (Fig.49). In this case it should be kept in mind that a reduction genioplasty is indicated to correct the macrogenia and at the same time increase the height of the symphysis. Once a satisfactory position has been achieved, trace the MMC on the PT. The part of the symphysis below the genioplasty osteotomy line is however, not traced now.

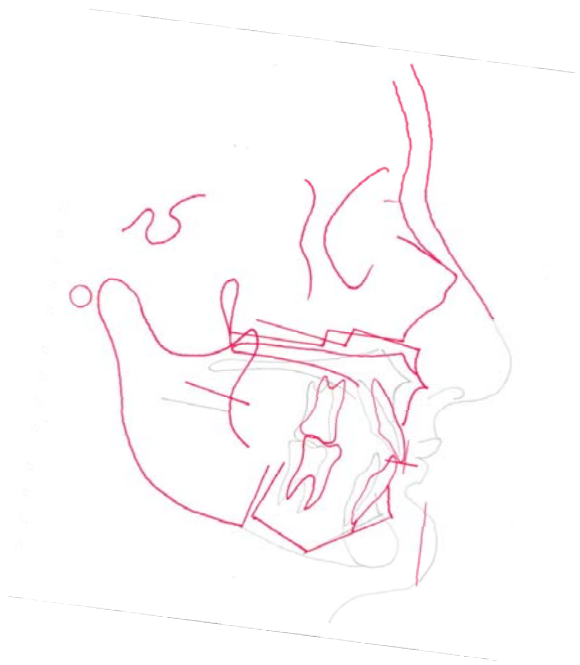


Figure 49. The MMCT, now between the OT and PT, is rotated (clockwise in this case), and guided by the desired incisor position and chin position (keeping in mind that a reduction genioplasty is planned), placed in the "best fit" position.

STEP 5 (Fig. 50):

Remove the MMCT and superimpose the PT on the OT. Soft tissue prediction is drawn using the same principles as for conventional prediction of soft tissue response to hard tissue change. Complete the prediction tracing by tracing the ideal soft tissue of the chin and the required reduction genioplasty (Fig.50). Note that in this instance a much smaller reduction is necessary than in the conventional prediction (Fig.45) resulting in a better soft tissue chin contour.

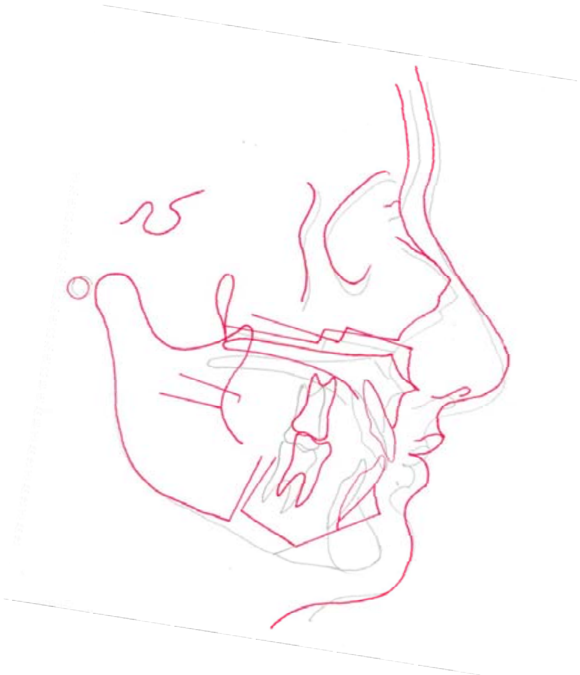


Figure 50. The soft tissue is now predicted and drawn. The ideal soft tissue chin contour is drawn guided by the contour of the underlying bony chin. Now also draw in the hard tissue of the chin. Although the soft tissue change is less predictable than chin advancements the soft tissue would move back approximately 90% of the hard tissue reduction.

STEP 6 (Fig. 51):

Evaluate the predicted aesthetic and functional result. If the result is not satisfactory changes may be indicated to improve the result. In the case demonstrated the magnitude of the chin reduction can be reduced by increasing the rotation of the MMC, however, it should be kept in mind what aesthetic effect the increased advancement of the maxilla may have. Surgical prediction tracing should however, always stay within the limits of sound surgical principles.

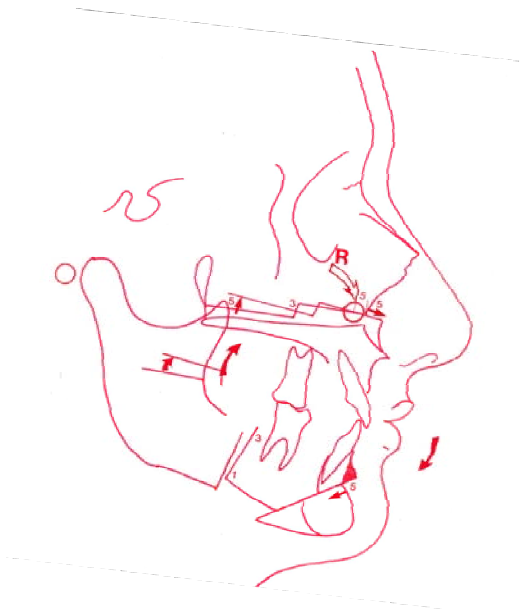


Figure 51. The completed surgical visual treatment objective. Point "R" indicates the rotation point of the actual surgical procedure at the level of the le Fort I osteotomy.

Note the point “R” where the le Fort I osteotomy lines of the OT and PT cross each other (Fig.51). This is the point around which the maxillomandibular complex will be rotated on the le Fort I osteotomy line during surgery. The exact position of the rotation point should be noted and used during the model surgery as well as during the actual surgical procedure. All jaw movements should be measured on the PT and model surgery, and recorded as is routinely done in CT planning.
A comparison of the PT of CT planning in figure 45 and the PT utilizing rotation of the maxillomandibular complex, demonstrates superior aesthetics achieved by the latter in figure 51.

5.2.1.2 Surgical prediction with CCR of the MMC

CASE 2:

Orthognathic surgeons are often consulted by patients who had previously been treated orthodontically during which time the dentition has been compensated for their skeletal malrelationship. Dental compensation for a skeletal discrepancy will often make the soft tissue profile worse and although the patients may have a functional occlusion, they may be dissatisfied with their appearance following their orthodontic treatment. In these cases the surgeon is left with a dilemma as treatment possibilities are now limited due to the fact that there is no dental discrepancy present that would allow for surgical repositioning of the mandible or the maxilla. Creation of a dental overjet to facilitate orthognathic surgery is often also limited by the fact that four bicuspid teeth have been removed. In exceptional cases the poor aesthetic result may be masked by a genioplasty procedure. Genioplasty however, is not a substitute for mandibular surgery and is often in itself a surgical compromise.
Rotation of the MMC may often be a solution for these cases. The occlusion that has been established by orthodontic treatment is maintained and utilized as part of the MMC to improve the patient’s aesthetics. Case 2 is an example of a patient with skeletal mandibular antero-posterior deficiency with an orthodontically compromised occlusion. Four bicuspid teeth were extracted, the upper incisors orthodontically retroclined and the lower incisors proclined to establish a Class I occlusion.

The cephalometric analysis reveals the following (Fig. 52):

1. Class I occlusion
2. Retroclined upper incisors
3. Proclined lower incisors
4. High mandibular plane angle
5. Convex profile
6. Increased nasolabial angle

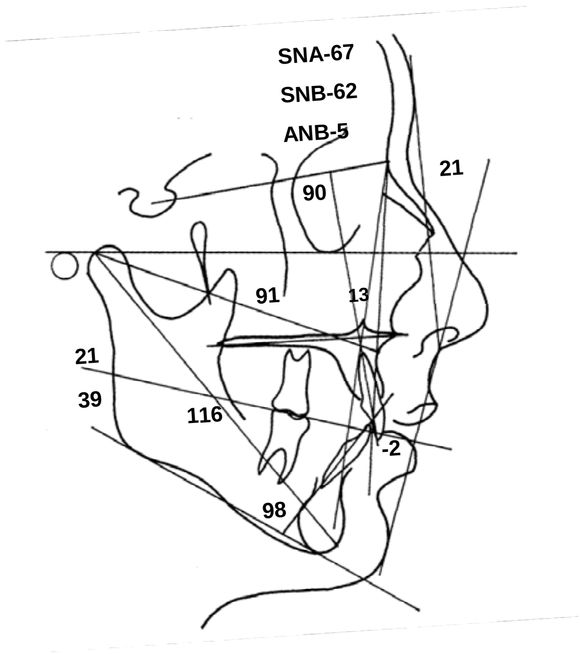


Figure 52. Cephalometric analysis of Case 2.

The fact that the chin shape has a favourable contour with a normal labio-mental fold precludes the possibility of improving the facial convexity by means of an advancement genioplasty. The unfavourable result is predicted and demonstrated in figure 53.

5.2.1.2.1 Surgical prediction tracing for Genioplasty as compromised treatment for mandibular advancement

Figure 53 illustrates the predicted profile after advancement genioplasty. The chin has been advanced for Pog' to touch the constructed lower facial plane forming an angle of -11 degrees with the upper facial plane. The unacceptable contour of the chin is evident and improvement of the profile by means of a genioplasty should therefore not be considered. The Holdaway analysis is a helpful guide to evaluate the relative relationship between the chin, the labio-mental sulcus and the lips as discussed elsewhere. The poor aesthetic result illustrated in figure 53 confirms the fact that genioplasty is not an alternative for mandibular surgery. In some cases conventional treatment planning requires excessive advancement or setback of the chin to achieve ideal antero-posterior position of Pog'. In these cases advancement genioplasty will lead to a “knobby” appearance while reduction of the chin will result in a flat labio-mental sulcus.

Rotation of the MMC allows the surgeon to maintain the chin shape or at least limit chin surgery and at the same time position Pog' in a more ideal antero-posterior relation to the facial structures. MMC rotation therefore allows the surgeon to first create the ideal chin contour and then position Pog' in the correct antero-posterior position.

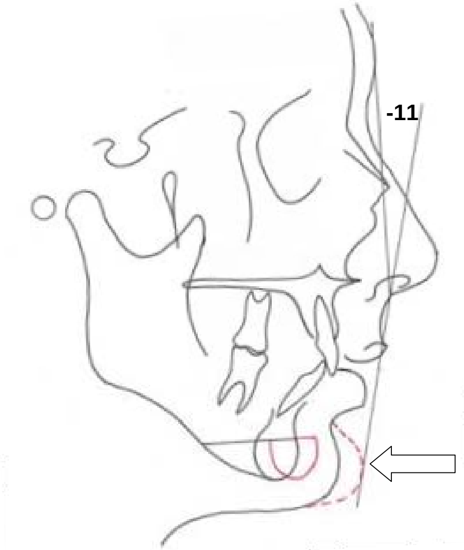


Figure 53. A VTO illustrating the expected soft tissue result following genioplasty advancing the chin. Pog' is advanced to touch the required facial contour angle of 11 degrees resulting in a too prominent and "knobby" chin.

5.2.1.2.2 Step by step surgical prediction tracing with CCR of the MMC

The alternative surgical treatment design involving rotation of the MMC in a counter-clockwise direction is tested by means of the surgical prediction.

Step 1 (Fig. 54)

Trace all the relevant hard and soft tissue structures on a clean piece of acetate paper. This tracing is called the "original tracing" (OT).

Step 2 (Fig. 54)

Draw the le Fort I osteotomy line on the maxilla and the vertical osteotomy line of the sagittal split osteotomy on the corpus of the mandible. Also construct the desired facial contour angle, in other words the desired antero-posterior position of the chin (Pog'). Draw a horizontal line below the upper lip to indicate the ideal maxillary incisor, upper lip relationship (ideal vertical position of the maxillary incisor).

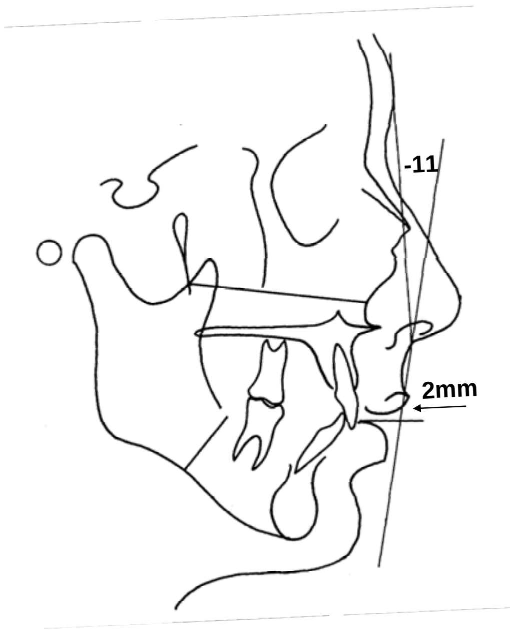


Figure 54. The le Fort I and vertical sagittal split osteotomy lines are drawn on the OT. A facial contour angle of -11 degrees is constructed to serve as a guide to the antero- posterior position of the chin, while a horizontal line approximately 2mm below the upper lip indicates the preferred vertical position of the maxillary incisor tooth.

Step 3 (Fig. 55)

Lay a clean piece of acetate paper over the OT. Use a red pencil and trace all the hard tissue structures below and including the le Fort I osteotomy line and anterior and including to the vertical osteotomy on the mandible. Also trace the soft tissue of the upper lip, lower lip and chin. This tracing represents the MMC and is called the "MMCT".

Figure 55. The MMCT traced from the OT represents the skeletal, soft tissue and dental structures that will be repositioned.

Step 4 (Fig. 56)

Place the MMCT on the OT and slide the MMCT superior so that the maxillary incisor tip of the MMCT touches the horizontal line indicating the desired vertical position of the incisor. Ensure that the le Fort I osteotomy lines on the OT and the MMC are parallel.

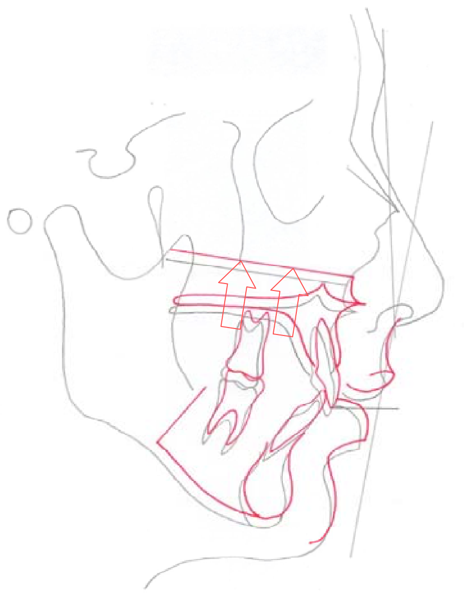


Figure 56. The ideal tooth/lip relationship is established by sliding the MMCT superiorly until the maxillary incisor edge coincides with the line. The le Fort I osteotomy lines are parallel.

Note: The main surgical objectives in this case are:

1. To advance the mandible.
2. To improve the angulation of the upper incisor.
3. To increase the nasolabial angle and increased lip support.

The principles discussed previously should now be applied. Considering the treatment aims, the MMC should be rotated in a counter-clockwise direction and to obtain the desired soft tissue requirements as mentioned above the rotation point should be high and anterior.

Step 5 (Fig. 57)

Place a pencil tip on the most anterior end of the le Fort I osteotomy line and rotate the MMCT counter-clockwise until the soft tissue of the chin on the MMCT coincide with the constructed lower facial plane on the OT.

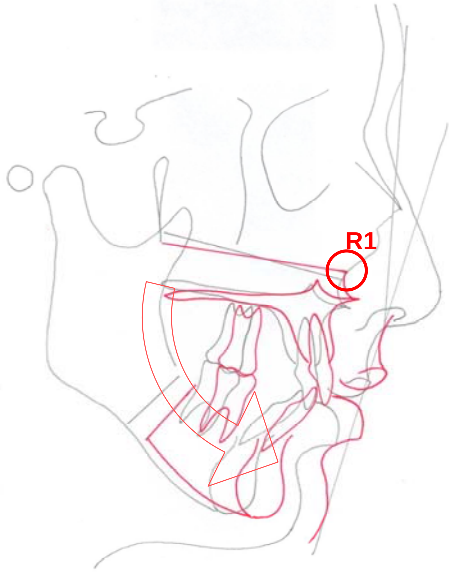


Figure 57. By rotating the MMC in a counter-clockwise direction and use the most superior point of the MMCT as rotation point R1. The chin is advanced to touch the constructed lower facial plane.

Step 6 (Fig.58).

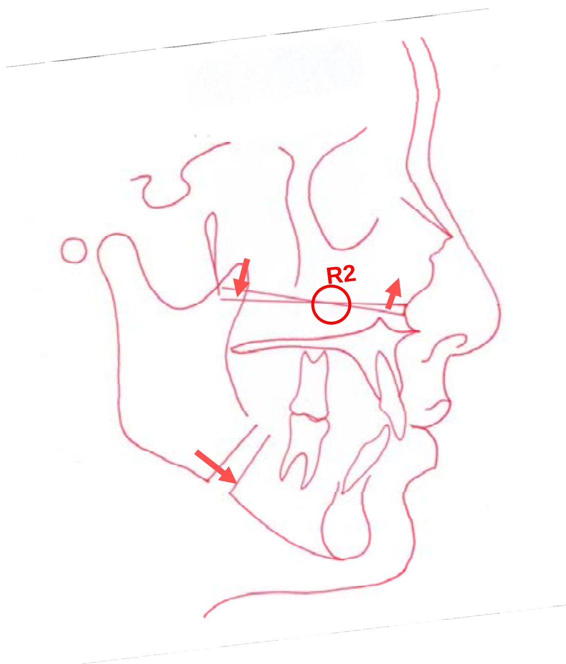


Figure 58. The osteotomy lines are retraced to indicate the skeletal surgical change and the surgical rotation point noted where the le Fort I osteotomy lines cross R2. The soft tissue changes are also predicted and drawn in.

5.2.1.3 Reconciling the cephalometric rotation point with the surgical rotation point

The fact that there are two rotation points, one around which the MMCT is rotated during the development of the VTO, and the other point around which the MMC will be rotated during the actual surgical procedure may be confusing. This is however an important concept that needs to be emphasized.

5.2.1.3.1 Rotation point during the development of the cephalometric VTO

At this stage the MMC is rotated according to the aesthetic principles discussed previously. The MMC is rotated around any point, posterior, inferior or at ANS, in a clockwise or counter-clockwise direction depending on the aesthetic requirements of the case. The prediction tracing is then completed and the skeletal structures traced in, the soft tissue prediction done and the osteotomy lines traced in.

5.2.1.3.2 Rotation point on the le Fort I osteotomy line at the time of surgery

Once the surgical VTO has been generated it should be noted that the original le Fort I osteotomy line and the osteotomy line on the prediction tracing cross at some point. The position of this point should be noted as it will serve as the surgeons guide for (a) when model surgery is performed and (b) when the actual surgery is done. During surgery the only accurate reference the surgeon will have is the le Fort I osteotomy line and an intermediate splint, manufactured during model surgery. In figure 59 this concept of rotating the MMC (triangle) around one point during the development of a VTO, which then leads to a rotation of the MMC around a different point on the le Fort I osteotomy line is illustrated.

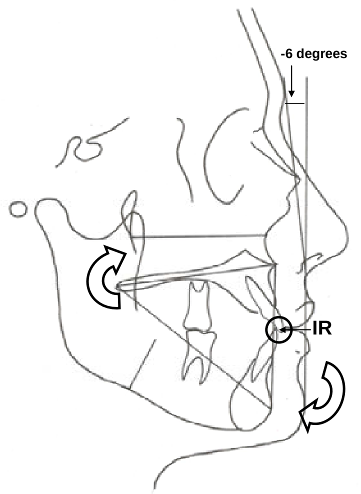


Figure 59a. The patient has a facial contour angle of -6 degrees with a relatively straight profile. To improve the convexity of the profile the MMC will be rotated clockwise around the incisor tip (IR).

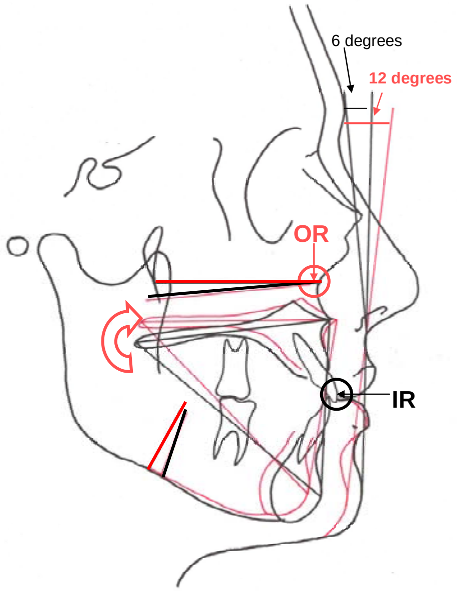


Figure 59b. By rotation the MMC around the incisor tip (IR) in a clockwise direction, the maxilla is advanced while the mandible is set back. The rotation of the triangle results in a rotation at the anterior edge of the le Fort I osteotomy line (OR). The profile is now more convex with a facial contour angle of -12 degrees.

5.3. Post-operative skeletal stability following clockwise and counter-clockwise rotation of the MMC compared to conventional orthognathic treatment

The skeletal changes following surgery and their long-term stability were recorded for the three groups and summarized in tables 1, 2 and 3.

5.3.1. Surgical and post-surgical changes

5.3.1.1 Conventional group (Table 9)

For the 22 patients in this group treated by CT planning principles, the average decrease in the OP was 0.32 degrees (op2-op1). The surgical repositioning of all the patients in this group consisted of maxillary advancement and superior repositioning and mandibular advancement.

TABLE 9

SURGICAL AND POST-SURGICAL CHANGES OF THE CONVENTIONAL TREATMENT GROUP					
VARIABLE (mm)	CHANGE	MEAN	SD	MIN	MAX
MAXILLARY ADVANCEMENT	ax2-1	2.24	1.95	-1.31	6.99
POST-OPERATIVE CHANGE	ax3-2	-0.66	1.21	-3.45	1.99
MAXILLARY SUPERIOR REPOSITIONING	ay2-1	-1.91	2.13	-5.29	2.6
POST-OPERATIVE CHANGE	ay3-2	0.55	1.42	-1.06	3.67
MANDIBULAR ADVANCEMENT	bx2-1	7.26	3.34	1.02	12.32
POST-OPERATIVE CHANGE	bx3-2	-0.99	1.70	-5.81	1.2
MANDIBULAR VERTICAL CHANGE	by2-1	-0.46	3.06	-5.84	5.6
POST-OPERATIVE CHANGE	by3-2	-0.39	1.91	-3.91	5.61
POSTERIOR MAXILLARY ADVANCEMENT	pnsx2-1	2.16	2.07	-1.85	7.26
POST-OPERATIVE CHANGE	pnsx3-2	-0.52	1.22	-3.08	1.7
POSTERIOR MAXILLARY VERTICAL CHANGE	pnsy2-1	-0.32	-0.93	-4.98	3.08
POST-OPERATIVE CHANGE	pnsy3-2	-0.02	0.98	-2.54	1.45
VARIABLE (DEGREES)					
OCCLUSAL PLANE ANGLE CHANGE	op2-1	-0.32	1.07	-3.1	1.7
POST-OPERATIVE CHANGE	op3-2	-0.24	1.76	-2.9	3.6
MANDIBULAR PLANE CHANGE	mp2-1	-1.62	2.78	-8.4	3.3
POST-OPERATIVE CHANGE	mp3-2	0.86	1.44	-1.3	4.8

The anterior maxilla (A point) was advanced by a mean of 2.24 mm (ax2-ax1), the mandible (B point) advanced by 7.26 mm (bx2-bx1) and the PNS by 2.16 mm (pnsx2-pnsx1). The maxilla was superiorly repositioned at A point by a mean of 1.19 mm (ay2-ay1), the mandible at B point, moved superiorly by 0.46 mm (by2-by1) while the posterior maxilla moved superiorly by 0.32 mm (pnsy2-pnsy1). The MP angle decreased by 1.62 degrees (mp2-mp1) as a result of the surgery.

Post-operatively the maxilla moved posteriorly at A point by a mean of 0.66 mm, the mandible (B point) relapsed by a mean of 0.99 mm and PNS moved posteriorly by a mean of 0.65 mm. Long-term vertical post-operative changes were as follows: the maxilla (A point) moved downwards by a mean of 0.55 mm, B point moved downwards by 0.39 mm while PNS also moved downwards by 0.53 mm. The OP angle decreased further by a mean of 0.24 degrees. The further decrease in the OP angle can be explained by the effect of the post-operative orthodontic "settling" of the occlusion. The MP angle increased in the long-term by 0.86 degrees (Table 4).

5.3.1.2 Clockwise rotation group (Table 11)

In this group of 26 patients, the mean OP angle change after surgery was 4.89 degrees (op2-op1), indicating the clockwise direction of rotation of the MMC. The mean maxillary advancement (A point) in this group was 2.73 mm (ax2-ax1) while the mandible moved posteriorly at B point, by an average 0.23 mm (bx2-bx1). The relatively small movement of B point is indicative of the rotation of the anterior mandible. The aim in the treatment design of this group of patients (Class II deep bite and Class III occlusion with good chin shape) are to rotate the mandibular incisors forward and Pogonion posteriorly which results in a small horizontal positional change at B point. Anterior repositioning of posterior nasal spine in this group was 3.62 mm (pns2-pns1). The mean vertical increase (downward movement) of the maxilla at A point was1.17 mm (xy2-ay1), the mandible at B point, was moved downward by 2.61 (by2-by1) and the posterior maxilla (PNS) was superiorly repositioned by 1.68 mm (pnsy2-pnsy1). An increase of 5.22 degrees of the MP angle was recorded after surgery.
The long-term post-operative data revealed the following: A point moved posteriorly by a mean of 0.55 mm, B point relapsed by 0.61 mm and PNS moved back by 0.65 mm. The anterior maxilla at A point moved upwards by 0.53 mm, while the mandible (B point) moved 0.86 mm upwards and PNS moved inferiorly by 0.39 mm after surgery. The long-term post-operative change of the OP angle was a decrease of 1.07 degrees and the MP angle decreased by 0.86 degrees. Both these angular changes can be attributed to post-operative orthodontic "settling" of the occlusion (Table 11).

TABLE 11

SURGICAL AND POST-SURGICAL CHANGES OF THE CLOCKWISE ROTATION GROUP					
VARIABLE (mm)	CHANGE	MEAN	SD	MIN	MAX
MAXILLARY ADVANCEMENT	ax2-1	2.73	2.39	-1.35	8.94
POST-OPERATIVE CHANGE	ax3-2	-0.55	1.51	-2.74	3.22
MAXILLARY SUPERIOR REPOSITIONING	ay2-1	1.17	2.76	-4.92	7.24
POST-OPERATIVE CHANGE	ay3-2	-0.53	1.64	-3.15	2.84
MANDIBULAR ADVANCEMENT	bx2-1	-0.24	5.53	-13.74	7.11
POST-OPERATIVE CHANGE	bx3-2	0.61	2.11	-5.72	4.71
MANDIBULAR VERTICAL REPOSITIONING	by2-1	2.61	3	-1	10.79
POST-OPERATIVE CHANGE	by3-2	-0.86	1.49	-3.53	2.5
POSTERIOR MAXILLARY ADVANCEMENT	pnsx2-1	3.62	2.74	-2.13	8.86
POST-OPERATIVE CHANGE	pnsx3-2	-0.65	1.7	-2.98	3.33
POSTERIOR MAXILLARY SUPERIOR REPOSITIONING	pnsy2-1	-1.68	2.16	-5.7	3.41
POST-OPERATIVE CHANGE	pnsy3-2	-0.39	1.32	-3.89	2.42
VARIABLE (DEGREES)					
OCCLUSAL PLANE ANGLE CHANGE	op2-1	4.89	2.48	2	12.1
POST-OPERATIVE CHANGE	op3-2	-1.07	1.95	-4.2	3.3
MANDIBULAR PLANE ANGLE CHANGE	mp2-1	5.22	3.92	-0.6	14.6
POST-OPERATIVE CHANGE	mp3-2	-0.86	1.81	-4	2.9

5.3.1.3 Counter-clockwise group (Table 12)

In this group, consisting of 41 patients, the OP angle decreased by 4.97 degrees (op2-op1) indicating the counter-clockwise direction of the rotation of the MMC. The anterior maxilla (A point) was advanced by 3.32 mm (ax2-ax1) and the posterior maxilla (PNS) by 2.85 mm (pnsx2-pnsx1). The mandible advanced by a mean of 10.81 mm (bx2-bx1) at Pog. This relatively large average advancement of the mandible in this group illustrates the fact that the CCR of the MMC enhances the surgeon's ability to advance the mandible further than with CT methods. The vertical skeletal changes as a result of surgery consisted of the following: the anterior maxilla (A point) was superiorly repositioned by 3.84 mm (ay2-ay1), the mandible (B point) moved upward by 2.83 mm (by2-by1) and PNS moved downward by 1.07 mm (pnsy2-pnsy1). The upward movement of the anterior maxilla and concomitant downward movement of the posterior maxilla illustrate the CCR of the maxilla. The MP angle decreased by 4.06 degrees (mp2-mp1).

In the long-term A point moved posteriorly by 0.58 mm, B point moved posteriorly by 1.85 mm and PNS moved posteriorly by 0.55 mm. The maxilla relapsed inferiorly by a mean of 0.66 mm, the mandible (B point) rotated downwards by 0.06 mm and PNS moved downwards by 0.37 mm. The OP angle increased by 1.6 degrees and the MP angle increased by 1.4 degrees after surgery (Table 12)

TABLE 12

SURGICAL AND POST-SURGICAL CHANGES OF THE COUNTER-CLOCKWISE ROTATION GROUP					
VARIABLE (mm)	CHANGE	MEAN	SD	MIN	MAX
MAXILLARY ADVANCEMENT	Ax2-1	3.32	1.75	0.61	7.39
POST-OPERATIVE CHANGE	Ax3-2	-0.58	1.35	-3.02	2.38
MAXILLARY SUPERIOR REPOSITIONING	Ay2-1	-3.84	2.24	-9.75	1.08
POST-OPERATIVE CHANGE	Ay3-2	0.66	1.46	-2.17	3.53
MANDIBULAR ADVANCEMENT	Bx2-1	10.81	3.73	2.68	19.05
POST-OPERATIVE CHANGE	Bx3-2	-1.85	2.29	-8.3	2.60
MANDIBULAR VERTICAL REPOSITIONING	By2-1	-2.82	2.49	-7.39	1.67
POST-OPERATIVE CHANGE	By3-2	0.06	2.03	-5	4.75
POSTERIOR MAXILLARY ADVANCEMENT	pnsx2-1	2.85	1.83	-0.22	7.1
POST-OPERATIVE CHANGE	pnsx3-2	-0.55	1.36	-3.89	2.98
POSTERIOR MAXILLARY SUPERIOR REPOSITIONING	pnsy2-1	-1.07	1.46	-4.02	4.33
POST-OPERATIVE CHANGE	pnsy3-2	0.37	1.28	-2.8	4.26
VARIABLE (DEGREES)					
OCCLUSAL PLANE ANGLE CHANGE	Op2-1	-4.97	2.58	-10	1.53
POST-OPERATIVE CHANGE	Op3-2	1.6	2.45	-2.23	8.7
MANDIBULAR PLANE ANGLE CHANGE	mp2-1	-4.06	3.32	-12	1.1
POST-OPERATIVE CHANGE	mp3-2	1.4	2.07	-3.1	5.1

The surgical movements and long-term skeletal changes after surgery of the clockwise and counter-clockwise groups were compared to the CT group using the parameters as described above and the results were tabulated in Table 13 and in Figure 60.

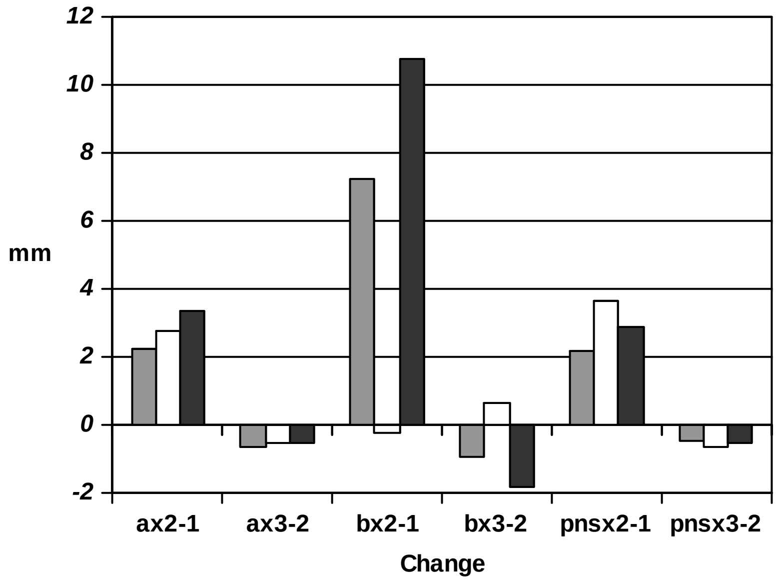
TABLE 13

A COMPARISON OF SURGICAL AND POST-SURGICAL CHANGES BETWEEN THE GROUPS					
CHANGE (mm)	CT	CR	CCR	t-test	WILCOXON
ax2-1(SD)	2.24(1.95)	2.74(2.39)		0.4360(ns)	0.4883(ns)
	3.32(1.75)		3.32(1.75)	0.0348(ns)	0.017(s)
ay2-1(SD)	-1.91(2.13)	1.17(2.76)		0.0001(s)	0.0002(s)
	-1.91(2.13)		-3.84(2.25)	0.0015(s)	0.0028(s)
ax3-2(SD)	-0.66(1.21)	-0.55(1.53)		0.7997(ns)	0.8562(ns)
	-0.66(1.21)		-0.58(1.35)	0.8197(ns)	0.8513(ns)
ay3-2(SD)	0.55(1.41)	-0.53(1.65)		0.0196(s)	0.016(s)
	0.55(1.41)		0.66(1.47)	0.7619(ns)	0.4577(ns)
bx2-1(SD)	7.26(3.36)	-0.23(5.53)		0(s)	0(s)
	7.26(3.36)		10.81(3.72)	0.0003(s)	0.0011(s)
by2-1(SD)	-0.46(3.06)	2.61(3.0)		0.0012(s)	0.0019(s)
	-0.46(3.06)		-2.82 (2.50)	0.0036(s)	0.005(s)
bx3-2(SD)	-0.99(1.69)	0.61(2.12)		0.0062(s)	0.0029(s)
	-0.99(1.69)		-1.85(2.30)	0.949(ns)	0.0988(ns)
by3-2(SD)	-0.39(1.91)	-0.86(1.49)		0.3587(ns)	0.263(ns)
	-0.39(1.91)		0.07(2.04)	0.379(ns)	0.1871(ns)
pnsx2-1 (SD)	2.16(2.07)	3.62(2.74)		0.0437(s)	0.0621(ns)
	2.16(2.07)		2.85(1.84)	0.1974(ns)	0.1944(ns)
pnsy2-1 (SD)	-0.32(1.94)	-1.68(2.16)		0.0277(s)	0.0151(ns)
	-0.32(1.94)		-1.07(1.46)	0.1207(ns)	0.0207(s)
pnsx3-2 (SD)	-0.53(1.23)	-0.65(1.70)		0.7727(ns)	0.5155(ns)
	-0.53(1.23)		-0.56(1.36)	0.937(ns)	0.9425(ns)
pnsy3-2 (SD)	-0.02(0.98)	-0.40(1.32)		0.2676(ns)	0.2912(ns)
	-0.02(0.98)		0.37(1.28)	0.1817(ns)	0.2638(ns)
CHANGE degrees)					
op2-1(SD)	-0.32(1.07)	4.89(2.48)		0(s)	0(s)
	-0.32(1.07)		-4.97(2.59)	0(s)	0(s)
op3-2(SD)	-0.24(1.76)	-1.07(1.95)		0.1306(ns)	0.1382(ns)
	-0.24(1.76)		1.60(2.45)	0.0011(s)	0.0035(s)
mp2-1(SD)	-1.63(2.78)	5.22(3.93)		0(s)	0(s)
	-1.63(2.78)		-4.06(3.32)	0.0032(s)	0.0053(s)
mp3-2(SD)	0.86(1.44)	-0.87(1.81)		0.0007(s)	0.0021(s)
	0.86(1.44)		1.40(2.08)	0.2327(ns)	0.3867(ns)

s= Significantly different to the CT group $P < 0.05$
ns = Not significantly different to the CT group $P > 0.05$

Table 13. Each distribution was evaluated by using the respective standard errors. Two sample test and non parametric Wilcoxon ranksum test were used to compare surgical and post-surgical changes.

ANTERO-POSTERIOR
SURGICAL AND POST-SURGICAL CHANGES



	ax2-1	ax3-2	bx2-1	bx3-2	pnsx2-1	pnsx3-2
■ CT	2.24	-0.66	7.26	-0.99	2.16	-0.52
□ CR	2.74	-0.55	-0.24	0.61	3.62	-0.65
■ CCR	3.32	-0.58	10.81	-1.85	2.85	-0.56

Figure 60. A summary of the antero-posterior surgical changes (mm) of the maxilla (ax2-1), the mandible (bx2-1) and posterior maxilla (pns2-1) and long-term post-surgical changes of the maxilla (ax3-2), the mandible (by3-2) and posterior maxilla (pns3-2) of the conventional treated group (CT), the clockwise rotation group (CR) and the counter-clockwise rotation group (CCR).

5.3.2 Long-term post-surgical changes

5.3.2.1 Long-term antero-posterior post-surgical changes

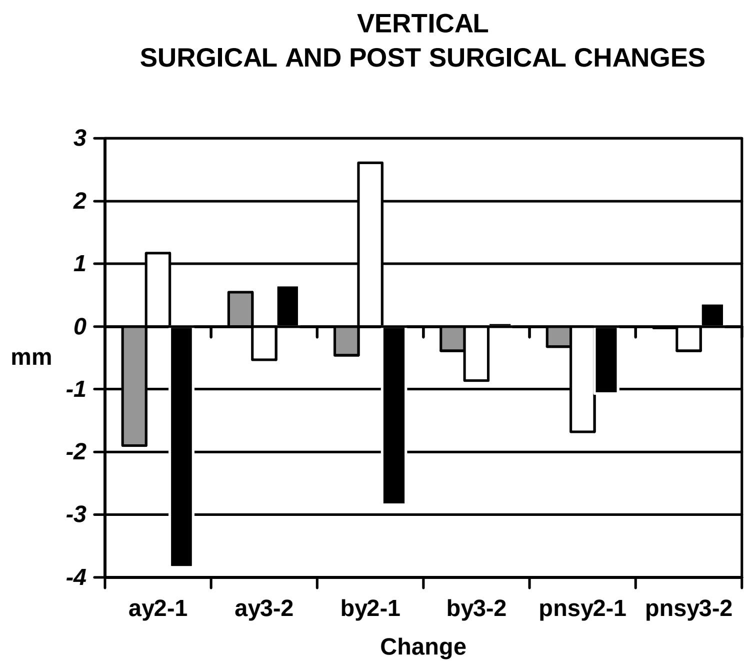
In all three groups the maxilla was advanced (ax2-1) during surgery. The advancement was partially due to the CR and CCR in all the groups although the points of rotation may have differed and is partially due to an intentional advancement for aesthetic reasons. Posterior repositioning of the maxilla in most cases will result in poor aesthetics. The long-term post-surgical stability (ax3-2) in all three groups was not statistical significantly different.

The mean mandibular advancements (bx2-1) of the CT and the CCR groups were substantial (CT = 7.26mm and CCR=10.81mm) with the advancement of the CCR group significantly more than the mandibular advancement of the CT group. CCR allows the surgeon to advance the mandible more than with CT as evident in difference in the amount of advancement between the CCR and the CT groups. Note that the antero-posterior position of B point in the CR group changed very little, in fact B point showed a relatively small mean setback of 0.24mm in this group. The small surgical change is due to the CR of the mandible during surgery resulting in advancement of the mandibular incisors and rotating Pog backwards. The long-term horizontal relapse of the mandible at B point (bx3-2) was not significantly different between the CT and the CCR groups.

The advancement of the posterior maxilla (pnsx2-1) at PNS in the CT and the CCR groups was basically the same however the maxillary advancement at PNS in the CR groups was significantly more compared to the advancement in the CT group. The greater advancement of the posterior maxilla in this group was due to the further forward and upward rotation of PNS following the deliberate CR of the MMC. Long-term difference in post-surgical stability in all three groups was not statistical significantly (pns3-2).

5.3.2.2 Long-term vertical post-surgical changes

The vertical repositioning of the anterior maxilla at A point (ay2-1) following surgery was significantly different between the groups. Due to the deliberate CCR of the MMC in the CCR group it resulted in the anterior maxilla (A point) being superiorly repositioned nearly twice the distance as in the CT group. The CR of the MMC caused A point to move inferiorly during surgery. The difference in post-operative change between the groups was insignificant (ay3-2) although the direction of movement at the time of surgery was opposite for the CR and CCR groups (upward for the CCR and downward for the CR group). The amount of inferior repositioning of the anterior maxilla in the CT group was, however, relatively small (1.17mm), while the posterior maxilla in this group was superiorly repositioned (1.68mm) (Fig 61).



	ay2-1	ay3-2	by2-1	by3-2	pnsy2-1	pnsy3-2
CT	-1.9	0.55	-0.46	-0.39	-0.32	-0.02
CR	1.17	-0.53	2.61	-0.86	-1.68	-0.39
CCR	-3.84	0.66	-2.84	0.06	-1.07	0.37

Figure 61. A summary of the vertical surgical changes of the maxilla (ay2-1), the mandible (by2-1) and posterior maxilla (pns2-1) and long-term post-surgical changes of the maxilla (ay3-2), the mandible (by3-2) and posterior maxilla (pns3-2) for the conventional treated group (CT), clockwise rotation group (CR) and the counter-clockwise rotation group (CCR).

5.3.2.3 Post-surgical angular changes

The OP of both the CT and the CCR groups was rotated in a counter-clockwise direction during surgery. The important difference however was that in the CT group the rotation took place around a point at the condyle, while in the CCR group the point of rotation was anterior to the condyle. The long-term post-surgical change of the OP angle (op3-2) in the CCR group was significantly more than in the CT group. The long-term post-surgical change of the OP in the CR group, although rotated in an opposite direction was not significantly different to the CT group. All the patients in the study received pre- and post-operative orthodontic treatment and some of the long-term post-operative changes in the OP angle may be due to post-operative orthodontic "settling" of the occlusion. The post-operative change in the mandibular plane angle (mp3-2) of the CCR group differed significantly from the CT group. The long-term post-operative change of the MP angle took place in the same direction as the OP relapse and may also be partially due to final orthodontic leveling of the occlusal curves (opening the bite slightly) but may also be evidence of the muscular and skeletal adaptation to the new relationship between bone, muscles and teeth.

5.4 Post-surgical clinical outcomes

The main objective of rotating the MMC is to improve the aesthetic clinical outcomes. The post operative clinical evaluation consisted of the assessment of facial appearance and the occlusion. The above clinical assessment was correlated to skeletal stability at B point as well as the amount of OP rotation.

At the longest postoperative follow-up evaluation, the following data was obtained from the three groups:
CT group (table 14): 17 patients (77%) were judged to have excellent results, 3 (14%) satisfactory results, and 2 (9%) poor results.

Table 14. Conventional treatment group (22 patients).

	Excellent	Satisfactory	Poor
Overall	17 (77%)	3 (14)	2 (9%)
Stability at B-point	15	6	1
Occlusal plane rotation(degrees)	-0,31	-0,34	-0,33

CR group (table 15): 20 patients (80 %) had excellent results, 3 (12%) satisfactory results, while 2 patients (8%) had poor results.

Table 15. Clockwise rotation group (25 patients).

	Excellent	Satisfactory	Poor
Overall	20 (80%)	3 (12%)	2 (8%)
Stability at B- point	18	5	2
Occlusal plane rotation(degrees)	4,1	3,7	4,3

CCR group (table 16): 32 patients (73%) demonstrated excellent outcomes, 6 (14%) satisfactory results, and 3 (7%) poor outcomes.

Table 16. Counter-clockwise rotation group (41 patients).

	Excellent	Satisfactory	Poor
Overall	32 (79%)	6 (14%)	3 (7%)
Stability at B-point	29	7	5
Occlusal plane rotation (degrees)	-4,1	-5,2	-5,4

The clinical outcome was not significantly associated with either the stability at B point or the amount of OP rotation in the clockwise- or counter-clockwise group.

Table 17. The overall distribution of clinical outcomes

Outcome	Excellent	Satisfactory	Poor
Group			
CT	17(77%)	3(14%)	2(9%)
CR	20(80%)	3(12%)	2(8%)
CCR	32(79%)	6(14%)	3(7%)

The distribution with respect to overall clinical outcome did not differ significantly between the groups (P=1.00)

Table 18. The distribution in each group in relation to B point stability.

Outcome	Excellent	Satisfactory	Poor
Group			
CT	15	6	1
CR	18	5	2
CCR	29	7	5

The outcome distribution with respect to stability at B point did not differ significantly between groups (P=0.814).

As expected the difference in amount of rotation of the OP between the three groups was very significant (Tables 14, 15 & 16). There was however, no correlation in each group regarding the mean rotation and clinical outcome.

6 Discussion

Following conventional treatment planning for patients with dentofacial deformities the clinician may like to further improve the antero-posterior and vertical relationship between the maxilla, the lips and the chin. In these instances the possibility of altering the OP by rotating the MMC to meet specific aesthetic challenges should certainly be recognized at this stage of the treatment planning phase. It is important to note that utilizing the principle of rotating the MMC or altering the OP angle, is by no means an attempt to treat or correct an “abnormal” OP.

The analysis of dentofacial deformities and subsequent treatment has certainly become a science that has to be applied to achieve optimal functional, aesthetic and stable results for each specific case. The nuances of obtaining the best aesthetic changes however, still require a certain “artistic flair”. It is in instances where CT planning principles cannot yield satisfactory or optimal aesthetic results, that rotation of the MMC should be contemplated as an alternative treatment design.

6.1 Evaluation of the efficacy of the MMC triangle

From the geometry of the surgical design, simplified by the construction of a triangle incorporating ANS, PNS and Po as well as the added possibility to rotate the MMC in a clockwise or counter-clockwise direction the following can be concluded:

(1) The values of the measurements obtained from the study correlate favorably with data found in the literature (Savara & Sing 1968, McNamara JB & Breeden WL 1993) and can therefore, with good reason be accepted as representative of normal skeletal dimensions for the human face. Using the average values on a constructed triangle between ANS, PNS and Pog in the face and then rotating the triangle, the profound effect that a relatively small change in one area (the surgical site) will have on another area of the face is clearly demonstrated.

(2) The aesthetic result of correcting a Class III occlusion and concave facial profile by mandibular setback combined with maxillary advancement can be enhanced by CR of the MMC.

(3) Selecting a rotation point low on the anterior leg of the triangle and rotating the MMC clockwise will enhance maxillary advancement with consequent enhancement of the midface fullness.

(4) Selecting a rotation point high on the anterior leg of the triangle and rotating the MMC in a clockwise direction will enhance mandibular setback.

(5) CR of the MMC around a point posterior to ANS will result in downward repositioning of the anterior maxilla. In this instance the change in maxillary incisor/upper lip relationship and maxillary incisor angulation should be kept in mind.

(6) The aesthetic result of surgical correction of Class II cases with convex profiles can be enhanced by operating on both jaws and rotating the MMC in a counter-clockwise direction.

(7) By selecting a rotation point high on the anterior leg of the triangle and rotating the MMC in a counter-clockwise direction, the mandibular advancement will be enhanced.

(8) CCR of the MMC around a point at the PNS will not only enhance the mandibular advancement, but also increase the amount that the anterior maxilla will be superiorly repositioned. The maxillary incisor /upper lip relationship and maxillary incisor angulation should be carefully considered in this instance.

(9) The impact of this movement on the change in the angulation of the incisor teeth especially the maxillary incisors should be considered and when necessary compensated for by means of orthodontic treatment.

6.2 The development of a method for a cephalometric visual treatment objective

The possibility to develop a VTO enabling the clinician to test the treatment objectives and to predict hard and soft tissue results accurately is unique in the field of medicine. The knowledge gained over the last three decades regarding soft tissue change in relation to repositioning of the jaws simplified planning and made the prediction of the soft tissue outcome more reliable. The development of a VTO has become an invaluable and essential part of orthognathic treatment planning. New surgical designs demands modifications to the known principles of development of a VTO. New or alternative possibilities to refine and improves the aesthetic outcome utilizing the rotation of the MMC in orthognathic surgery confirms the cliché that surgical orthodontic correction of dentofacial deformities is both an “art and science”.

The proposed method of developing a VTO for rotation of the MMC can be added to the orthognathic surgeon’s armamentarium.

6.3 Post-operative skeletal stability

The post-operative stability of orthognathic surgical procedures has been the subject of numerous publications over many years. The stability of maxillary procedures, mandibular procedures as well as the stability following simultaneous repositioning of both jaws has been studied and it has become clear that stability following surgical repositioning of the jaws varies a great deal. It was found that factors such as the magnitude of surgical movement, the direction of movement, the type of fixation and surgical technique employed, plays an important role in post-operative stability (Epker & Schendel 1980, Van Sickels, Larsen & Thrash 1988).

In a landmark study reported by Proffit, Turvey & Phillips (1996) various surgical procedures were ranked according to post-operative stability. Of all the procedures or combinations of procedures they found that superior repositioning of the maxilla was the most stable, while maxillary expansion the least stable. Mandibular advancement combined with superior repositioning of the maxilla using rigid fixation was ranked about in the middle of the group of procedures studied with 90% of patients judged to have excellent clinical outcomes. These results compared well with other studies (Fossill, Turvey & Phillips 1992, Hennes, Wallen, Bloomquist & Crouch 1988, Satrom, Sinclair & Wolford 1991, Ayoub, Strirrups & Moos 1993). These authors also stated that stability is greatest when soft tissues are relaxed following surgery and least when they are stretched. It is therefore not surprising that the least stable mandibular procedure is when the mandible is advanced and the chin moved upwards. This mandibular movement usually occurs when open bites are closed with mandibular surgery (counter-clockwise rotation). It is felt that in these circumstances the pterygomandibular sling is stretched by a downward rotation of the gonial angles and that relapse occurs as a result of muscular forces. Stretching of the suprahyoid muscles may be an additional factor causing relapse following this mandibular movement. However, although suprahyoid myotomies have been successfully used in animal studies (Ellis & Carlson 1983), human studies have not supported these results (Wessberg, Schendel & Epker 1982)

Data from the abovementioned studies confirms that the post-operative stability following CR of the MMC should be greater than when the MMC is rotated in a counter-clockwise direction. The fact that CCR of the MMC is usually implemented to achieve greater advancement of the mandible would also suggest that this procedure is less stable.

Chemallo, Wolford and Buschang (1994), however, reported stable results following both clockwise and CCR of the MMC. They stipulate that this is made possible by proper pre-operative orthodontic treatment, surgical precision and the presence of healthy temporomandibular joints. Rosen (1993) reported similar results and made certain surgical recommendations to improve the stability.

Skeletal stability is greatest when soft tissues are relaxed following surgery and least when soft tissues are stretched. Superior repositioning of the maxilla relaxes the soft tissue and has proved to have good post-operative stability (Proffit, Phillips & Turvey 1987). Advancement of the mandible however stretches the soft tissues and has been shown not to be as stable as when the maxilla is moved upwards (Watzke et al 1990). Excellent stability however also requires neuromuscular adaptation which is effected by muscular length more than just muscular adaptation (Proffit, Turvey and Phillips 1996).

Conventional treatment group:
The surgical movements recorded in table 1 demonstrated that the CR of the MMC around the condyle results in a mean decrease of the OP angle by 0.32 degrees.
The patients in this group maintained a relatively stable result which compares favorably with other reports in the literature (Hennes et al 1988, Fossil et al. 1992, Proffit, Turvey & Phillips 1996).

Clockwise rotation group:
The rotational movement of the maxilla caused PNS to move upward (1.68mm) and the anterior maxilla to move downward (1.91mm) resulting in an increase in the OP angle of 4.89 degrees. This rotation allowed the mandibular incisors to advance while the chin rotated backwards reducing chin prominence and allowing B point to virtually maintain its position (anterior movement of 0.24mm). The long-term vertical post-operative change of B point and A point in this group took place in the opposite direction to the CT group and the change would appear to be significant. However the net relapses for both movements are comparable.

Counter-clockwise rotation group:
In this group the OP angle decreased by a mean of 4.97 degrees and the MP angle by 4.06 degrees illustrating the increased CCR obtained and in turn facilitating increased mandibular advancement. A significantly greater decreased OP angle compared to the CT group (OP=0.32 degrees and MP=1.63 degrees) was obtained by the rotation.
Although the amount of mandibular advancement in the CCR group was significantly more than in the CT group (CCR=10.81mm, CT=7.26mm) the amount of relapse between the groups did not differ significantly in the long-term follow-up after surgery (CCR=1.85mm, CT=0.99mm). The maxillary superior repositioning in the CCR group was also greater than in the CT group (CCR=3.84mm, CT=1.91mm) and also demonstrated insignificant relapse (CCR=0.66mm, CT=0.55mm).

Reports in the literature identify three factors that may influence the stability following orthognathic surgical procedures:

1. **Stretching of soft tissues:**
   In a study of factors contributing to relapse following mandibular advancement in fifty one patients Van Sickels, Larsen and Thrash (1988) found that in 37,9% of the patients the magnitude of advancement was the only predictable factor identified for relapse. In the CCR group studied the mandibular advancement was greater than the other two groups (CCR:10.81mm, CR group:-0.24mm and the CT group:7.26mm). One would therefore expect the CCR group to be less stable than the CT group.

2. **Neuromuscular adaptation:**
   The adaptation of the neuromusculature is fortunately good following most orthognathic procedures. The adaptation of the pterygomandibular sling following stretching was, however, found to be poor. Any orthognathic procedure lengthening the posterior mandibular height such as closing an open bite by means of a mandibular surgery would be expected to have poor stability. It was found that the downward rotation of the gonial angle as the chin rotates upward would stretch the soft tissue envelope and muscular forces would cause the skeletal relapse.

   This mechanism is most probably true in cases where the sagittal split osteotomy is performed through the lower border of the mandible and would involve the gonial angle. Splitting the mandible along the lower border and increasing the ramus height will also stretch the M.medial pterygoid and the stylomandibular ligament (Fig. 62).

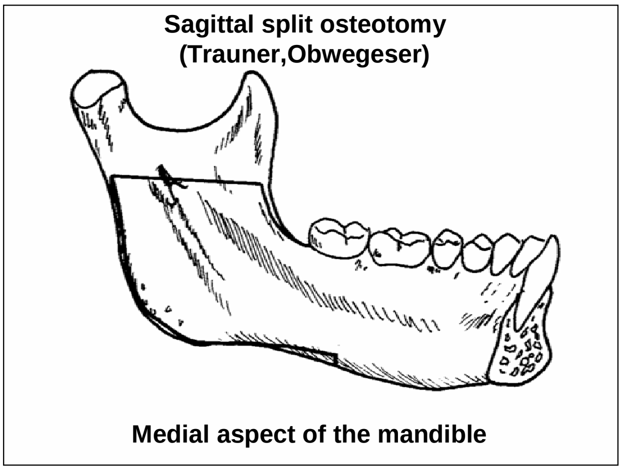


Figure 62a. The medial side of the mandible demonstrating the sagittal split osteotomy performed through the lower border of the corpus and posterior border of the ramus of the mandible.

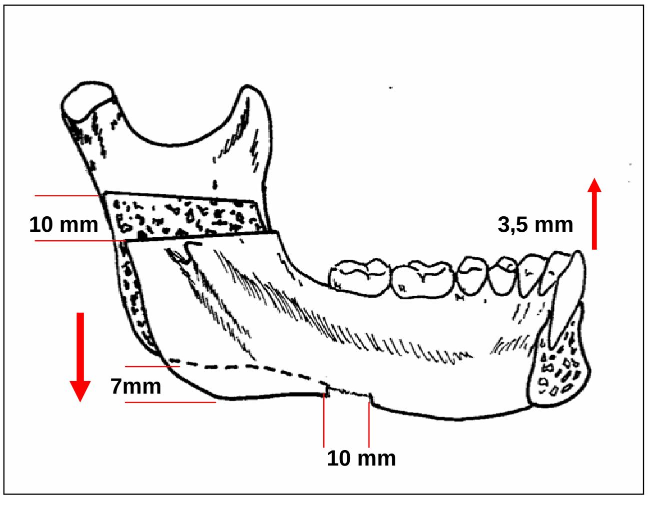


Figure 62b. The mandible is advanced (10mm) and rotated counter-clockwise (3,5mm at the incisor region), lengthening the ramus by 7 mm.

However, with the Epker modification (1977) of the sagittal split osteotomy the medial cortex of the mandible will split short, from just posterior to the lingula downwards and anteriorly to the lingual aspect of the vertical osteotomy through the buccal cortex (Fig. 63). The lower and posterior border of the mandibular angle is not involved in the split.

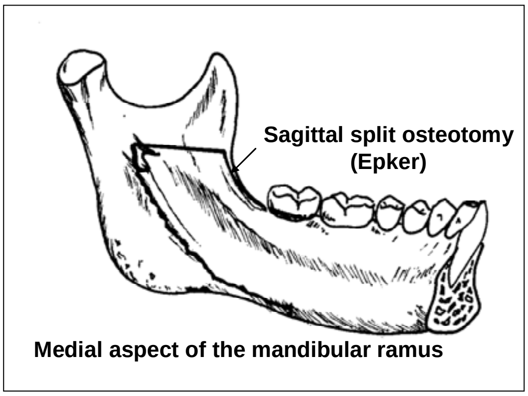


Figure 63a. The medial side of the mandible illustrating the Sagittal split osteotomy. The horizontal osteotomy is performed to just posterior to the lingula. The vertical osteotomy through the buccal cortex is extended through to the medial cortex on the inferior border. This design results in the medial osteotomy running from just posterior to the lingula downward to the lingual side of the vertical osteotomy.

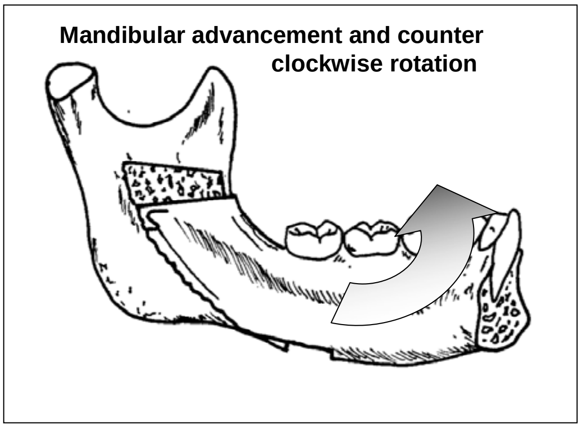


Figure 63b. The mandible is advanced and rotated counter-clockwise. Note that there is no increase in the posterior height.

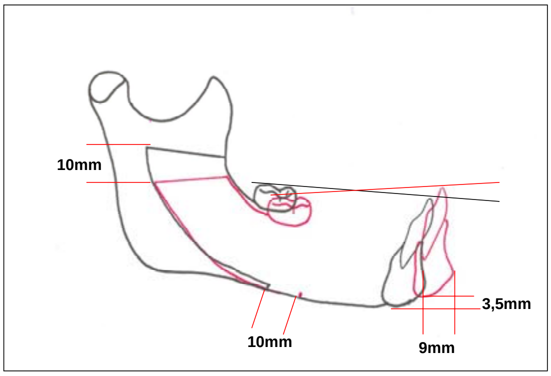


Figure 63c. A diagram illustrating the geography of surgical change following a counter-clockwise rotation of the mandible with 10mm advancement at the osteotomy site, 9mm advancement at Pog and 3,5mm upward rotation at the menton.

Downward rotation of the posterior edge of the distal segment as a result of counter-clockwise rotation would therefore not stretch the pterygomandibular sling. Advancement of the mandible will also advance the distal segment out of the sling as the M.Masseter attachment on the lateral side of the mandible seldom exceeds beyond the anti-gonial notch (Fig. 64). Stability is further enhanced by incising the pterygomandibular sling to reduce any possible muscle stretching and to also improve neuromuscular adaptation. The Masseter muscle has three layers: A superficial, middle and deep layer (Last, 1973).

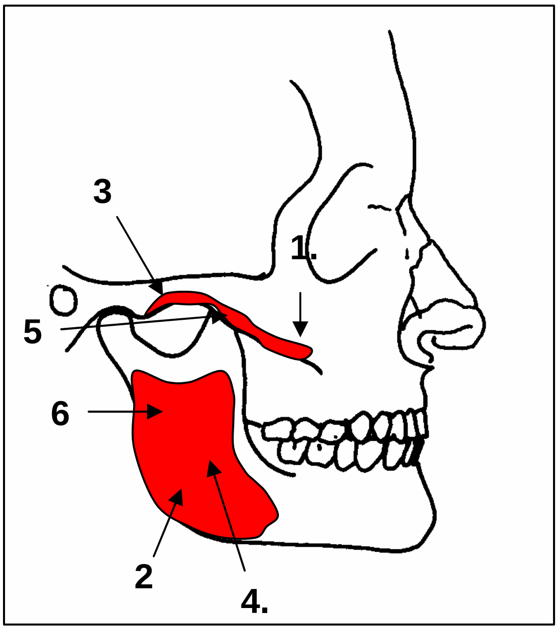


Figure 64a. Attachment of the M.masseter:

Superficial layer:	**Origin:**	**zygomatic process of the maxilla and from anterior two thirds of lower border of the zygomatic arch (1).**
	Insertion:	**angle and lower half of the lateral surface of the ramus of the mandible (2).**

Middle layer:	**Origin:**	**deep surface of the anterior two thirds of the zygomatic arch and from the lower posterior border of the posterior third (3).**
	Insertion:	**middle of the ramus of the mandible (4).**
Deep layer:	**Origin:**	**deep surface of the zygomatic arch (5).**
	Insertion:	**upper part of the ramus and the coronoid process (6).**

Middle and deep layers form the deep part of the M.Masseter.

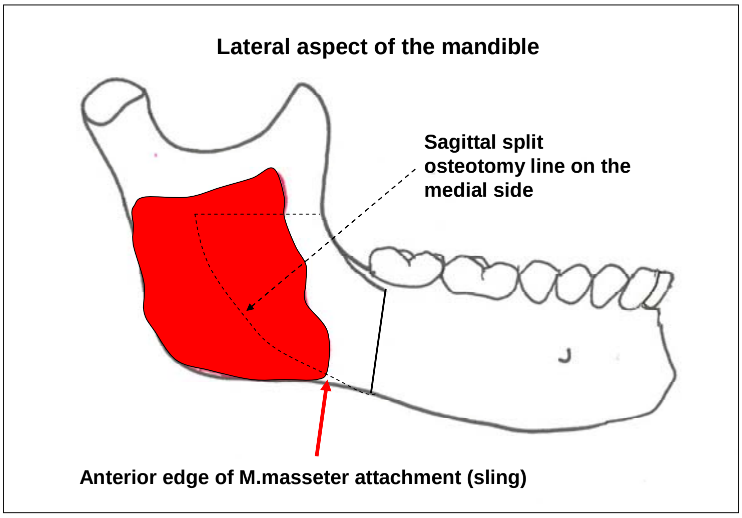


Figure 64b. An illustration of the relationship of the M. masseter attachment on the lateral surface of the mandibular ramus and the Sagittal split osteotomy on the medial side of the ramus. The arrow indicates the anterior border of the pterygomandibular sling.

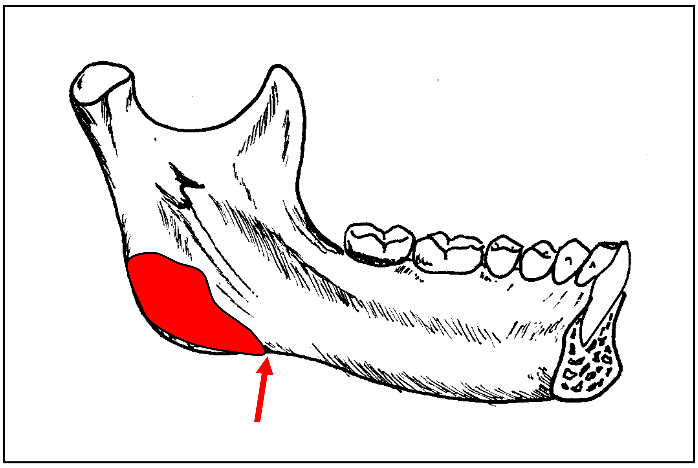
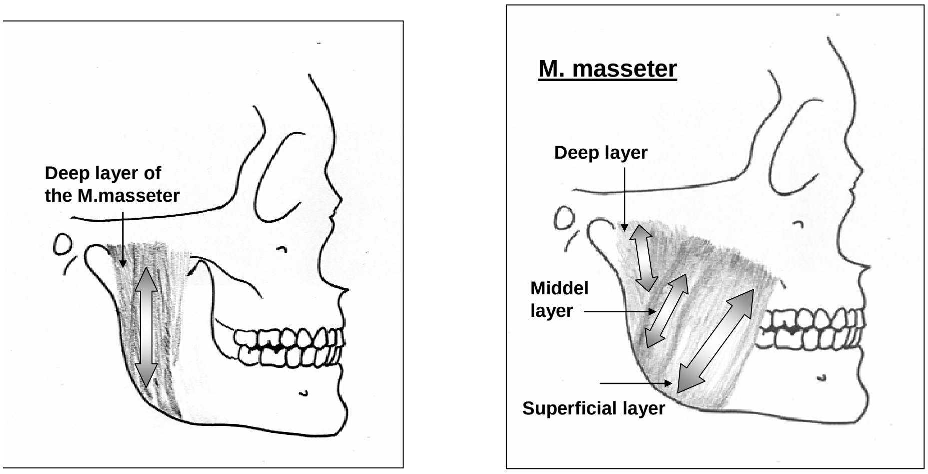


Figure 64c. The area of attachment of the medial pterygoid muscle and stylomandibular ligament on the medial surface of the mandibular angle. The arrow indicates the anterior border of the pterygomandibular sling.

3. **Muscle orientation:**

Muscular adaptation is least possible when muscle orientation is changed. The changes in the inclination of the mandibular ramus will alter the orientation of the mandibular elevators (M.masseter and M.temporalis). The M.masseter bundle groups and their orientation are illustrated in figure 65a and b, while the attachment and orientation of the M.temporalis is illustrated in figure 65c.



a

b

Figure 65a, The deep muscle group of the masseter muscle tends to have a vertical orientation while b, the superficial masseter muscle groups have a more oblique orientation.

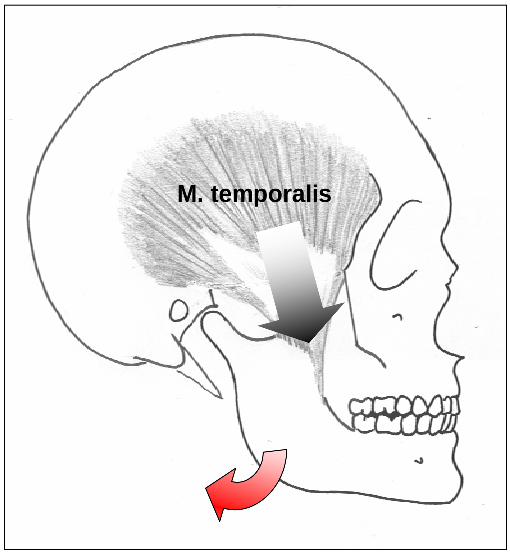


Figure 65c. The M temporalis muscle attachments and muscle bundle orientation.

Downward and backward rotation of the distal segment may cause the posterior part to encroach on the attachment of the M.medial pterygoid and stylomandibular ligament on the medial side of the mandibular angle (Fig. 64c). Failure to strip this muscle and ligament attachment from the angle will limit downward rotational or setback procedures and will tend to rotate the ramus posteriorly altering the orientation as well as stretch the elevator muscles (Fig. 66).

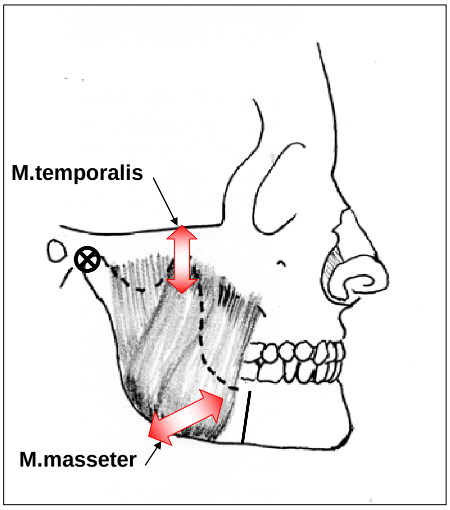


Figure 66. Downward and backward rotation of the mandibular ramus will tend to stretch the M. temporalis and M. masseter muscles leading to an unstable result.

6.4 Clinical outcomes

Excellent post operative skeletal stability is not always accompanied by excellent aesthetic outcomes. Excellent aesthetic outcomes are dependant on meticulous treatment planning and accurate execution of the orthodontic treatment and surgical procedure. It is however interesting that; excellent clinical results can be obtained even in the presence of postoperative skeletal and dental change. Post operative orthodontic treatment can often compensate for small skeletal changes however the compensation is limited by orthodontic parameters for dental stability.

The clinical outcomes of both the CR and the CCR groups rendered satisfactory or better clinical outcomes, 92% and 93% respectively which compares well with the CT group (91%).

It is however important to keep in mind that the main aim of utilizing the concept of rotation of the MMC is to achieve a better aesthetic result than what would have been possible by utilizing CT treatment planning concepts. Before definitive surgical treatment plans were decided on for all the patients in this study, a treatment planned according to conventional treatment concepts was fist developed for each patient. The decision to utilize an alternative treatment design was only made once it was found that CT methods could not achieve ideal aesthetic results. This selection may be the reason why the clinical aesthetic outcomes are relatively high.

7 Summary and conclusion

An alternative orthognathic treatment design facilitating surgical jaw movements which enables the surgeon to achieve certain aesthetic results that cannot be obtained by means of conventional orthognathic treatment planning is described. The surgical design is described in detail and the concept formalized by achieving the goals of the study:

1. The geography of the design is simplified by the construction of a triangle representing the MMC. The triangle includes the ANS, PNS and Pog and by rotating the triangle clockwise or counter-clockwise various aesthetic results can be achieved is demonstrated. It is shown that by varying the point around which the MMC is rotated further improvements of facial change can be achieved. By developing an understanding of all the treatment possibilities, the surgeon will certainly increase the treatment options that he or she may offer patients.

2. The surgical VTO using rotation of the MMC as treatment design differs from the development of a VTO for conventional treatment planning. A method of developing a surgical VTO as well as indications for specific aesthetic requirements are described and illustrated by application of the design. The advantages of the design are illustrated by comparing the VTO of CT planning cases and the VTO's utilizing the concept of rotation of the MMC for the same patients.

3. By comparing the post-operative skeletal stability in three groups of patients following either CT (22), or CR (26), or CCR (41) it is shown that the post-operative skeletal stability of the CR and CCR groups of patients compared favorably with the group of patients treated by CT treatment planning. The long-term post-operative stability of all three groups also compared well with skeletal stability reported in the literature following double jaw surgery.

4. All three groups compared well regarding clinical outcomes as well as skeletal stability at B point. The percentage of excellent clinical results was relatively high in all three groups of patients (CT, CR and CCR). These generally excellent outcomes can be ascribed to the fact that all the patients in the study had the benefit of pre-surgical consideration of utilizing the alternative surgical design (rotation of the MMC). There were therefore no limitations placed on the aesthetic objectives which may sometimes be the case with CT designs.

The concept of surgical rotation of the MMC independent of the mandibular OP (rotation around a point at the mandibular condyle) is formalized and the surgical design has been given a scientific basis.

Although it seems as if most of the basic scientific parameters of orthognathic surgery have been established, new innovations, exciting developments in technology and a better understanding of bone and soft tissue biology are constantly improving the treatment we offer our patients. The development of an artistic flair, an imagination and the ability to think originally and creatively are, however, unbounded and the lack there of can sometimes be the only limiting factor to optimal treatment planning. “Creativity can solve almost any problem. The creative act, the defeat of habit by originality, overcomes everything” (Lois 1977). I am convinced that the treatment design described in this thesis will expand the vision of many orthognathic surgeons and enhance their imagination in the treatment planning for patients with dentofacial deformities. The surgeon can apply this treatment design and perform orthognathic surgery with confidence and so achieve even better treatment outcomes for patients with dentofacial deformities!

It can be concluded that the rotation of the MMC is a valuable alternative orthognathic surgical design in selected cases when satisfactory aesthetic results can not be obtained by CT planning methods.

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Role in publications

List of papers:

1. McCollum AG, Reyneke JP & Wolford LM (1989). An alternative for the correction of the Class II low mandibular plane angle. Oral Surg Oral Med Oral Pathol 67(3): 231-241.
   Role: wrote paper, designed surgical technique, drew illustrations, performed surgery on the cases presented.

2. Reyneke JP (1990). Surgical manipulation of the occlusal plane. Int J Adult Orthod Orthognathic Surg 5(2): 99-110.
   Role: Only author.

3. Reyneke JP (1998). Surgical manipulation of the occlusal plane: new concepts in geometry. Int J Adult Orthod Orthognathic Surg 13(4): 307-316.
   Role: Only author.

4. Reyneke JP (1999). Surgical cephalometric prediction tracing for the alteration of the occlusal plane by means of rotation of the maxillomandibular complex. Int J Adult Orthod Orthognath Surg 14: 55-64.
   Role: Only author.

5. Reyneke JP, Bryant RS, Suuronen R, Becker PJ (2006). Post-operative skeletal stability following clockwise and counter-clockwise rotation of the maxillomandibular complex compared to conventional orthognathic treatment (accepted for publication).
   Role: wrote the paper, drew illustrations, tabled results, interpreted results and did statistical analysis of the results with the help of Dr P Becker, Medical Research Council of South Africa.

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An alternative for the correction of the Class II low mandibular plane angle

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The traditional orthodontic and/or orthognathic surgical management of the Class II deep-bite case with a low mandibular plane angle has often been difficult; optimal esthetic results have not always been achieved, and long-term stability was often unpredictable. Many of these patients may benefit functionally and esthetically from appropriate orthodontic treatment and double-jaw surgical intervention to reorient the occlusal plane toward normal (8 degrees ± 5 degrees to Frankfort horizontal) by moving the posterior maxilla and mandible superiorly and correcting into a Class I skeletal and occlusal relationship. As the occlusal plane angulation is increased, the upper incisor angulation decreases, the lower incisor angulation increases, the chin rotates down and backward relative to the lower incisor occlusal plane tips, and the mandibular plane angle increases. The principle of changing the occlusal plane has provided a means to improve the functional and esthetic results for the correction of this type of facial deformity, as well as many others.
(ORAL SURG ORAL MED ORAL PATHOL 1989;67:231-41.)

Orthodontic correction of a deep overbite and a large overjet is hampered in patients who have low mandibular plane angles and heavy muscles of mastication. Characteristically, these persons have broad faces, short lower anterior facial heights, and Class II, Division 1 or Division 2 malocclusion. The clinical management of these patients can challenge the skills of both the orthodontist and the oral and maxillofacial surgeon. In the past, the achievement of an acceptable functional and esthetic result has been extremely difficult and posttreatment stability has been unpredictable.

In the orthodontic literature, many terms have been used to describe a face with decreased lower-third anterior height. Several hint at a suspected underlying cause. Schudy,[1] for example, described the "low angle type," which correlates decreased lower-third anterior facial height with a low angle

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between the mandibular plane and sella-nasion. In describing "skeletal deep-bite," Sassouni[2] identified a parallelism between mandibular, occlusal, and palatal planes and the anterior cranial base in subjects with decreased lower-third anterior facial heights and deep overbites. Wilmar[3] used the term *idiopathic short face* and suggested that the etiology lies in reduced maxillary dentoalveolar height, thereby allowing the mandible to rotate in a closing direction. Wolford et al.[4] described mandibular deficiencies as a syndrome with three basic classifications: type I (low mandibular plane angle), type II (median mandibular plane angle), and type III (high mandibular plane angle). The classic esthetic cephalometric and occlusal features of the three types were presented. For mandibular deficiency syndrome type I, a brief discussion of double-jaw surgery was given. There was documentation of a decrease in anterior facial height and an increased posterior facial height in the type I morphology as compared to the median group. Opdebeeck and Bell[5] studied 120 untreated white persons with decreased lower-third anterior facial heights and identified two groups. Short-face syndrome I (SFS I) is characterized by long vertical rami, a reduction in the angle between the anterior cranial base and the mandibular plane, a facial proportion index close to 10[6], and slightly decreased posterior maxillary height. In contrast, short face syndrome II (SFS II) exhibits short vertical rami, a slightly reduced mandibular plane angle relative to the anterior cranial base, a facial proportion index of around zero, and significantly decreased vertical maxillary height.

In anthropology, facial types have been assessed from the frontal view. Kollman,[7] in 1882, related facial widths to facial heights and used the term *euryprosopia* (*eury* = broad, *prosopia* = face) to describe a person with a broad face. He described faces of medium proportion as *mesoprosopic* and long faces as *leptoprosopic.*

No similar classification existed for the lateral view until Bimler,[8] in 1957, introduced his "suborbital facial index," which relates suborbital facial height to facial depth. Bimler retained the terms *mesoprosopic* and *leptoprosopic* to also identify medium and long faces as seen in the lateral view. He described persons whose faces were deep in the anteroposterior dimension and short in the vertical dimension as *dolichoprosopic.*

Sheldon[9] related facial types to body type. An endomorphic body has an abundance of fat, and the face is well rounded, while an ectomorphic body has a thin, tall figure surmounted by a long, thin face.[9] The mesomorphic person has a heavy, well-muscled, thick-set body and a square face with prominent facial muscles and bones.

The combination of dolichoprosopia, euryprosopia, and Class II, Division 1 or Division 2 malocclusion with deep bite may be treated in the growing person by means of an orthodontic approach (for example, functional appliances followed by fixed appliance therapy). However, stability and esthetics may be compromised. A combination of orthodontics and various surgical techniques has been used with great success in the treatment of this type of deformity. McIntosh[10] first described simultaneous sagittal ramus and total subapical body osteotomies to allow the surgical advancement of the dentoalveolar process of the mandible. Epker and Fish[11] demonstrated surgical orthodontic treatment of these cases, their method entailed an advancement of the mandible together with a reduction genioplasty, performed after preliminary orthodontic treatment.

Despite the considerable interest shown in the diagnosis and treatment of the functional and esthetic problems associated with this type of facial deformity, optimal resolution of the skeletal and dental malrelationship is not routinely achieved.

This article describes the clinical and cephalometric diagnosis of persons with euryprosopic and dolichoprosopic facial patterns who also have Class II, Division 1 malocclusions. An alternative surgical-orthodontic approach to the treatment of these persons as developed by Wolford will be presented. Two cases treated in this manner are demonstrated.

CLINICAL FEATURES

Frontal view

In the euryprosopic facial type, the most notable feature is the square appearance of the face, due more to excessive bigonial width than to shortness in the anterior facial height (soft tissue nasion-menton), as seen in Fig. 1, *A*. The masseter muscles are strongly developed, and hence the sides of the face tend to be vertically parallel. There may be increased intercanthal and interpupillary distances, a broad nasal dorsum, a wide mouth, and wide alar bases. The labiomental sulcus is sharply defined.

Profile view

The dolichoprosopic face demonstrates the proportionately reduced anterior facial height compared to facial depth (Fig. 1, *B*). The chin is prominent and excessively defined, and this lends a straight or even slightly concave appearance to the face, and the chin length from the throat may be greater than normal. The retropositioned lower lip is curled and everted

Fig. 1. Case 1. **A,** Typical euryprosopic facial pattern. **B** Lateral view demonstrates the dolichoprosopic facial form. **C,** Posttreatment frontal view. **D,** Posttreatment profile view.

because of interferences of the maxillary incisors; this greatly increases the depth of the labiomental sulcus. The mandibular plane is flat, the inferior border of the mandible may be convex, and the gonial angle is decreased. The upper incisor teeth may be exposed below or in some cases above the upper lip, and the nasolabial angle may be normal or acute, depending on the degree of proclination of the upper incisors.

Intraoral

An Angle Class II, Division 1 or Division 2 relationship is the characteristic malocclusion (Fig. 2, *A* and *B*). The upper incisors may be markedly flared with excessive spacing. The lower incisors are usually overerupted, exaggerating the curve of Spee. They often occlude heavily on the amelocemental junction of the upper incisor teeth or palatal gingiva and may cause attrition and recession of the palatal mucosa. According to Sassouni,[2] the teeth are frequently small and malshaped.

Cephalometric and anatomic features

The mandibular, occlusal, palatal, and sella nasion planes exhibit a parallelism (Fig. 3, *A*). The Frankfort horizontal and palatal planes are also nearly parallel, but the palatal plane may tip up anteriorly so that the two planes tend to converge. The normal angulation between these planes is +6 to +7 degrees.[12] In these cases it may vary from +1 to −5 degrees. Likewise, the normal occlusal plane angulation to Frankfort horizontal is 8 degrees ± 5 degrees,[12] but in this facial type a negative inclination is common. In the sagittal plane, the upper and lower jaws relate fairly well to each other. The upper facial height (nasion to ANS) and the lower facial height (ANS to menton) are nearly equal, indicative of a decrease in the lower-third facial height. The

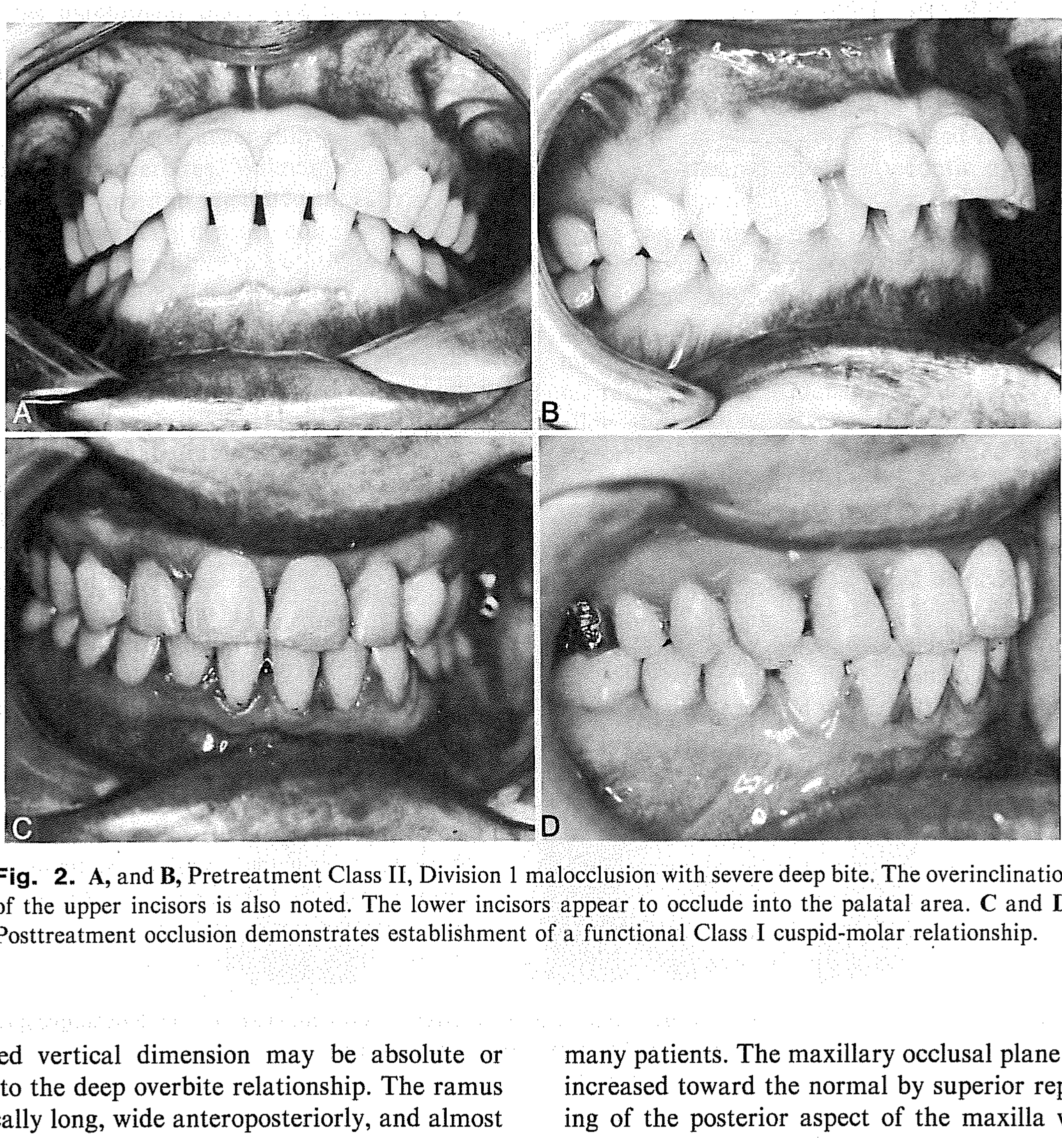

Fig. 2. **A,** and **B,** Pretreatment Class II, Division 1 malocclusion with severe deep bite. The overinclination of the upper incisors is also noted. The lower incisors appear to occlude into the palatal area. **C** and **D,** Posttreatment occlusion demonstrates establishment of a functional Class I cuspid-molar relationship.

decreased vertical dimension may be absolute or related to the deep overbite relationship. The ramus is vertically long, wide anteroposteriorly, and almost at right angles to the corpus. Antegonial notching is sometimes absent, and the lower border of the mandible may be markedly convex. The symphysis is large and bulbous and is oriented forward and sometimes upward. A posteroanterior facial radiograph demonstrates the wide bigonial dimension.

OBJECTIVES

The principal objectives in treating these cases are to (1) correct the malocclusion, (2) increase the lower-third facial height, (3) eliminate the acute labiomental fold, (4) establish a balanced lower lip position with the upper lip, and (5) establish a balanced anteroposterior chin position.

GEOMETRY OF THE CHANGE

Increasing the occlusal plane angulation in relation to the Frankfort horizontal in the correction of this type of facial deformity offers a solution for many patients. The maxillary occlusal plane angle is increased toward the normal by superior repositioning of the posterior aspect of the maxilla with the anterior maxilla as a fulcrum. The posterior body of the mandible is raised by means of bilateral mandibular ramus sagittal osteotomies, allowing the lower incisor teeth to move downward and forward into a Class I occlusal relationship. The chin rotates downward and backward relative to the lower incisors. Diagrams *A* and *B* in Fig. 4 illustrate the geometric change. When the maxilla is repositioned in one piece, the selected vertical and anteroposterior position of the upper incisor dictates the point of rotation of the maxilla. For maximum retraction of the upper incisor tip, the point of rotation is in the region of the anterior nasal spine (Fig. 5, *A*). If greater retraction is desired, the entire maxilla can be moved posteriorly. If the point of rotation is at the tip of the central incisors (Fig. 5, *B*), the anterior nasal spine area will rotate forward. If further support to the upper lip and nose is desired, the maxilla can be advanced farther forward.

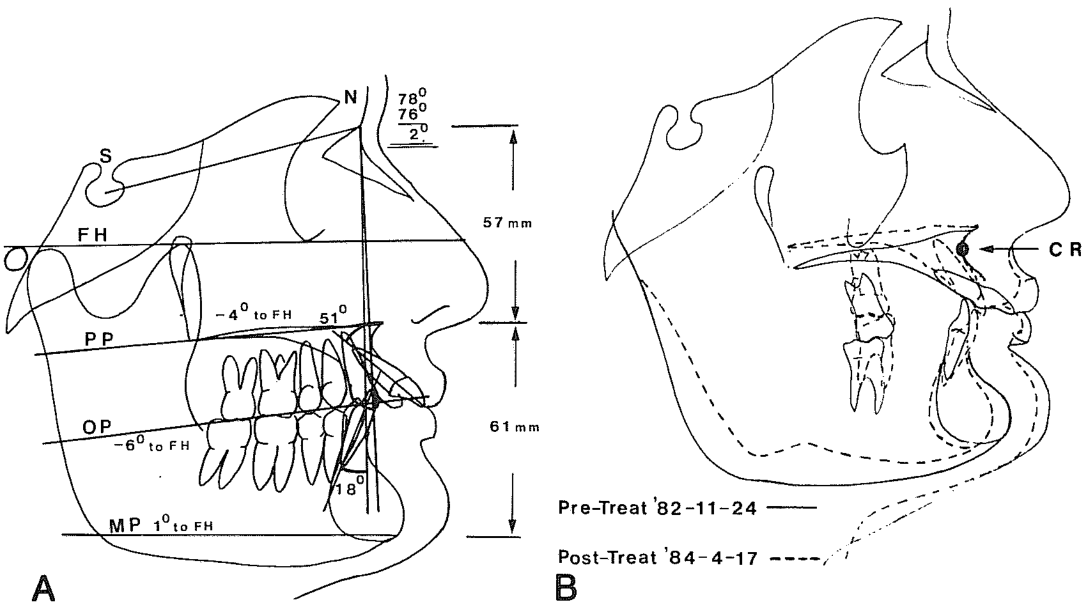

Fig. 3. **A**, Cephalometric analysis demonstrates characteristic cephalometric parameters of this facial type. **B**, Superimposition of the pretreatment and posttreatment cephalometric tracings illustrates changes accomplished with surgical and orthodontic procedures. Note the center of rotation of the maxillomandibular complex at point "A" in this patient.

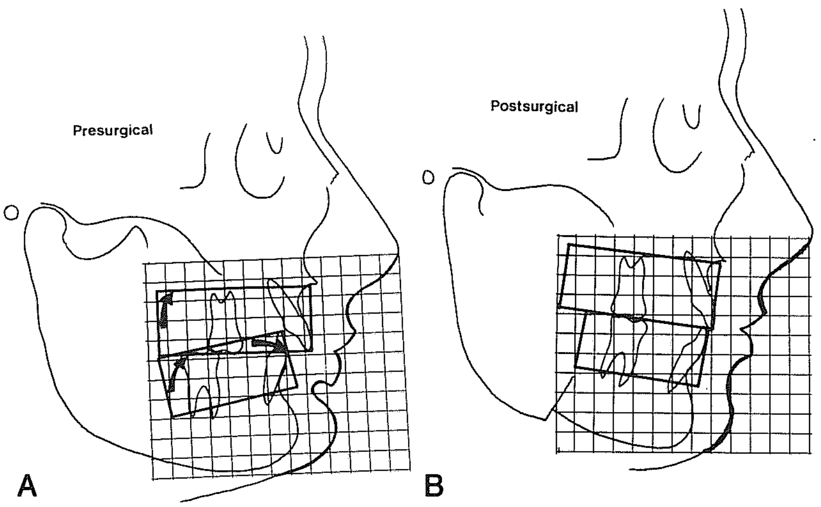

Fig. 4. **A**, Proposed geometry of skeletal and soft tissue changes. Note the clockwise rotation of the maxillomandibular complex. **B**, Changes in position of facial structures with establishment of Class I skeletal and occlusal relationship as well as normalization of occlusal plane angle are noted. Also, observe the decreased inclination of the maxillary incisors and the increased inclination of the lower incisors.

If the maxilla is segmentalized into three pieces, cut between the lateral incisors and cuspids, the angulation of the incisors can be selected independently of the change in the occlusal plane. This approach may simplify orthodontic treatment in the upper arch and improve the postsurgical stability by eliminating the necessity for presurgical orthodontic overangulation of the maxillary incisors. The amount of change in the occlusal plane angulation can be selected but is somewhat dependent on the desired angular improvement of the upper incisors and approximation of the occlusal plane toward normal. As the occlusal plane angulation is increased, the mandible undergoes a clockwise rotation. The inci-

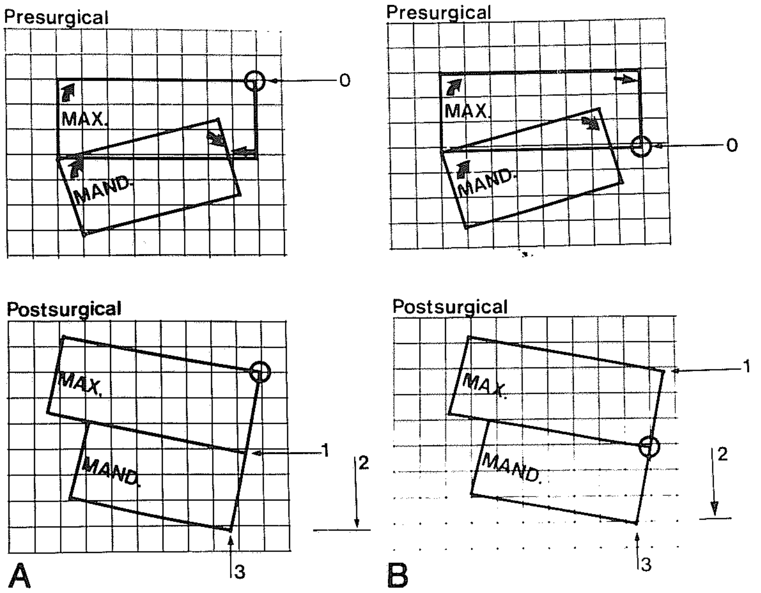

Fig. 5. A, Rotation point of maxilla at anterior nasal spine creates posterior rotation of upper incisor tip *(1)*, increase in vertical facial dimension *(2)*, with chin point position slightly posterior to its original spatial relationship *(3)*. **B,** Rotation point of maxilla at incisor tip causes anterior movement of anterior nasal spine area *(1)* and increase in vertical facial dimension *(2)*, Anteroposterior position of the chin may not change significantly anteroposteriorly, even though the Class II occlusal relationship is being corrected *(3)*.

sors will move farther forward relative to the chin. Also, the mandibular incisor angulation will increase. When the rotation point of the maxilla is at ANS, the chin moves forward less than when the rotation point is positioned at the incisal tip (Fig. 5, *A* and *B*).

TREATMENT TECHNIQUE

Careful planning of the preoperative orthodontic treatment is vital to place the teeth in axial positions that will allow the best possible changes after surgery. A pretreatment surgical treatment objective (STO)[13] will help define the presurgical orthodontic goals. Usually, the upper incisors are overangulated (unless a three-piece maxillary osteotomy is performed) and the lower incisor angulation is decreased relative to the norm. The surgical procedures will decrease the inclination of the upper incisors and increase the inclination of the lower incisors as the occlusal plane angulation is increased.

To achieve the desired rotation of both maxilla and mandible, double-jaw surgery is required. The posterior vertical height of the maxilla is reduced through a Le Fort I ostectomy (Fig. 6, *A*); this tips the maxillary occlusal plane up posteriorly. A bilateral sagittal split osteotomy allows the mandible to follow the rotation of the maxilla. The posterior aspect of the distal segment is elevated in an upward and forward direction into a Class I relationship with the maxillary dentition (Fig. 6, *B*). The lower incisor teeth are advanced and rotated down and forward to establish a normal interincisal and cuspid relationship. Thus, the deep overbite and the large overjet are corrected simultaneously. The symphysis is rotated inferiorly and posteriorly in relation to the mandibular incisor tips. In cases of a very prominent chin button, an anteroposterior reduction genioplasty may be indicated. To accommodate the upward movement of the posterior aspect of the distal segment of the mandible, the lingual cortical bone on the proximal segment above the medial horizontal osteotomy should be trimmed (Fig. 7). If the proximal segment is maintained in its original spatial position, a step is created at the lower border of the mandible where the distal segment is elevated. This improves the severe line of convexity on the inferior border of the mandible but maintains the square-jaw appearance. The proximal segments can be rotated upward and forward, decreasing the prominence of the gonial angles and eliminating some of the squareness of the face. Also, the lateral gonial angle can be trimmed if necessary to reduce the bigonial width.

The muscles of mastication are not adversely affected by the procedure and remain attached to the proximal segment of the mandible unless the gonial angles are trimmed, (The masseter muscle will be

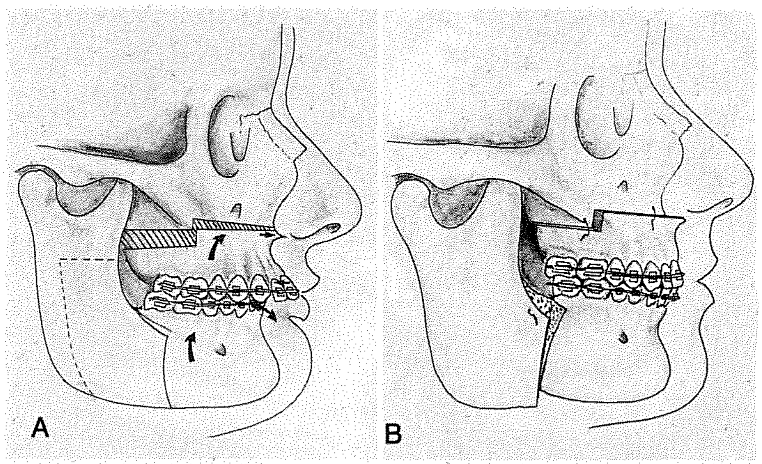

Fig. 6. A, Proposed osteotomy cuts and directions of movement that are relatively typical for correction of this facial type. **B,** Postoperative bony, dental, and soft tissue changes that can be anticipated.

detached.) Stabilization of the maxilla can be provided by an occlusal splint, transosseous wiring, suspension wires, or (preferably) bone plates. Stabilization of the mandible can be achieved with interosseous wiring and 6 to 8 weeks of intermaxillary fixation or with the use of bone screws, which permits release of intermaxillary fixation at the completion of surgery.

Postoperative orthodontic treatment is necessary for the achievement of optimal occlusion. Vertical, Class II, and/or Class III elastics with small horizontal components of force may be helpful in seating the occlusion. Particular attention is paid to the interincisal relationship. This is finished at a little less than normal—at approximately 125 degrees with an overbite of 1 mm, if possible—to allow for physiologic settling.

After the appliances have been removed, a removable retention appliance is fitted to the upper teeth and a lower lingual intercanine retainer is bonded. The upper removable retainer is worn full-time for 3 months and thereafter at night for an additional 3 months or longer as required. The lower lingual retainer remains in place for at least 12 months after debanding. Consideration could be given to the use of a positioner where indicated.

SOFT TISSUE CHANGES

When the rotation point of the maxillomandibular complex is at the anterior nasal spine, the upper incisor tips rotate posteriorly, causing the upper lip to retract and the nasolabial angle to increase. When the rotation point is near the incisor tip, the movement of ANS causes soft tissue subnasale to move forward. This can be advantageous in those persons who have flattened paranasal regions. The tip of the nose may elevate with slight widening of the alar base. The width of the alar bases can be controlled with an alar base cinch suture. Careful planning is mandatory if the most favorable balance between upper lip and nose is to be obtained.

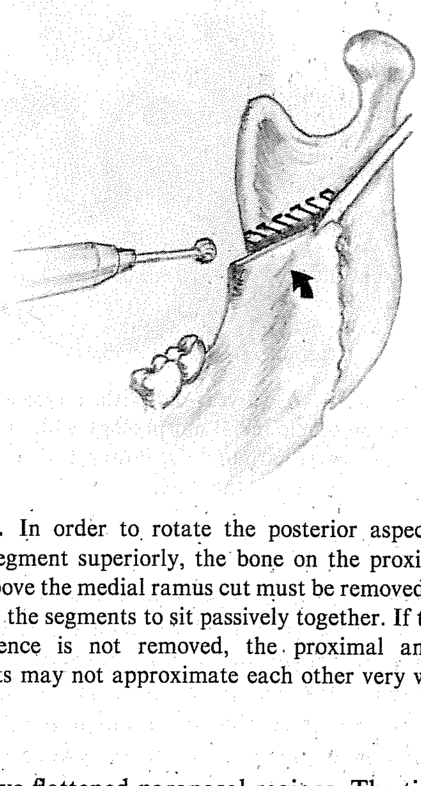

Fig. 7. In order to rotate the posterior aspect of the distal segment superiorly, the bone on the proximal segment above the medial ramus cut must be removed in order to allow the segments to sit passively together. If this bony interference is not removed, the proximal and distal segments may not approximate each other very well.

In most cases, the center of rotation is positioned between ANS and the incisor tip so that extreme movement at the incisor tip and ANS does not usually occur unless an anteroposterior maxillary excess or deficiency exists. In the mandible, the lower

Fig. 8. A, A 15-year-old with a typical euryprosopic facial pattern. **B,** Profile view shows a typical dolichoprosopic facial morphology with an extremely prominent chin, **C,** Posttreatment results show good frontal facial harmony. **D,** Postoperative profile view shows establishment of good harmony between the chin, lips, cheeks, and nose.

incisor teeth are moved in a downward and forward direction, thus supporting the recessive and everted lower lip, which moves into a more normal, harmonious position with the upper lip. This considerably reduces the excessively deep labiomental fold. The chin point moves downward and backward in relation to the lower incisor tips.

A mild depression is created in the antegonial region of the mandible by elevation of the distal segment of the mandible, and this deemphasizes the convex lower border.

Despite trimming of the gonial regions, bigonial width may still look excessive. The gonial width can be further reduced by the additional performance of a vertical symphysis or bilateral anterior mandibular body osteotomies to narrow the mandible in conjunction with maxillary osteotomies to decrease the transverse width of the maxilla.

CASE REPORTS

CASE 1

A 35-year-old woman complained of "pressure sensitivity and loosening of the upper incisor teeth." She was well aware of her protrusive upper incisors. Extraoral examination showed a protrusive upper lip, a curled and everted lower lip, an exaggerated labiomental fold, and a prominent chin. The upper incisor-to-lip relationship was 1 mm (Fig. 1, *A* and *B*).

The patient had a Class II, Division 1 malocclusion with a large overjet (11 mm), markedly proclined upper incisors, and an excessive incisor overbite (6 mm) (Fig. 2, *A* and *B*). The overerupted lower incisors had created an extremely accentuated curve of Spee and had caused severe attrition to the palatal aspect of the amelocemental junction of upper incisors, with marked recession of the palatal mucosa. These teeth were moderately mobile, and periapical and occlusal radiographs revealed significant alveolar bone loss.

Cephalometric analysis showed the characteristic paral-

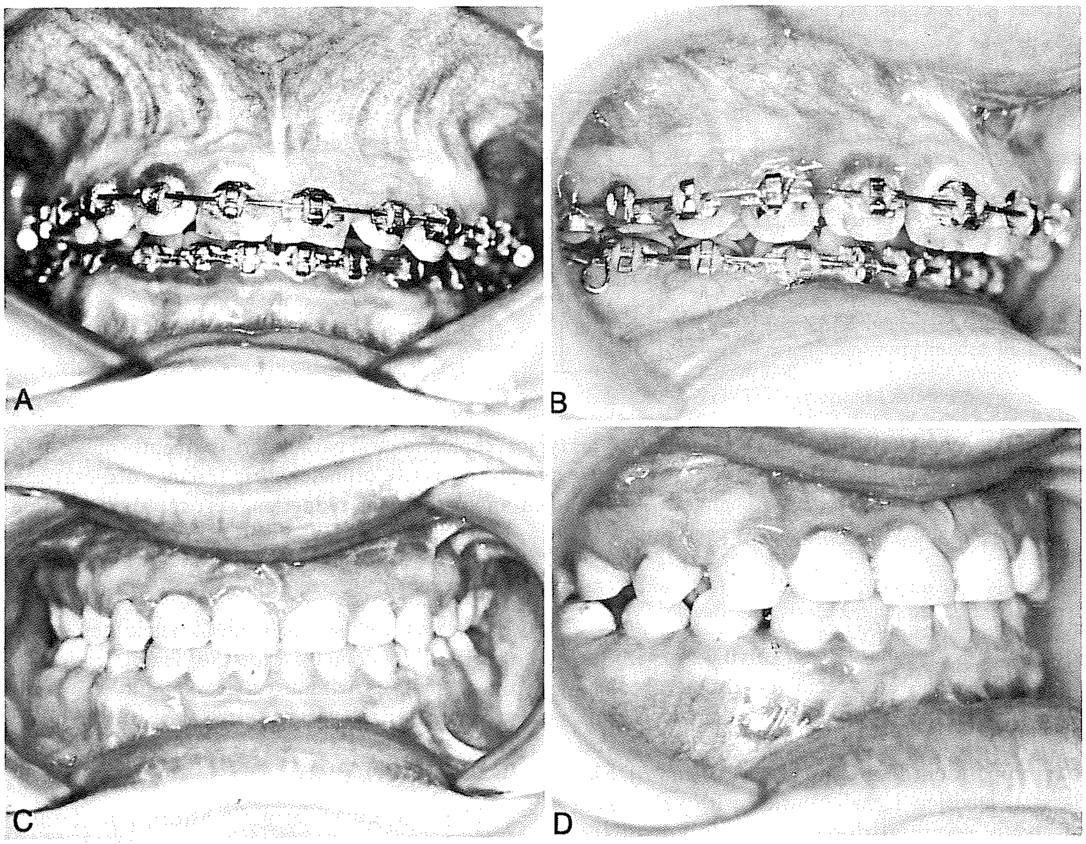

Fig. 9. A and **B,** A Class II cuspid-molar relationship is present. **C** and **D,** Posttreatment occlusal results show the establishment of a stable Class I cuspid-molar relationship.

lel mandibular, occlusal, palatal, and anterior cranial base planes. The reduced lower anterior facial height was combined with an increase in facial depth (Fig. 3, *A*). The bigonial width on the posteroanterior cephalogram (not shown) exceeded lower facial height.

In the preoperative orthodontic phase of treatment, the teeth in the lower arch were leveled with the aid of Class III mechanics. With the depression of the lower incisors and opening of the bite, discomfort in the upper incisor teeth was relieved. The upper incisors were retracted from 51 degrees to NA to 37 degrees, a distance of 4 mm at the incisal tips. The upper canine and lateral incisor roots were diverged, and a small space was left for an interdental osteotomy to further improve the upper incisor angulation if necessary. After the presurgical orthodontic treatment was completed, the dental models showed that it would not be necessary to segmentalize the maxilla. The lower dentition was stabilized with a 0.018 × 0.025 inch continuous arch and the upper arch, in segments, with wire of the same dimensions. The center of rotation of the maxilla for optimal results was in the vicinity of point A (Fig. 3, *B*).

A Le Fort I maxillary ostectomy was performed, and the posterior maxilla was superiorly repositioned by 8 mm. A horseshoe-shaped palatal osteotomy was necessary to allow full elevation of the dentoalveolus without altering the vertical position of the palate so that the functional nasal airway dimension would not be altered.[14] The anterior nasal spine was trimmed and the piriform fossa deepened to accommodate the soft tissues of the nasal and paranasal areas for the mild forward tipping of this region. An alar base cinch suture was employed to control the width of the nose.

A bilateral sagittal split osteotomy of the mandible allowed the molar region of the distal fragment to be rotated up and forward into a Class I relationship with the maxillary molars. The lower incisors rotated downward and forward into a normal relationship with the upper incisors. The gonial region was trimmed laterally to reduce the bigonial width and further decrease the square appearance of the mandible. The bilateral step created on the inferior margin on the mandible was contoured. The surgical procedures were stabilized with interosseous wires, zygomatic buttress suspension wires, and 6 weeks of intermaxillary fixation. Postsurgical orthodontic therapy followed the 6-week fixation period in order to finish the occlusion. Today, rigid skeletal stabilization would be used with bone plates for the maxilla and bone screws for the mandible, with no intermaxillary fixation necessary after surgery.

The soft tissue, dental, and skeletal objectives have been satisfactorily achieved by this method of treatment (Fig. 1, *C* and *D* and 2, *C* and *D*). The results have been stable in this patient since completion of treatment (Fig. 3, *B*).

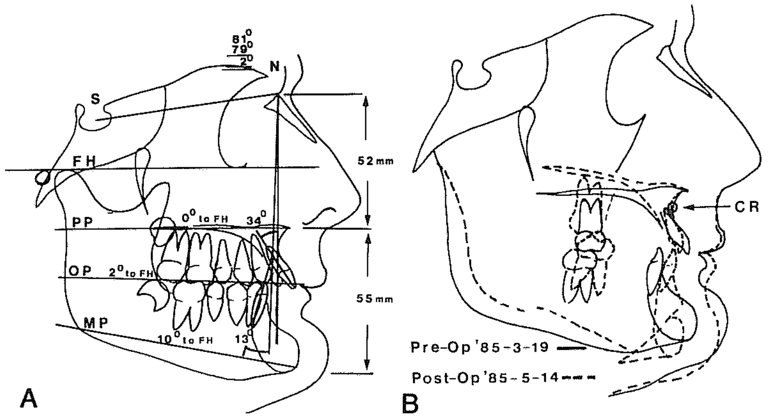

Fig. 10. **A,** Cephalometric analysis demonstrates typical cephalometric parameters frequently observed in this facial type. **B,** Superimposition of preoperative and postoperative cephalometric tracings demonstrates dental, skeletal, and soft tissue changes. Note that an anteroposterior reduction, vertical augmentation, osseous genioplasty procedure was performed.

CASE 2

The patient was first seen at the age of 10 years with the complaint that her teeth were "peculiar." Extraoral examination revealed the typical euryprosopic, dolichoprosopic facial form with a prominent chin, deep labiomental sulcus, and retropositioned lower lip (Fig. 8, *A* and *B*). She had a Class II, Division 1 malocclusion with very small hypoplastic teeth, severe attrition, and early loss of the lower first molars with marked mesial migration of the lower second molar teeth.

An acrylic removable appliance with an anterior bite plane was fitted to inhibit attrition and encourage posterior tooth eruption in an attempt to combat the severe deep bite. Fixed edgewise appliance therapy was commenced 2½ years later in the permanent dentition, and the lower first molar extraction spaces were closed. Despite the use of straight-pull and cervical-pull headgear, Class II elastics, and excellent cooperation, resolution of the Class II malocclusion was impossible (Fig. 9, *A* and *B*). The deep overbite was still 5 mm and the over-jet was 7 mm.

Three years after commencement of fixed appliance therapy, surgery was planned with the center of rotation of the maxilla placed in the vicinity of point A (Fig. 10, *A*). A Le Fort I maxillary ostectomy was performed, and the posterior maxilla was elevated 7 mm in a clockwise rotation (Fig. 10, *B*). Bilateral mandibular sagittal split osteotomies permitted the distal segment of the mandible to follow the rotation of the maxilla, so that a normal molar, cuspid, and incisor relationship could be obtained. A genioplasty was necessary to reduce the malshaped chin and augment its height. A fixation period of 6 weeks was followed by postoperative orthodontic treatment. Because of the poor shape and small size of the teeth, it was more difficult to achieve a satisfactory functional occlusion; hence the postoperative orthodontic treatment took longer than normal.

Comparison of presurgical and posttreatment photographs (Figs. 8 and 9) illustrates the improvement in facial appearance, while the cephalometric composite tracing (Fig. 10, *B*) demonstrates the dental, skeletal, and soft tissue changes with excellent stability of the result 16 months after the surgical procedure.

DISCUSSION

The concept of surgical alteration of the occlusal plane angulation as developed by Wolford appears to resolve not only the mechanical difficulties of treating dolichoprosopic and euryprosopic Class II deepbite cases; it also offers an increased spectrum of esthetic advantages with predictable stability, as demonstrated in the two cases presented.

The prime presurgical orthodontic goal is to position the upper and lower incisors appropriately so that the surgical procedures will place them in a normal position. The upper incisors, which are often excessively proclined but within alveolar bone, will influence the degree of change of the occlusal plane angulation if a one-piece maxillary osteotomy is performed. Multiple-piece maxillary osteotomy with the four incisors in a segment provides greater independence in establishing the incisor angulation position and the mandibular occlusal plane angulation. The lower incisor position dictates the amount of forward and downward rotation of the mandible. Selection of the point of rotation controls the nasolabial angle, the position of soft tissue subnasale, the anteroposterior position of the incisal tip, and the position of the chin. The lower anterior facial height is increased and the lower lip and labiomental fold are restored to harmonize with the rest of the face.

The surgical technique involves standard procedures for superior repositioning of the posterior part of the maxilla and bilateral mandibular ramus sagittal split osteotomies with forward and downward rotation anteriorly and upward and forward rotation of the posterior aspect. Technically, this procedure is relatively simple as compared to a total subapical osteotomy and may have less morbidity relative to the inferior alveolar nerve.

In the two cases presented here skeletal, dental, and facial harmony has been established and over the 17- to 24-month posttreatment period, the results have proved to be stable.

Okeson[15] links condylar guidance and a nearly parallel occlusal plane with short posterior cusps. The two cases reported differ in this regard, one having deep cusps and the other small, flat cusps. Cognizance is taken of the alteration of the plane of occlusion, cusp height, and interplay with condylar guidance. However, no temporomandibular joint symptoms of any description have been reported by either patient.

The principle of changing the occlusal plane has provided us with a means to improve the function and the esthetic results in the correction of many other facial deformities where double-jaw surgery is indicated.

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Surgical manipulation of the occlusal plane

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Abstract

With combined surgical repositioning of the maxilla and the mandible, the occlusal plane is usually determined by the autorotation of the mandible. By manipulation of the cant of the maxillary occlusal plane, additional control of the esthetic result is obtained. In the approach discussed in this paper, prime attention is paid to repositioning of the maxilla into the most favorable situation by a deliberate rotation around points that are anterior in the face. The mandible is then surgically adjusted to secure a good occlusion. In this way, the cant of the occlusal plane becomes a priority in treatment planning, rather than simply an inevitable consequence of maxillomandibular surgery. The technique of treatment planning is discussed in detail, and three cases are presented to illustrate the concept. Of special importance is the enhancement of facial esthetics that is offered by the deliberate manipulation of the occlusal plane.

Introduction

The occlusal plane is often altered as a result of the surgical correction of jaw deformities. The effects of these changes have attracted considerable attention, not only in treatment planning,[1,2] but also in consideration of posttreatment stability.[2,3] The most dramatic and deliberate alteration of the occlusal plane occurs during the surgical correction of severe facial asymmetries.[2] A change of the plane, however, is most often simply the inevitable consequence of any surgical adjustment to the vertical position of the maxilla and the resultant autorotation of the mandible, which occurs about a point at or behind the head of the condyle. To achieve satisfactory occlusal contact in these cases, the maxilla must be aligned along a "new" occlusal plane, which is determined by the extent of the autorotation of the mandible. Hence, it is the position assumed by the mandible that dictates the final cant of the occlusal plane. Should any anteroposterior repositioning of the maxilla or mandible also be required, that move-

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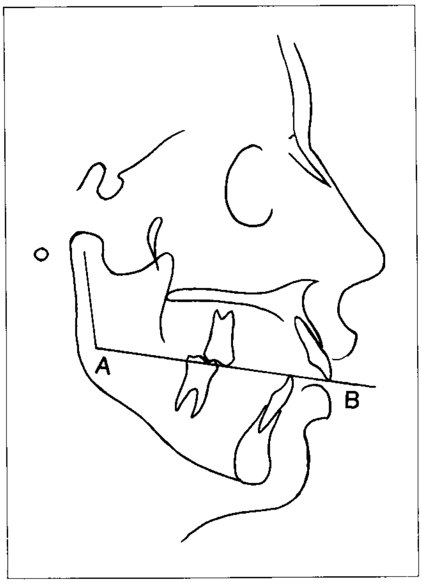
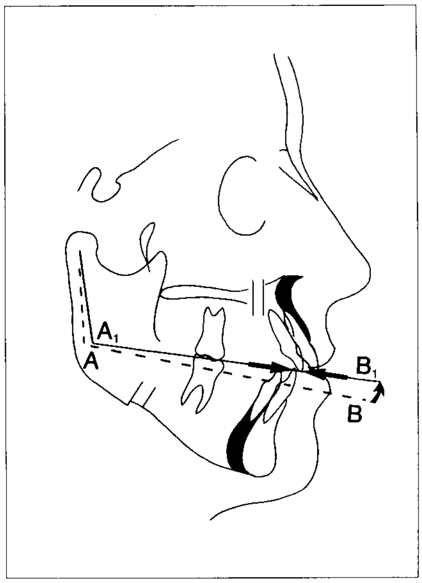
Fig 1a (left) Lateral cephalometric tracing of a patient with vertical maxillary excess, maxillary anteroposterior excess, and mandibular anteroposterior deficiency. *(A-B)* The preoperative occlusal plane.

Fig 1b (right) The maxilla is superiorly repositioned at an angulation that will accommodate *(A_1-B_1)* the "new" occlusal plane, which has been changed from *(A-B)* the preoperative occlusal plane, by the autorotation of the mandible. The mandible is advanced and the anterior segment of the maxilla is set back along this plane.





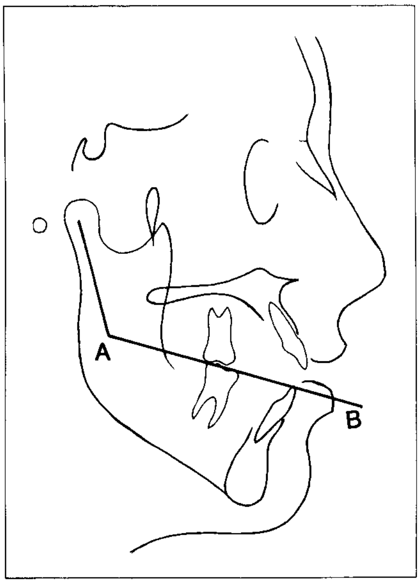


Fig 2a A lateral cephalometric tracing of a patient with an anterior open bite. The relationship of the maxillary incisor to the lip line is favorable. *(A-B)* The cant of the occlusal plane.

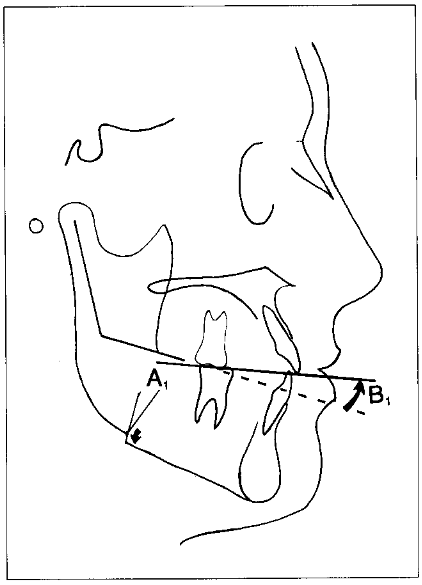


Fig 2b Apparent correction of the open bite by surgical adjustment of the mandible. *(A_1-B_1)* The occlusal plane has been rotated in a counterclockwise direction. Stability is doubtful.

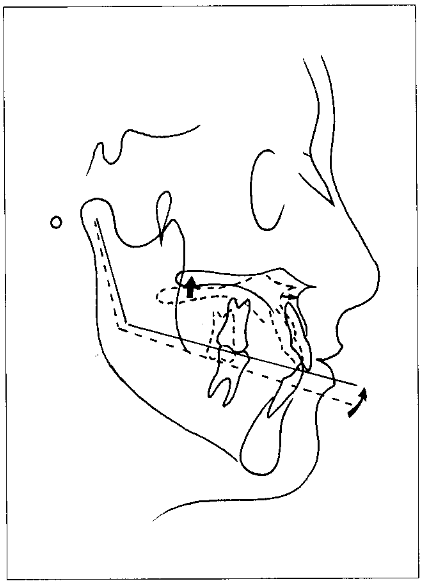
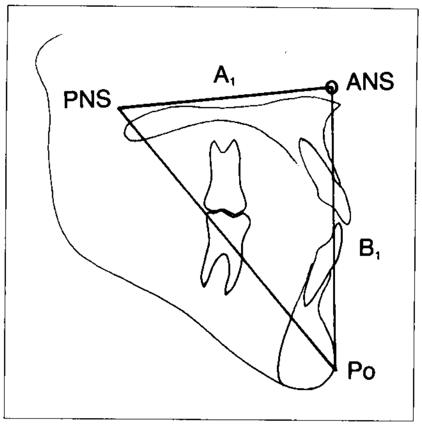


Fig 2c Surgical correction of open bite by superior repositioning of posterior maxilla and autorotation of the mandible. *(dotted line)* Preoperative; *(solid line)* postoperative.

ment must *of necessity* take place along that occlusal plane, which has been defined by the position of the mandible after autorotation (Fig 1).

Any "counterclockwise" rotation of the mandibular occlusal plane may jeopardize posttreatment stability. For example, Epker and Schendel[4] have emphasized that correction of an open bite deformity by such a surgical movement will most likely relapse (Figs 2a and 2b). A more satisfactory result can be



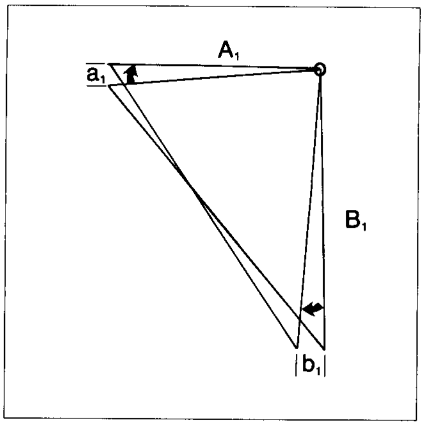


Fig 3a (left) (○) Manipulation of occlusal plane. Center of maxillary rotation at *(ANS)* anterior nasal spine. *(A_1)* Maxillary length (distance between anterior nasal spine and *[PNS]* posterior nasal spine); *(B_1)* Lower third facial height (distance between anterior nasal spine and *[Po]* pogonion). For clarity, points *ANS* and *PNS* are positioned higher in diagram than actual anatomic points.

Fig 3b (right) (○) Center of rotation located at anterior nasal spine; *(a_1)* superior repositioning of the posterior maxilla; *(b_1)* posterior rotation (displacement) of pogonion; *(A_1)* maxillary length; *(B_1)* lower third facial height. The ratio of the extent of the movement would be $\frac{a_1}{b_1}:\frac{A_1}{B_1}$.

achieved by superior repositioning of the posterior maxilla and autorotation of the mandible (Fig 2c).

While counterclockwise rotation of the mandible is contraindicated, a clockwise manipulation of the mandibular occlusal plane around a point anterior in the face has been shown to be stable, and this approach confers distinct esthetic advantages.[5]

Deliberate manipulation of the occlusal plane recently has been proposed for the surgical correction of a Class II malocclusion in a patient with a low mandibular plane angle morphology.[5] In this approach, it is the new position of the maxilla that primarily determines the cant of the occlusal plane, and it is the mandible that, secondarily, requires surgical adjustment to accommodate the inclination of the maxillary dental arch.

Further experience has revealed that the method achieves favorable results in the treatment of other abnormal facial patterns as well. The approach is advantageous in dealing with both Class I and Class III problems.

The technique allows variation in the position of a center of rotation around which the inclination of the maxilla may be adjusted. The center may be located at the anterior nasal spine (ANS), at the tip of the maxillary central incisor, or at any intermediate point. Any required anteroposterior repositioning of the maxilla or mandible will take place along the new occlusal plane.

Geometry of manipulation of the occlusal plane

Center of rotation at ANS (Fig 3)

Surgical superior repositioning of the posterior maxilla at posterior nasal spine (PNS) as a result of rotation around a point at ANS will result in the following changes:

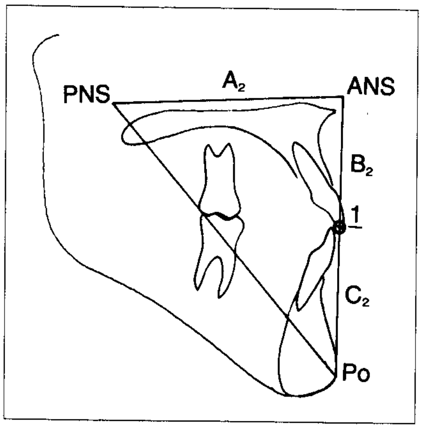
1. Alteration of occlusal plane angle (occlusal plane–sella-nasion [SN] line)
2. Retraction of maxillary incisor tip
3. Change of angulation of long axis of maxillary incisor relative to SN
4. Posterior displacement of pogonion (Po)

The extent of posterior movement of pogonion (Fig 3b, b_1) is greater than that of the superior repositioning of the posterior maxilla (Fig 3b, a_1) because the vertical height of the lower third of the face (ANS-Po) is greater than the maxillary length (ANS-PNS) (Fig 3a). The ratio of the movements may be expressed:

$$\frac{a_1}{b_1} = \frac{\text{ANS-PNS}}{\text{ANS-Po}}$$

Center of rotation at the maxillary incisor tip (Fig 4)

Surgical superior repositioning of the maxilla as a result of rotation around a



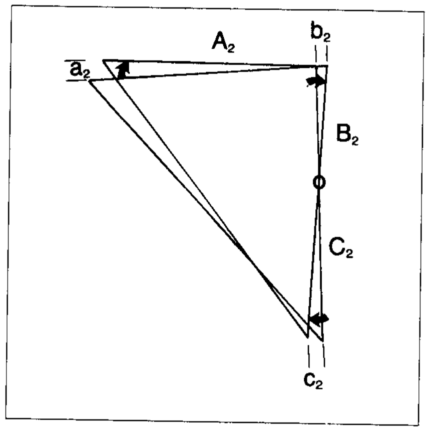


Fig 4a (left) Manipulation of occlusal plane. *(○)* Center of maxillary rotation located at the tip of the maxillary incisor; *(A_2)* distance from *(PNS)* posterior nasal spine to *(ANS)* anterior nasal spine; *(B_2)* distance from anterior nasal spine to *(1)* tip of maxillary incisor, *(C_2)* distance from tip of maxillary incisor to *(Po)* pogonion.

Fig 4b (right) *(○)* Center of rotation located at the tip of maxillary incisor; *(a_2)* superior repositioning of the posterior maxilla; *(b_2)* advancement of anterior nasal spine; *(c_2)* posterior repositioning of the pogonion; *(A_2)* distance from posterior nasal spine to anterior nasal spine; *(B_2)* distance from anterior nasal spine to tip of maxillary incisor; *(C_2)* distance from tip of maxillary incisor to pogonion. The ratio of movement in this case is $\frac{b_2}{c_2} = \frac{B_2}{C_2}$.

point at the tip of the maxillary central incisor results in the following changes:

1. Alteration of occlusal plane angle (occlusal plane–sella-nasion line)
2. Advancement of the maxilla at the anterior nasal spine
3. Change of angulation of incisors relative to SN (to a lesser extent than when rotation is around ANS)
4. Posterior displacement of pogonion (to a lesser extent than when rotation is around ANS)

The ratio of the extent of movement of ANS (Fig 4b, b_2) to the movement of pogonion (Fig 4b, c_2) is the same as the ratio between the distance from ANS to the tip of the maxillary central incisor (Fig 4b, B_2) and the distance from the tip of the maxillary central incisor to pogonion (Fig 4b, C_2):

$$\frac{b_2}{c_2} = \frac{B_2}{C_2}$$

The selection of the precise point of maxillary rotation is dictated primarily by the esthetic requirements of the case. For those patients who require more upper lip and paranasal support (and less chin retraction), the maxillary incisor tip is used as center of rotation. If no maxillary advancement is desired and definitive posterior displacement of the chin is planned, the rotation point is placed superiorly at anterior nasal spine.

Indications

To illustrate the applicability of the technique, a patient with a Class III malocclusion is illustrated in Fig 5. The problem is characterized by vertical maxillary excess and mandibular anteroposterior excess.

First a prediction tracing is completed to test the effect of the conventional approach of superior repositioning of the maxilla, permitting autorotation and subsequent retraction of the mandible. The cant of the occlusal plane, therefore, would be dictated by the inclination of the mandibular dental arch after autorotation. The prediction tracing is examined to assess whether the desired esthetic result can be achieved. The lower third of the face is still too prominent (a facial contour angle of less than −9 degrees) (Fig 5b). A superior repositioning of the posterior maxilla, however, allows for a favorable clockwise rotation of the entire lower third of the face around a center at anterior nasal spine (Fig 5c). This modification of the operative plan could enable the surgeon to achieve a more ideal esthetic result and is tested on a second prediction tracing (compare Fig 5b to Fig 5c).

Apart from the esthetic objectives, anatomic considerations also influence the selection of the center of rotation and determination of the extent of change

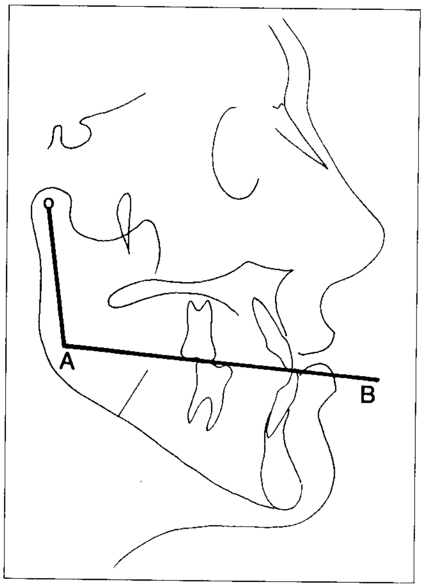


Fig 5a Lateral cephalometric tracing of a patient with vertical maxillary excess and mandibular anteroposterior excess. *(A-B)* Occlusal plane.

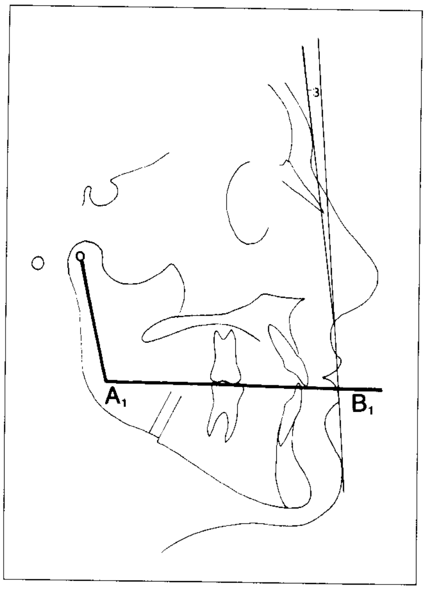


Fig 5b Trial prediction tracing of the patient in Fig 5a. The maxilla has been superiorly repositioned and *(A_1-B_1)* the new occlusal plane determined by the mandible after autorotation. The mandible is now set back according to this plane. Note the facial contour angle of −3 degrees. The chin is still too prominent.

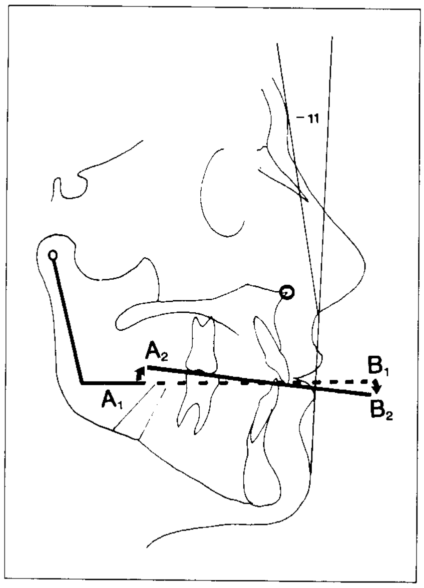


Fig 5c Surgical prediction tracing of the patient in Fig 5a. However, after *(A_1-B_1)* autorotation of the mandible, the occlusal plane is manipulated by *(A_2-B_2)* further superior repositioning of the posterior maxilla. The center of rotation is located at ANS. A more esthetic facial contour angle is established (−11 degrees), as a result of the distalization of the chin point.

of the occlusal cant. Excessive superior repositioning of the posterior nasal spine (more than 5 to 6 mm) may compromise the nasal airway.[6] Where indicated, therefore, it may be necessary to perform a horseshoe-shaped osteotomy of the posterior nasal floor to separate the dentoalveolar portions of the maxillae from the palate, which thus remains attached to the nasal septum. The vertical dimension of the nasal airway is thereby maintained, while the dentoalveolar segments are free to be repositioned.

An excessive change in the occlusal plane angle could have an effect on the balance between the condylar guidance of the emmenentia articularis and the cuspal angulations responsible for protrusive disclusion.[7] No negative effects on the function of the temporomandibular joints have been experienced by patients in a series of 26 cases in which the maximal change in the occlusal plane angle has been 9 degrees.

Clinical examples

Three patients, with Class I, II, and III malocclusions, respectively, are presented to illustrate this surgical design.

Case 1 (Figs 6a to 6l)

An 18-year-old patient reported for treatment. The main complaint was that her mandible appeared prominent (Figs 6a and 6b). She had a Class I occlusion with slight crowding (Figs 6c to 6e). The lower third of her face was vertically excessive and there was also a tendency to a mandibular anteroposterior excess (a facial contour angle of 1.5 degrees).

Various surgical treatment options were considered. It was finally decided to correct the facial disharmony by utilizing the technique of surgical manipulation of the occlusal plane.

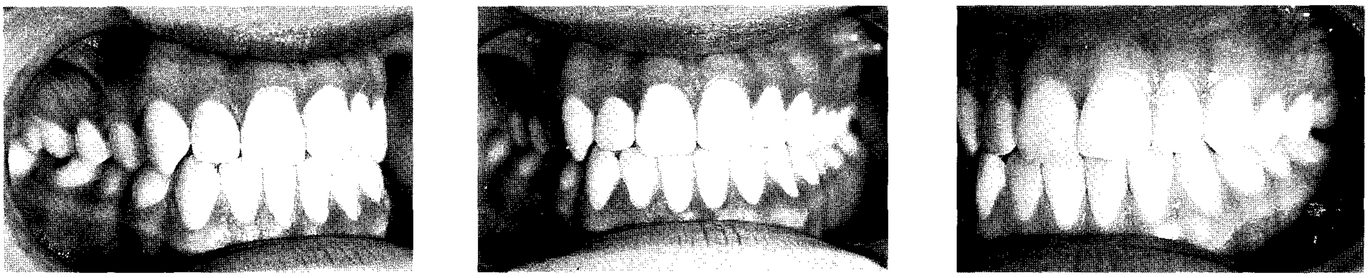
Surgical plan (Figs 6f and 6g)

1. Vertical reduction of the maxilla by a Le Fort I osteotomy (3 mm anteriorly and 7 mm posteriorly). This adjustment could be achieved by rotation of the maxillary occlusal plane around ANS, together with a vertical impaction.
2. Bilateral sagittal split ramus osteotomy and mandibular setback, following the rotation of the maxillary occlusal plane.

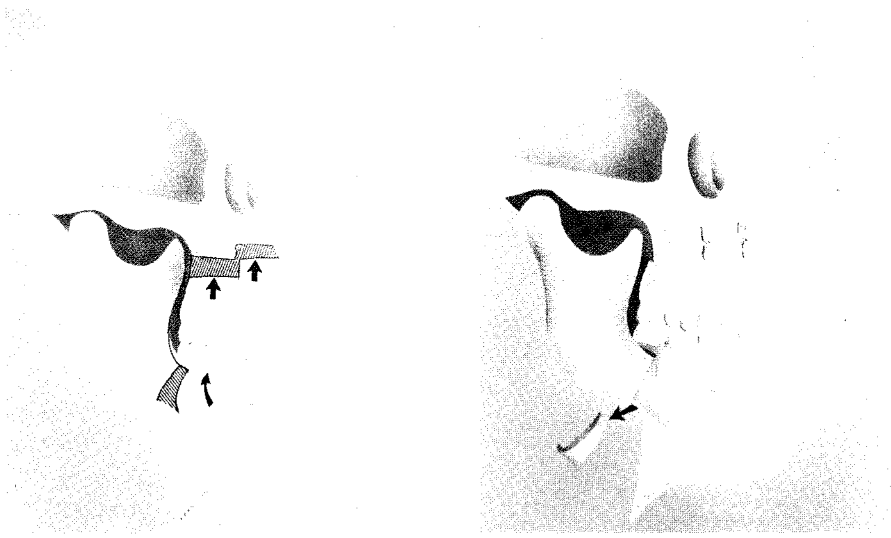
After a 3-month preoperative period in which the arches were aligned and the Class I occlusion was refined, surgery was performed. This resulted in a 6-mm posterior and 3-mm superior displacement of pogonion. The soft tissue contour of the labiomental fold and chin was maintained. The orthodontic bands were removed after a total treatment time of 6 months.

A pleasing esthetic and functional result was achieved (Figs 6h to 6l).

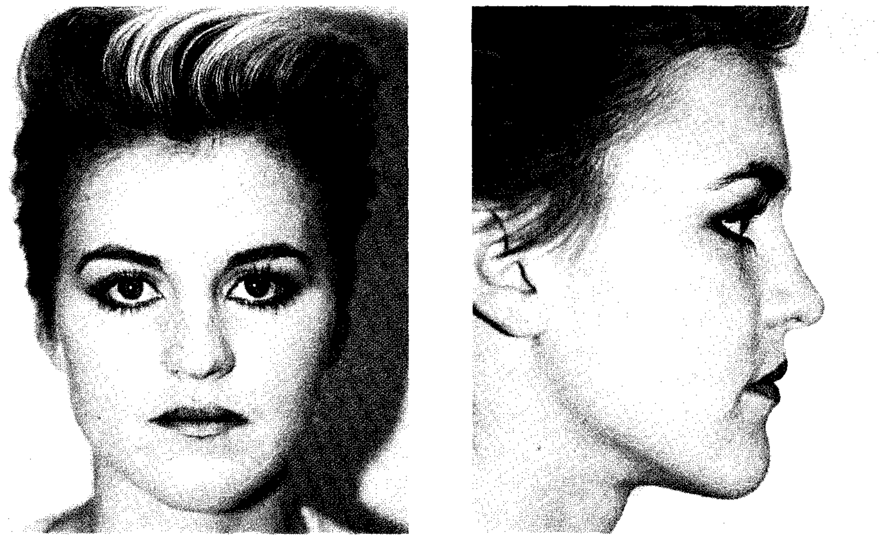
Figs 6a and 6b Facial appearance of patient with a slight vertical maxillary excess and a prognathic tendency in a Class I occlusion.



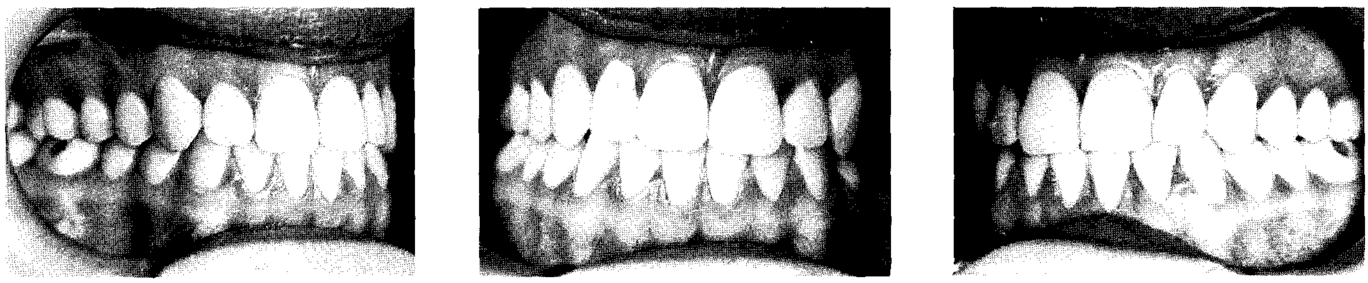
Figs 6c to 6e Pretreatment occlusion.



Figs 6f and 6g The surgical plan. The maxilla is superiorly repositioned by a Le Fort I osteotomy, 3 mm anteriorly and 7 mm posteriorly. In this case, posterior repositioning of pogonion is desirable. The anterior nasal spine is therefore chosen as the center of rotation. The preoperative occlusion was maintained by rotation of the mandible through a bilateral sagittal split osteotomy. The osteotomized buccal cortical plate is narrower at the top than it is inferiorly.



Figs 6h and 6i Postoperative facial appearance.



Figs 6j to 6l Postoperative occlusion.

Case 2 (Figs 7a to 7l)

A 19-year-old woman sought treatment to decrease the prominence of her maxillary incisors. She was also concerned about her "knobby" chin (Figs 7a and 7b). The patient presented with a Class II deep bite malocclusion and maxillary protrusion. The maxillary first premolars had been removed previously, and residual extraction spaces remained (Figs 7c to 7e).

The treatment plan involved a full surgical-orthodontic program.

Preoperative orthodontics

The intention during this phase was to align the maxillary arch in three segments (teeth 15 to 17, 25 to 27, and 13 to 23), diverging the roots of teeth 15 and 13 and 23 and 25 to facilitate surgical closure of spaces. Further, treatment was intended to level and align the mandibular arch to ensure coordination with the maxillary arch.

Surgical plan (Figs 7f and 7g)

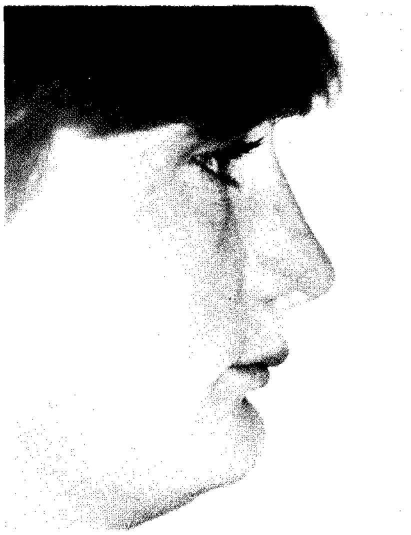
1. Three-piece Le Fort I maxillary osteotomy with superior repositioning (2 mm anteriorly and 6 mm posteriorly). The occlusal plane would be rotated around the tip of the maxillary incisor. This would result in a slight advancement of the anterior nasal spine and at the same time improve the angulation of the maxillary incisors. Closure of the spaces in the area of the first premolars would complete the maxillary surgery.
2. Bilateral sagittal split ramus osteotomy and advancement and tipping of the body of the mandible, following the rotation of the maxillary occlusal plane.
3. Reduction genioplasty with angulated osteotomy cuts to gain a slight vertical increase in the anterior mandibular segment.

Postoperative orthodontics

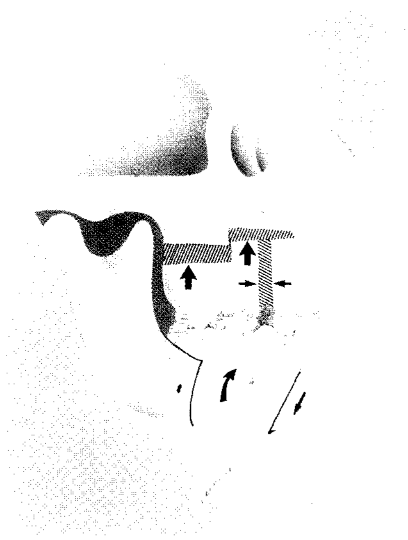
The occlusion would be refined, and, after the bands were removed, effective retention would be instituted.

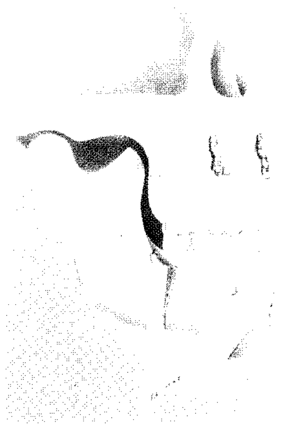
An acceptable status was achieved after a total treatment time of 16 months (Figs 7h and 7i). The treatment is stable 4 years after removal of the bands (Figs 7j to 7l).

Figs 7a and 7b Facial appearance of a patient with a mandibular deficiency in a Class II pattern.



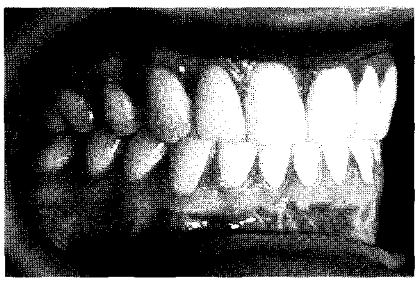
Figs 7c to 7e Pretreatment occlusion.

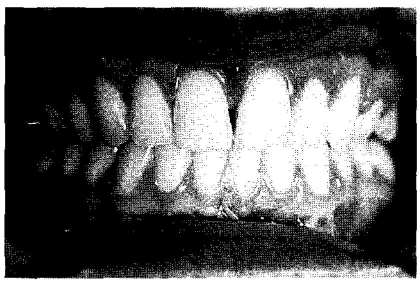


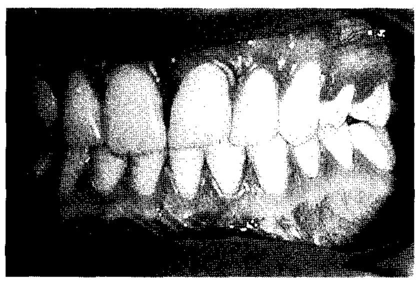


Figs 7f and 7g The surgical plan. A three-piece Le Fort I osteotomy is performed and the maxilla is superiorly repositioned, 2 mm anteriorly and 6 mm posteriorly. The maxillary occlusal plane is therefore rotated using the tip of the maxillary incisor as the center of rotation. The residual extraction space in the region of the first premolars is closed. The body of the mandible undergoes clockwise rotation during a bilateral sagittal split osteotomy. To increase the vertical height of the mandible and reduce the "knobby" chin further, a sliding genioplasty is performed.

Figs 7h and 7i Postoperative facial appearance.







Figs 7j to 7l Postoperative occlusion.

Case 3 (Figs 8a to 8l)

A 17-year-old girl was referred by her dentist for correction of an Angle Class III malocclusion (Figs 8a and 8b). Previous orthodontic treatment had involved the removal of the mandibular second premolars (Figs 8c to 8e).

The patient was diagnosed as presenting vertical maxillary excess combined with anteroposterior mandibular excess. A surgical-orthodontic treatment plan was formulated.

Preoperative orthodontics

Complete fixed appliances would be required to align the maxillary teeth on basal bone, decompensate the mandibular incisors, and level both arches. The mandibular second premolar extraction spaces were to be maintained for postoperative prosthodontic replacements.

Surgical plan (Figs 8f and 8g)

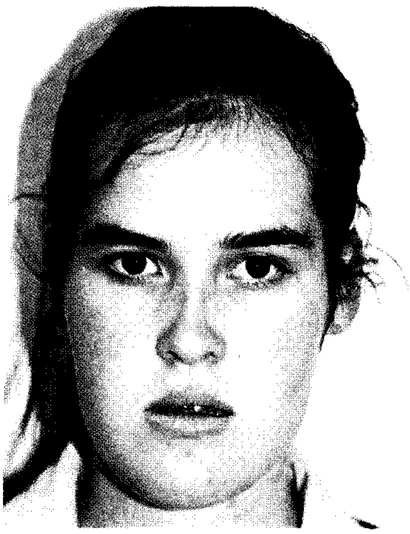
1. A Le Fort I maxillary osteotomy to intrude the maxilla 5 mm anteriorly and posteriorly (instead of following the autorotation of mandibular occlusal plane).
2. Bilateral sagittal split osteotomy and mandibular setback with clockwise rotation, following the maxillary occlusal plane.

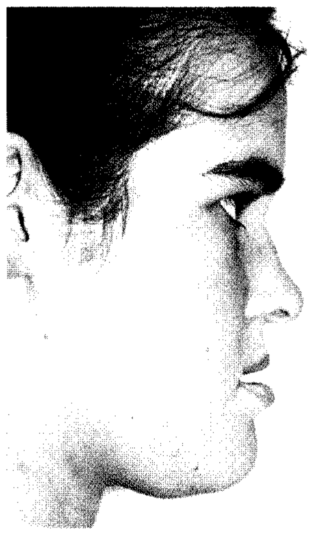
Postoperative orthodontics

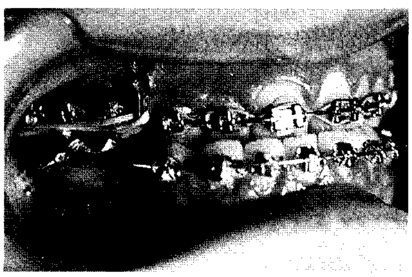
The occlusion would be refined and a period of retention would follow.

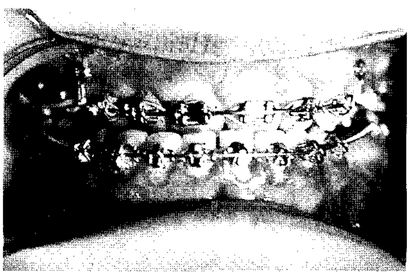
After 18 months of treatment, a pleasing result was achieved (Figs 8h to 8l). The patient was referred to a prosthodontist for the prostheses required in the mandibular arch.

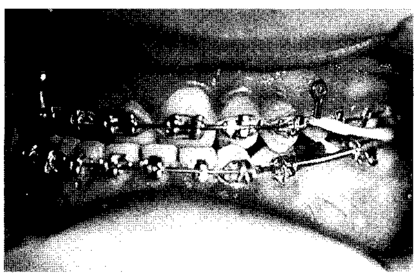
Figs 8a and 8b Facial appearance of a patient with vertical maxillary excess, mandibular anteroposterior excess, and a Class III malocclusion.



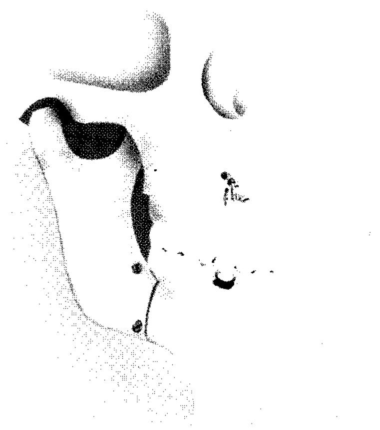


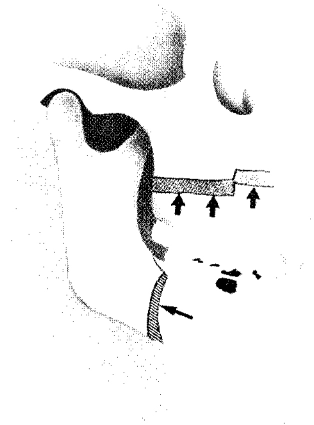




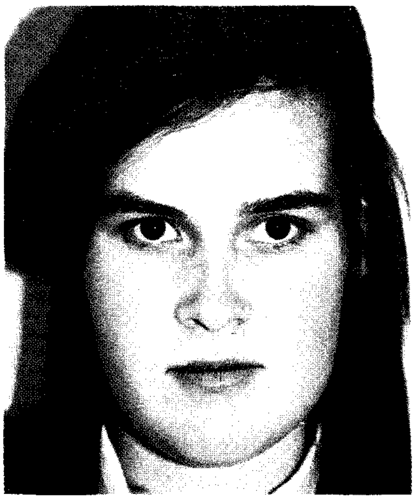


Figs 8c to 8e Presurgical occlusion. The patient, unfortunately, had lost both mandibular second premolars previously.

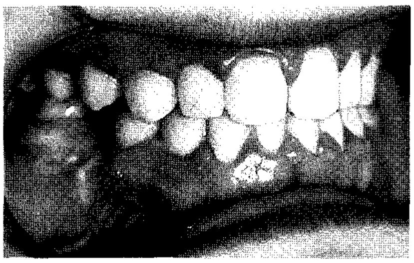


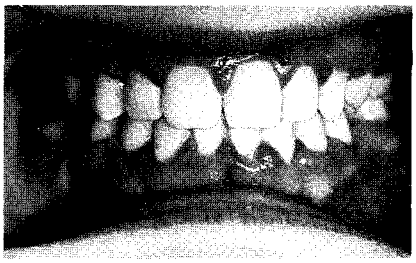


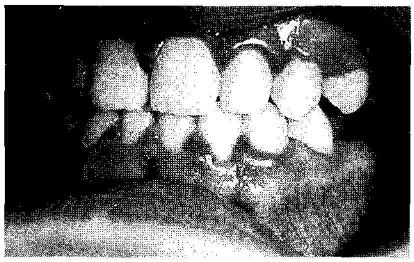
Figs 8f and 8g The surgical plan. The maxilla is superiorly repositioned by 5 mm anteriorly and posteriorly. (Normally, following autorotation of the mandible, superior repositioning of the maxilla is less posteriorly than it is anteriorly.) The mandible is set back by a bilateral sagittal split osteotomy. Point of rotation is at anterior nasal spine.



Figs 8h and 8i Postoperative facial appearance.







Figs 8j to 8l Postoperative occlusion. The mandibular second premolars have been replaced by fixed partial dentures.

Summary

When maxillomandibular surgery is planned for the correction of a dentofacial deformity, the cant of the occlusal plane is, in most cases, determined by the autorotation of the mandible. The achievement of optimal esthetic results may be limited by this plane. However, the anteroposterior chin position can be controlled by selective alteration of the maxillary occlusal plane angulation. Furthermore, by selection of the point around which this rotation takes place, more control over esthetic results can be obtained.

The physiologic change created by these jaw movements should be kept in mind. Although no adverse effects have been experienced by the 26 patients in whom this treatment concept has been utilized, the series is still too small to draw any definitive conclusions.

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Surgical manipulation of the occlusal plane: New concepts in geometry

Rotation of the maxillomandibular complex and the consequent alteration of the occlusal plane angulation to improve functional and esthetic results have been well documented. The decision to change the occlusal plane angulation cannot be arbitrary and is made only when desired results cannot be obtained by conventional treatment planning. The geometry of rotation should be accurately planned by establishing a specific point around which the maxillomandibular complex should be rotated to achieve specific esthetic results. Treatment planning using anterior nasal spine and maxillary incisor tip as rotation points has been described and results demonstrated. This article will introduce additional points of rotation that may be considered based on a triangle constructed during treatment planning. Two clinical examples are presented in which these types of rotation were implemented. (Int J Adult Orthod Orthognath Surg 1998;13:307–316)

The occlusal plane is often altered in the surgical correction of dentofacial deformities. This is simply the inevitable consequence of any surgical adjustment to the vertical position of the maxilla and the resultant autorotation of the mandible, which occurs around a point at or just behind the head of the condyle.

The principle of deliberately changing the occlusal plane as a means of improving the functional and esthetic result was first described for the treatment of patients with a Class II low mandibular plane angle.[1] Other dentofacial deformities have subsequently been treated by deliberate surgical alteration of the occlusal plane.[2] The latter placed special emphasis on the selection of points around which the maxillomandibular complex can be rotated to enhance treatment results and focused on clockwise rotation of the occlusal plane.

Recently Wolford et al[3] discussed the surgical alteration of the occlusal plane by increasing the occlusal plane angle by clockwise rotation or decreasing the plane angle by counter-clockwise rotation. Counter-clockwise rotation of the mandibular occlusal plane has generally not been supported as an acceptable treatment modality due to the unpredictability of the results.[4–6] The poor stability can most probably be attributed to the fact that surgical procedures that decrease the angle of the occlusal plane by rotation beyond a point at the condyle will tend to increase the posterior vertical height of the mandible or rotate the proximal segment (mandibular ramus) posteriorly.[7] Care should be taken, however, not to rotate the proximal segment posteriorly during surgery, but rather to maintain its original position while the distal segment rotates.

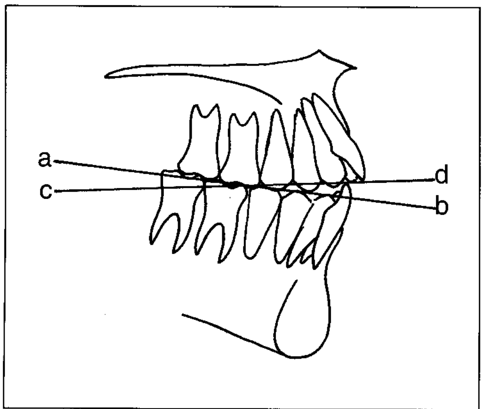


Fig 1 The functional occlusal plane (ab) is a line through the overlapping cusps of the molars and premolars. The occlusal plane (cd), as described by Downs, is a line bisecting the overlapping cusps of the first molars and the incisal overbite.

Modification of surgical techniques[8,9] and use of rigid fixation has also improved the stability of results.[10] In a recent study evaluating stability after occlusal plane alteration (clockwise and counter-clockwise), Chemello et al[6] reported results to be stable.

By deliberately changing the occlusal plane angle and therefore rotating the maxillomandibular complex, additional control of the esthetic result can be achieved that cannot be attained by conventional means.[1-3]

Manipulation of the occlusal plane, also called *alteration*[3] or *rotation,*[11] can be defined as rotation of the maxillomandibular complex to enhance esthetic and functional treatment results. These rotations should take place around a preselected point in a clockwise or counterclockwise direction and, as a consequence, will alter the occlusal plane angulation. The mandible (and also the occlusal plane) will thus not rotate around a point just posterior of the condyle (as in the case of conventional planning) and is by no means an attempt to correct the occlusal plane angle to a normal angulation.

The occlusal plane

One of the most important principles of integrating diagnostic information is the establishment of a common reference plane. Most cephalometric analyses construct an occlusal plane by drawing a line along the contact points of the molar teeth to a point bisecting the overbite (or open bite) between the maxillary and mandibular incisors.[12] The functional occlusal plane is represented by a line that runs from the most posterior molar contact point to the most anterior premolar contact point.[1,13,14] This occlusal plane is the most practical for orthognathic patients because the presence of accentuated curves of Spee, open bites, and severe malocclusions often makes construction of the occlusal plane difficult. Thus the functional occlusal plane may differ from the maxillary or mandibular occlusal plane (Fig 1).

According to the Steiner analysis,[15] an angle of 14 degrees between the occlusal plane and sella-nasion is considered normal. The cant of the occlusal plane can also be measured to the slope of the Frankfort horizontal plane. The minimal angular measurement is 1.5 degrees, the maximal is 14.0 degrees, and the mean is 9.3 degrees. The large variability can most probably be ascribed to the great variety of the Frankfort horizontal plane.[13]

The occlusal plane is one of the planes used as a diagnostic feature; ie, patients with a dolichocephalic head and leptoprosopic face will tend to have a high occlusal plane angle, while patients with a brachycephalic head and euryprosopic face will tend to have a low occlusal plane angle. This angle is also often used in the description of cases, ie, Class II low or high angle cases.

The transverse cant of the occlusal plane should also be an important consideration in treatment of patients with facial asymmetry. Evaluation and correction of this plane, where indicated, forms an integral part of the treatment of facial asymmetry.[16] When surgical manipulation of the occlusal plane is considered, the aim is not to conform to normal cephalometric values but rather to enhance the esthetic result.

Landmarks used

ANS = anterior nasal spine
PNS = posterior nasal spine
Po = pogonion

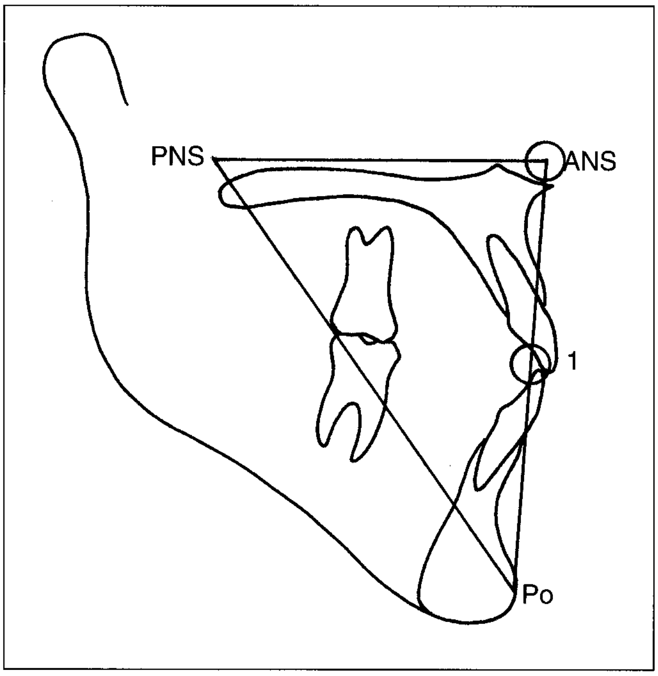


Fig 2 A triangle involving PNS, ANS, and Po is constructed to demonstrate the rotation of the maxillomandibular complex. Rotation points are at ANS and the maxillary incisor tip (1).

Geometry and planning of occlusal plane manipulation

Surgical repositioning of the jaws involves complicated three-dimensional movements of geometrically complex structures. The diagnostic information gained from the preoperative clinical examination, study models, and radiographic evaluation must be carefully integrated to establish the appropriate surgical treatment plan.

The decision to alter the occlusal plane is not an arbitrary one and should be considered only if conventional treatment planning does not produce satisfactory results. It is extremely difficult to simply "place" or "select" a new occlusal plane without selecting a point around which to rotate the maxillomandibular complex or alter the occlusal plane. It is easier and more accurate from a planning and surgical point-of-view to rotate the maxillomandibular complex around a preselected point.

The geometry of clockwise rotation of the maxillomandibular complex using ANS and the maxillary incisor tip as rotation points has been described and esthetic and functional results demonstrated by Reyneke and Evans in 1990.[2] This was illustrated by constructing a triangle involving PNS, ANS, and Po (Fig 2). The choice of the point of rotation is dictated by the esthetic requirements of each patient.

Similarly, if counter-clockwise rotation of the maxillomandibular complex or decreasing the occlusal plane angle is planned, these same points of rotation may be used to improve the treatment results. This article will introduce additional points of rotation that may be considered, based on the same constructed triangle during the treatment planning phase.

These points are located between PNS and ANS. Rotation around these points will either increase or decrease the occlusal plane angle. Opposite esthetic results can be achieved by either clockwise or counter-clockwise rotation of the maxillomandibular complex, while the magnitude of the effects can be enhanced by moving the point more anteriorly or posteriorly. The desired position of the maxillary incisor and the chin will assist in establishing the point of rotation as well as the direction of rotation. A list of changes that can be expected at different points of rotation[17] follows each type of rotation.

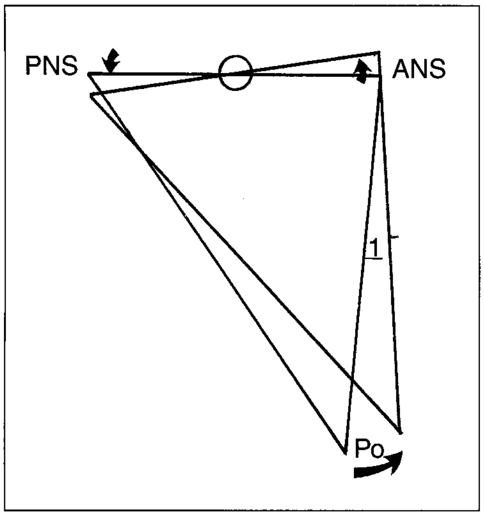
Counter-clockwise rotation around points ***posterior to ANS*** *(Fig 3)*

Effects of this rotation will be enhanced by placing the rotation point further posterior.

1. Decreased occlusal plane angle
2. Decreased mandibular plane angle
3. Decreased exposure of the maxillary incisor
4. Decreased anterior lower face height
5. Decreased mandibular incisor angulation
6. Increased chin projection
7. Increased maxillary incisor angulation

Counter-clockwise rotation around a point ***at ANS*** *(Fig 4)*

1. Decreased occlusal plane angle
2. Decreased mandibular plane angle
3. Decreased mandibular incisor angle



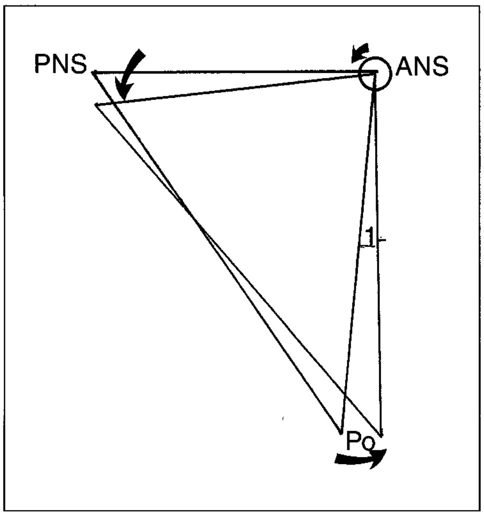
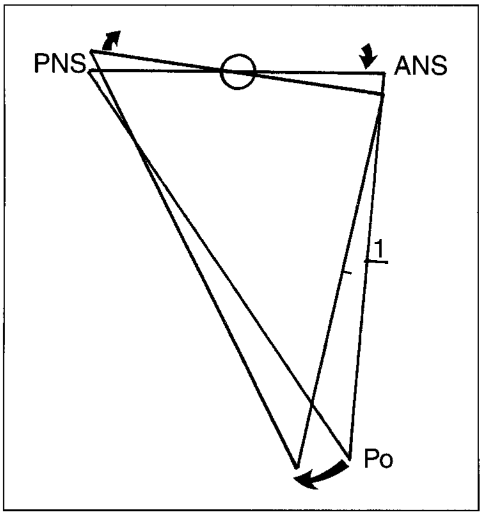


Fig 3 (left) A triangle (maxillomandibular complex) is rotated in a counter-clockwise direction around a point at the buttress area. The anterior maxilla is superiorly repositioned, while the posterior maxilla is moved inferiorly. Pogonion and maxillary incisor rotate forward and slightly superiorly.

Fig 4 (right) A triangle (maxillomandibular complex) is rotated in a counter-clockwise direction around a point at ANS. The posterior maxilla is repositioned inferiorly, while the maxillary incisor and pogonion are advanced.



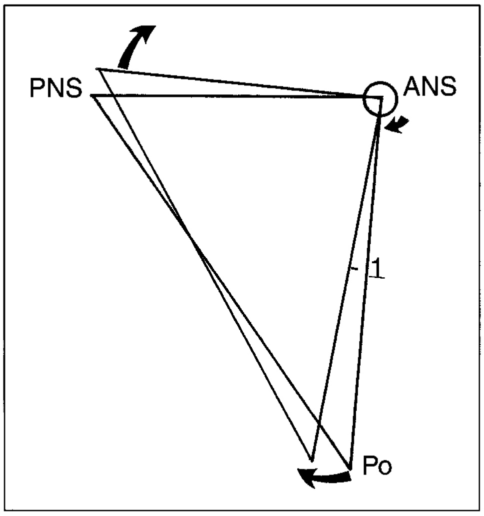


Fig 5 (left) The triangle (maxillomandibular complex) is rotated in a clockwise direction around a point at the buttress area. The anterior maxilla is moved inferiorly, while the posterior maxilla is superiorly repositioned. The maxillary incisor moves posteriorly with slight vertical increase, while pogonion rotates posteriorly and downward.

Fig 6 (right) Clockwise rotation of the triangle (maxillomandibular complex) around ANS maintains the vertical height of the anterior maxilla, while it superiorly repositions the posterior maxilla. The maxillary incisor and pogonion rotate posteriorly.

4. Increased chin projection
5. Increased maxillary incisor angulation
6. Slight increase in maxillary incisor exposure

Clockwise rotation around points ***posterior to ANS*** *(Fig 5)*

Effects of this rotation will be enhanced by placing the rotation point further posterior.

1. Increased occlusal plane angle
2. Increased mandibular plane angle
3. Increased maxillary incisor tooth exposure
4. Increased lower face height
5. Increased mandibular incisor angulation
6. Decreased maxillary incisor angulation
7. Decreased chin projection

Clockwise rotation around a point ***at ANS*** *(Fig 6)*

1. Increased occlusal plane angle
2. Increased mandibular plane angle
3. Increased mandibular incisor angle
4. Decreased maxillary incisor angle
5. Decreased chin projection
6. Slight increase in maxillary incisor exposure

Discussion

Alteration of the occlusal plane as a treatment plan should be considered only after conventional treatment planning has been carried out and found not to produce optimal results. Rotation of the maxillomandibular complex requires very accurate and comprehensive cephalometric treatment planning and model surgery followed by meticulous surgery.

The change in the occlusal plane is inevitable due to rotation of the maxillomandibular complex to achieve a more desirable esthetic result and is by no means arbitrary.[18] It should not be considered an attempt to make the occlusal plane more normal. Most cases that will require this alternative as part of the treatment plan will have relatively high or low occlusal plane angles. As a consequence of the rotation of the maxillomandibular complex, the final occlusal plane angle will possibly be closer to a more normal value, although the primary goal is not to treat the abnormal angulation of the occlusal plane.

Clinical examples

Two patients are presented to illustrate the surgical design with clockwise and counter-clockwise rotation, respectively, using rotation points posterior to ANS.

Case 1

A 36-year-old woman had orthodontic treatment as a child with extraction of teeth 5(14), 12(24), and 21(34) (tooth 30[46] was missing). Her main complaint was that her "bite feels uncomfortable" and her "chin appears too prominent and asymmetric" (Figs 7a to 7e). Her diagnosis included: *(1)* maxillary anteroposterior and vertical deficiency; *(2)* mandibular anteroposterior excess; *(3)* macrogenia; *(4)* edge-to-edge incisor relationship; *(5)* Class II molar relationship on the right; *(6)* asymmetric chin on the right; *(7)* low occlusal plane angle; and *(8)* slightly proclined maxillary incisors.

Treatment planning included presurgical orthodontics to level and align both arches, with slight decompensation of mandibular incisors.

During surgery, the maxilla was rotated in a clockwise direction, after a 5-mm advancement, with the rotation point 5 mm posterior to the piriform rim (Fig 7f). The rotation affected superior repositioning of the posterior maxilla (3 mm) and downgrafting of the anterior maxilla (3 mm) at the piriform rim. This rotation: *(1)* enhanced the perinasal areas; *(2)* advanced the subnasal area; *(3)* improved the maxillary incisor angle; *(4)* increased vertical height of the anterior maxilla, thus increasing maxillary tooth exposure under the upper lip; and *(5)* created a posterior open bite, due to decrease in posterior maxillary vertical height.

Bilateral sagittal split osteotomy was performed following alteration of the maxillary occlusal plane to set the mandible back. The rotation caused the mandibular incisor teeth to advance (1 mm) and the chin to rotate posteriorly (3 mm).

A reduction genioplasty angled the osteotomy so that the chin slid downward and posteriorly (6 mm). At the same time, the chin was moved to the left to correct the asymmetry. This reduced the chin prominence, increased the anterior face height, and established facial symmetry.

Three months of postsurgical orthodontics was needed to refine the occlusion.

The patient was seen 2 years 3 months after surgery and showed good facial harmony and a stable occlusion (Figs 7g to 7j).

Figs 7a to 7d Pretreatment photographs.

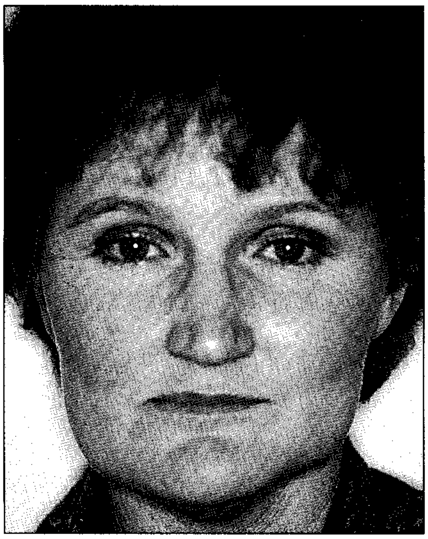


Fig 7a

Fig 7b

Fig 7c

Fig 7d

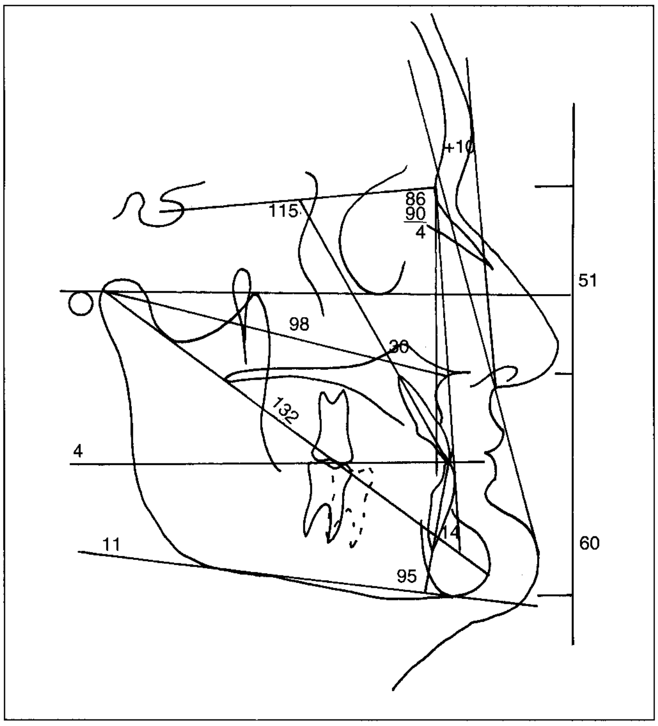


Fig 7e Pretreatment cephalometric analysis.

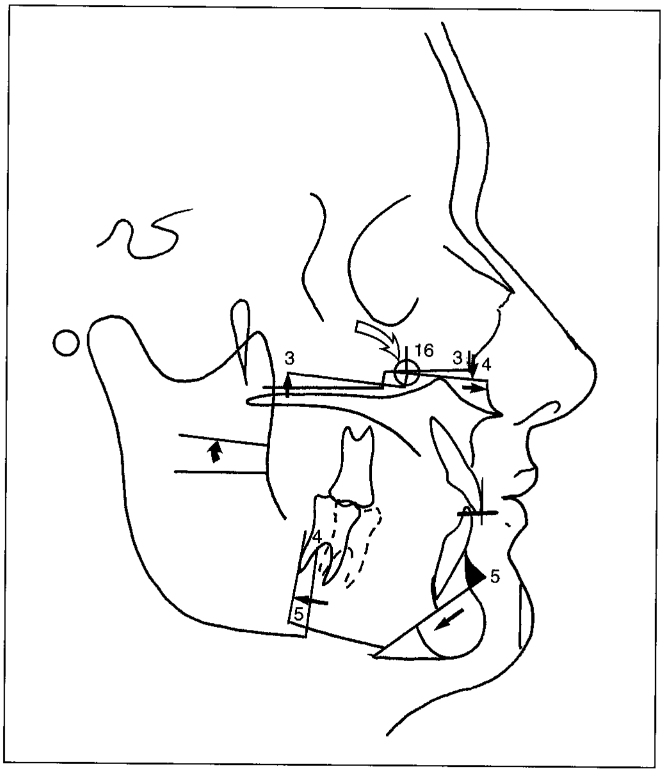


Fig 7f Surgical prediction tracing. The maxillomandibular complex is rotated in a clockwise direction around a point 16 mm posterior to the piriform rim. The posterior maxilla is superiorly repositioned by 3 mm, while the anterior maxilla is moved downward by 3 mm. At the same time, the maxilla is advanced by 4 mm. Rotation of the maxilla is followed by rotation of the mandible by means of a bilateral sagittal split osteotomy. Chin prominence is reduced by a sliding genioplasty. The chin button is still slightly prominent, but further anteroposterior reduction would obliterate the labiomental fold, resulting in poor chin contour.

Figs 7g to 7j Posttreatment facial appearance and occlusion.

Fig 7g

Fig 7h

Fig 7i

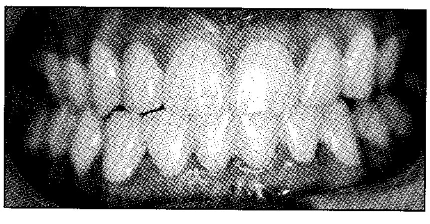


Fig 7j

Case 2

A 16-year-old girl reported for treatment with the main complaint that she had a "double chin" and that her "nose appeared large compared to the rest of her face" (Figs 8a to 8e). She previously had orthodontic treatment consisting of the extraction of 5(14), 12(24), 20(35), and 29(45), and she had worn headgear for 12 months. Her diagnosis consisted of: *(1)* mandibular anteroposterior deficiency; *(2)* maxillary anteroposterior deficiency; *(3)* microgenia; *(4)* lack of dental support for upper and lower lips; *(5)* accentuated curve of Spee; *(6)* 3.5-mm crowding in mandibular arch; and *(7)* increased incisor overjet.

Presurgical orthodontics were performed to level and align both arches and interproximally reduce mandibular incisor teeth to align and derotate.

Surgery included rotation of the maxilla in a counter-clockwise direction around a point 16 mm posterior to the piriform rim (Fig 8f). The anterior maxilla was superiorly repositioned by 3 mm, while the posterior maxilla was downgrafted by 3 mm by means of a Le Fort I osteotomy. This maxillary movement *(1)* improved the relation of the maxillary incisor to the upper lip (the incisors rotated anteriorly, improving lip support, while the 3-mm superior repositioning improved the vertical tooth-lip relationship); *(2)* improved the maxillary incisor angulation; and *(3)* created an anterior open bite.

The mandible was advanced, and followed the alteration of the occlusal plane of the maxilla by means of bilateral sagittal split osteotomy. The mandibular teeth were rotated into a Class I occlusal relationship with the maxillary teeth.

An advancement sliding genioplasty improved the anteroposterior chin position and contour.

Four months of postoperative orthodontics was necessary to finalize the occlusion. The mandibular teeth were retained by means of a canine-to-canine banded retainer, while a maxillary Hawley retainer was used.

The patient was seen 18 months after surgery, with pleasing esthetic and functional results (Figs 8g to 8j).

Figs 8a to 8d Pretreatment photographs.

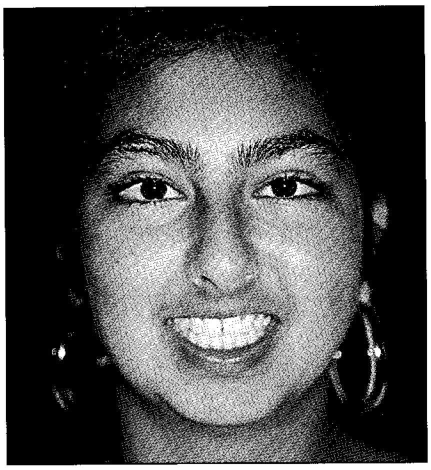


Fig 8a

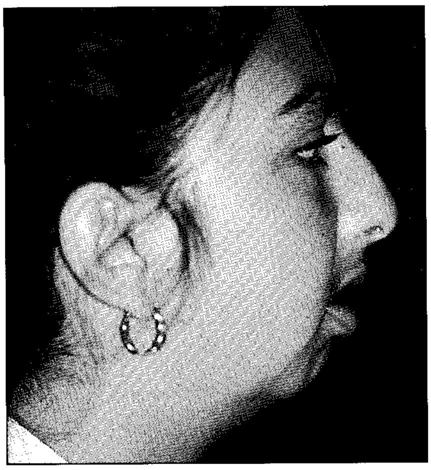


Fig 8b

Fig 8c

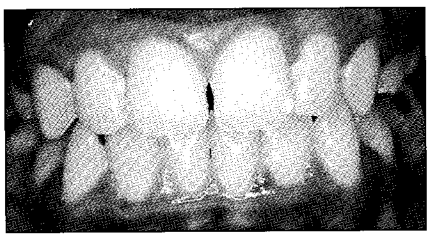


Fig 8d

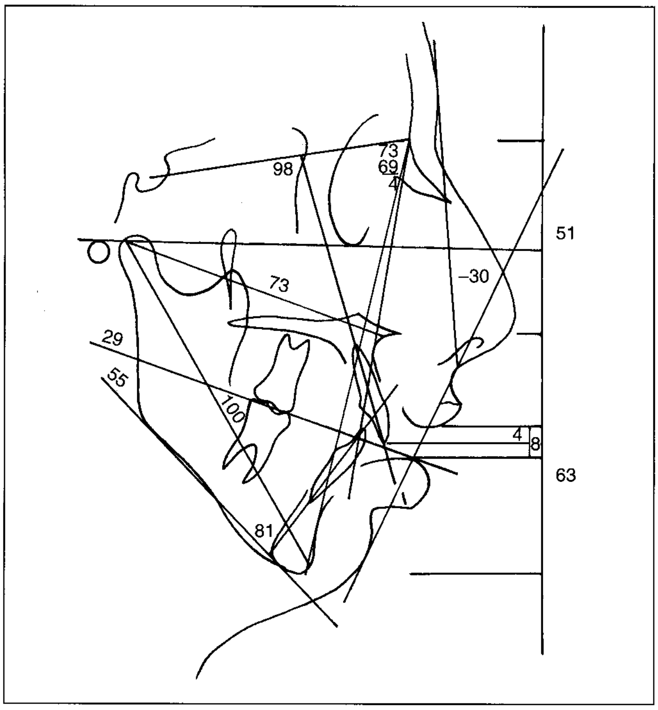


Fig 8e Pretreatment cephalometric analysis.

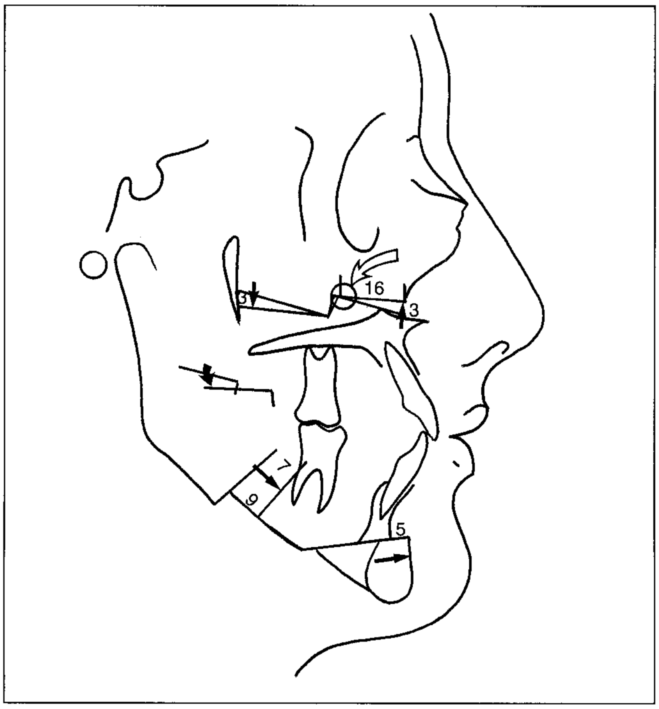


Fig 8f Surgical prediction tracing. The maxillomandibular complex is rotated in a counter-clockwise direction around a point 16 mm posterior to the piriform rim. The anterior maxilla is superiorly repositioned by 3 mm, while the posterior maxilla is downgrafted by 3 mm. The mandible is advanced, following rotation of the occlusal plane of the maxilla. The chin is advanced by 5 mm by means of sliding genioplasty.

Figs 8g to 8j Posttreatment facial appearance and occlusion.

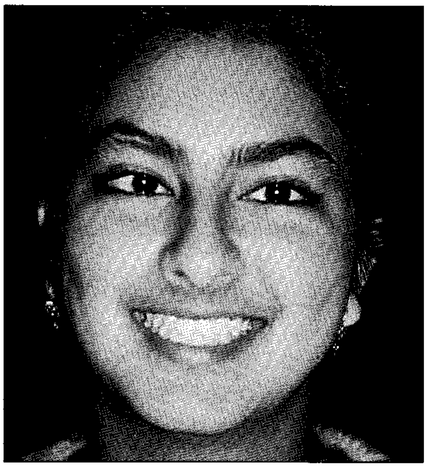


Fig 8g

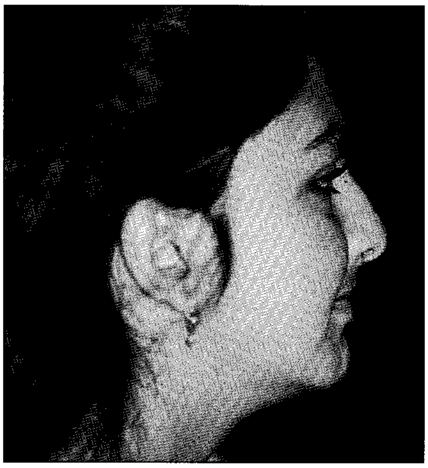


Fig 8h

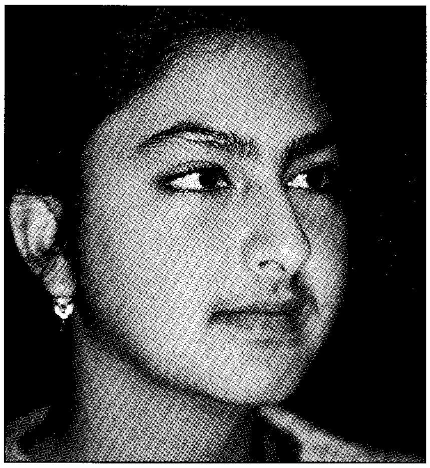


Fig 8i

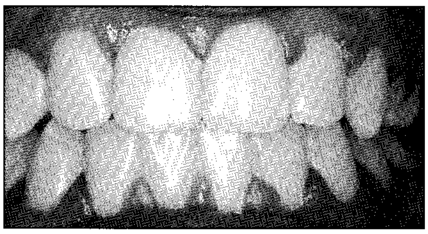


Fig 8j

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Surgical cephalometric prediction tracing for the alteration of the occlusal plane by means of rotation of the maxillomandibular complex

The surgical cephalometric prediction tracing involving the alteration of the occlusal plane differs from the conventional surgical prediction tracing. When conventional surgical prediction is developed, the final occlusal plane is dictated by the occlusal plane of the mandible, with or without autorotation. The mandible (and therefore the mandibular occlusal plane) will rotate around a point at or just posterior to the condyle. This principle is not adhered to in treatment planning requiring rotation of the maxillomandibular complex and consequent alteration of the occlusal plane. The aim of this paper is to present a method for developing a surgical cephalometric prediction tracing involving rotation of the maxillomandibular complex. (Int J Adult Orthod Orthognath Surg 1999;14:55–64)

Surgical prediction tracing is performed twice in the orthognathic treatment planning of a patient. The first prediction is done as part of the initial treatment plan, following the orthodontic cephalometric prediction of tooth movements required as part of the surgical orthodontic treatment. This surgical prediction is used, first, to determine whether the proposed surgical procedure is possible and, second, to establish whether the planned surgery will produce the desired esthetic result. At this stage the magnitude of the surgical movements is not as important as the feasibility of the proposed surgery within the limits of sound surgical principles. If satisfactory esthetic and occlusal results cannot be achieved according to the initial surgical prediction tracing, the clinician may have to alter the orthodontic treatment plan to produce the necessary tooth positions, that will in turn facilitate the desired surgical procedure for optimal esthetic and functional results. Several prediction tracings may be needed at this stage, each employing different orthodontic and surgical options.

The second surgical prediction tracing is performed at the immediate preoperative stage. At this stage the preoperative orthodontic goals will have been achieved according to the preoperative models and cephalogram. On this surgical cephalometric prediction, the magnitude of surgical movement is accurately measured, correlated with the model surgery, and recorded. Specific soft tissue changes in relation to bony repositioning is predicted and expected changes drawn.

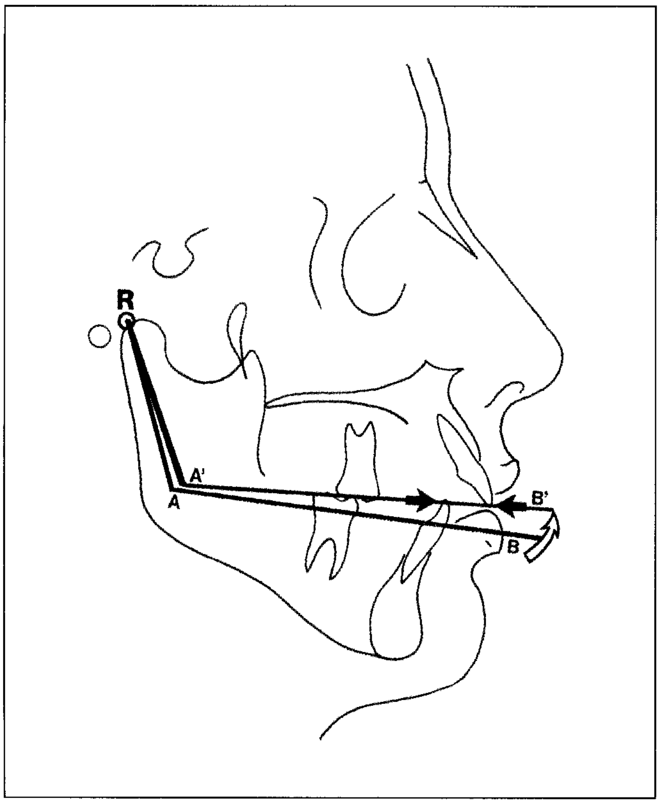

Fig 1 The maxilla has been superiorly repositioned and the mandible autorotated around a point (R) at or just posterior to the mandibular condyle. The occlusal plane has changed from AB to A'B'. Any anteroposterior corrections will take place along this "new" occlusal plane.

The method of developing a surgical cephalometric prediction tracing has been described, and the relation between hard tissue change and the expected soft tissue response is well documented.[1,2] Various adjunctive soft and hard tissue surgical procedures have also been described to enhance pleasing soft tissue results and to limit undesirable esthetic changes.[3]

The mandibular occlusal plane plays an important role in the conventional surgical cephalometric treatment planning: Where no vertical changes are planned, the maxilla and mandible can be repositioned anteroposteriorly, as indicated, along the mandibular occlusal plane. Where vertical change of the maxilla is indicated, the "new" occlusal plane will be dictated by the mandibular occlusal plane after autorotation of the mandible. This rotation takes place at or just posterior to the condyle (Fig 1). Any anteroposterior repositioning of the maxilla and mandible will take place along this "new" plane.

Alteration of the occlusal plane by rotation of the maxillomandibular complex to improve esthetic and functional results in orthognathic surgery has been documented[4-6]; however, surgical cephalometric prediction has not been described. Surgical cephalometric prediction tracing for the alteration of the occlusal plane differs from the conventional prediction tracing for double-jaw surgery.

In patients requiring rotation of the maxillomandibular complex, the final occlusal plane will not be dictated by the occlusal plane of the mandible (with or without autorotation). The rotation of the maxillomandibular complex will take place around a predetermined point.[5] This rotation point is determined during surgical cephalometric prediction tracing and influenced by the esthetic requirements of each patient.

Rotation of the maxillomandibular complex is considered as a treatment option only if acceptable esthetic and functional results cannot be achieved by means of conventional treatment planning methods.

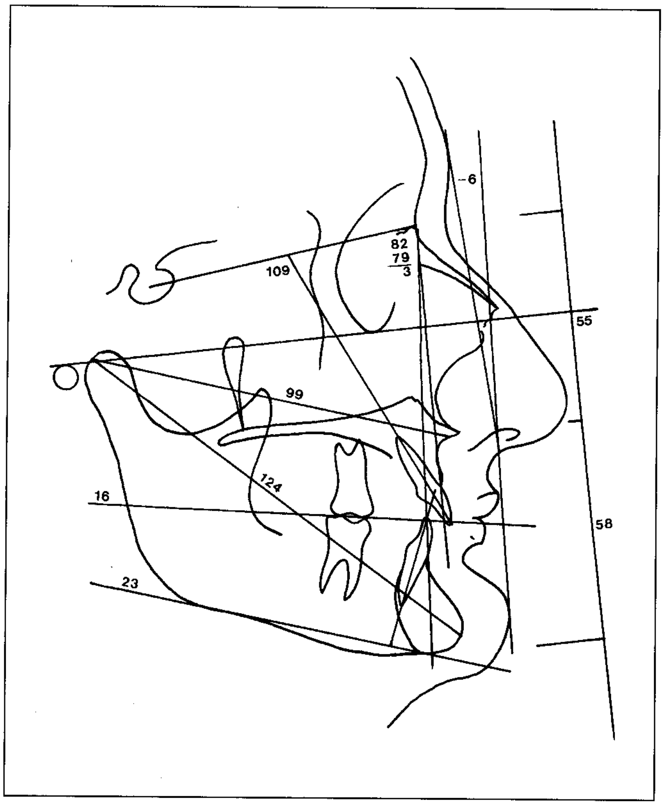

Fig 2 Presurgical cephalometric analysis of Patient 1.

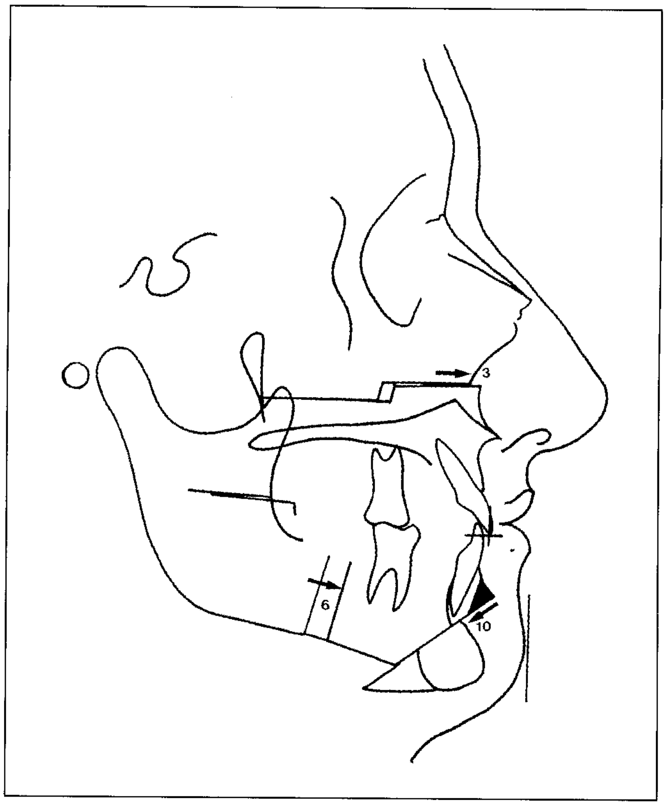

Fig 3 Surgical prediction tracing according to conventional principles. The surgery involves advancement of the maxilla and mandible and a reduction genioplasty. A large reduction genioplasty is necessary to reduce the prominence of the chin. An unesthetic chin contour, however, is achieved by obliteration of the labiomental fold and poor definition of the lower border of the mandible.

The aim of this paper is to present a method of surgical cephalometric prediction tracing involving rotation of the maxillomandibular complex and inevitable alteration of the occlusal plane. Surgical cephalometric prediction tracing involving rotation of the maxillomandibular complex in a clockwise and counterclockwise direction is demonstrated.

Method

One should be thoroughly familiar with conventional techniques for the prediction of results for the correction of dentofacial deformities and should have a good understanding of the relation between hard tissue changes and expected facial soft tissue reaction. While tables of expected average soft tissue changes are available,[1] soft tissue changes are surgeon-specific, due to individual surgical techniques and soft tissue handling. Each surgeon should, therefore, be able to predict his or her individual surgical results accurately.

Step-by-step surgical predictions for two patients are presented.

Patient 1

The presurgical cephalometric analysis of Patient 1 is seen in Fig 2. The diagnosis is *(1)* Class II occlusion, *(2)* maxillary anteroposterior deficiency, *(3)* macrogenia, and *(4)* mandibular alveolar anteroposterior deficiency. Figure 3 illustrates conventional surgical prediction

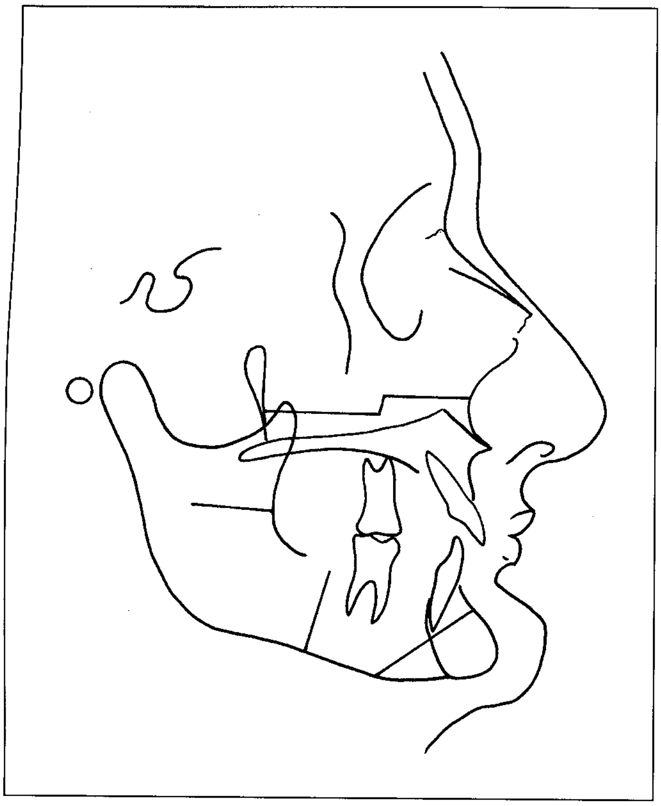

Fig 4a The original tracing of Patient 1. The intended osteotomy lines are drawn as close as possible to the actual anatomic site of the osteotomies for more accurate measuring. The horizontal and vertical osteotomy lines of the sagittal ramus osteotomy are drawn to monitor horizontal and vertical mandibular movement.

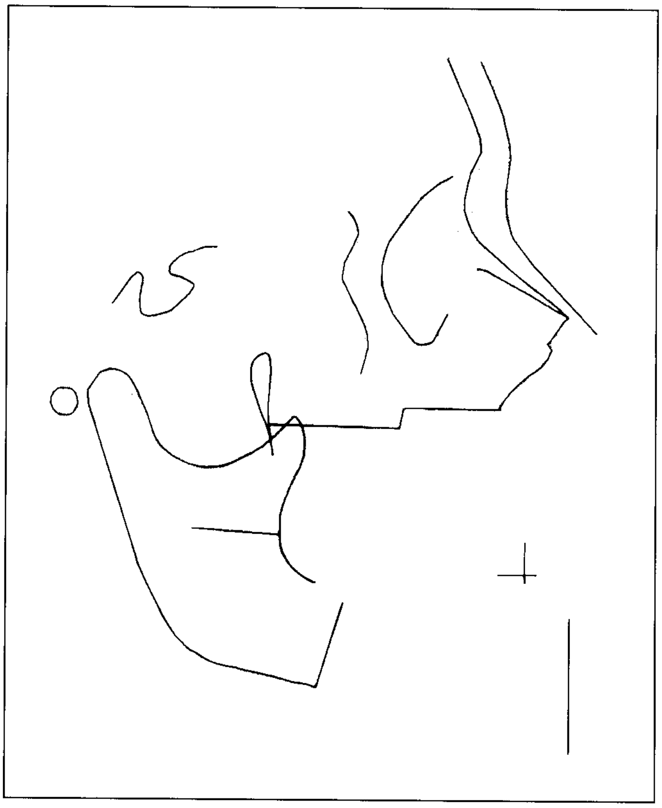

Fig 4b The prediction tracing. All the hard and soft tissue structures that will not be influenced by the surgery are traced. Guidelines for the ideal maxillary incisor position are indicated by a "box," and a vertical line is drawn to indicate the ideal anteroposterior position of the chin.

involving maxillary advancement, mandibular advancement, and reduction genioplasty. It is not possible to achieve good esthetic chin contour and acceptable anteroposterior position at the same time by means of a reduction genioplasty. The alternative of rotation of the maxillomandibular complex in a **clockwise direction** is tested by means of a surgical cephalometric prediction.

Step 1 (Fig 4a): A cephalometric tracing is performed on the immediate preoperative radiograph. This tracing will be called the original tracing (OT). Lines representing the intended osteotomies on the maxilla, mandible, and symphysis are drawn. Where no vertical change of the chin is indicated, the line is drawn horizontally, keeping the mental nerve and root apices of the mandibular teeth in mind. In this case, however, vertical increase as well as anteroposterior reduction is required. The osteotomy line should therefore be angled downward. The osteotomy lines should be drawn as close as possible to the anatomic position where the osteotomies will be performed for accurate measurement.

Step 2 (Fig 4b): Acetate tracing paper is placed over the OT, and all the structures that will not be altered by the surgery are traced. This tracing will be called the prediction tracing (PT). The ideal position of the maxillary incisor edge should be indicated on the PT by a "box," where the horizontal line indicates the ideal vertical position of the incisor tip and the vertical line indicates

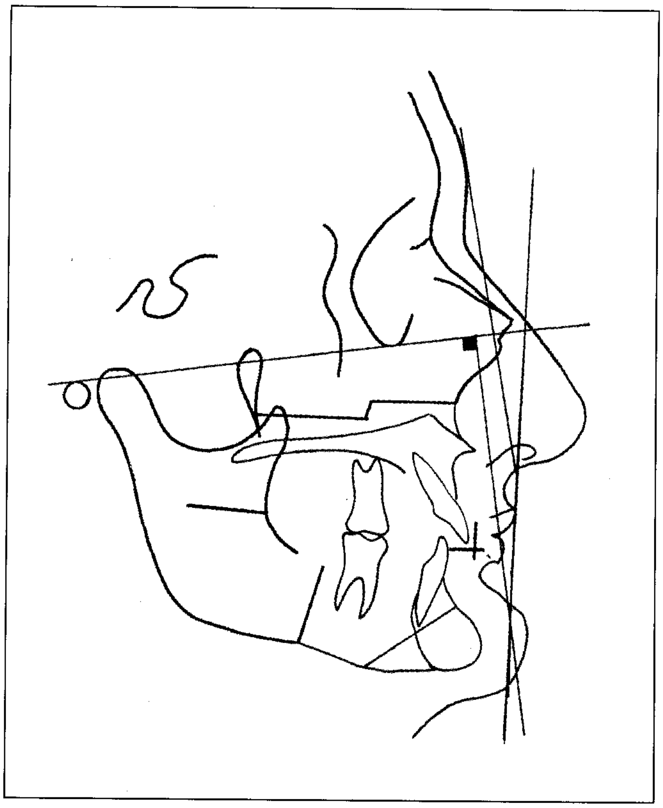

Fig 4c The facial contour, the 0-meridian, and the surgeon's clinical judgment act as guidelines to establish the ideal anteroposterior position of the chin. The ideal maxillary incisor position in relation to the upper lip is indicated by a vertical line (indicating the ideal anteroposterior position of the anterior tooth surface) and a horizontal line (indicating the ideal vertical position of the incisor tip).

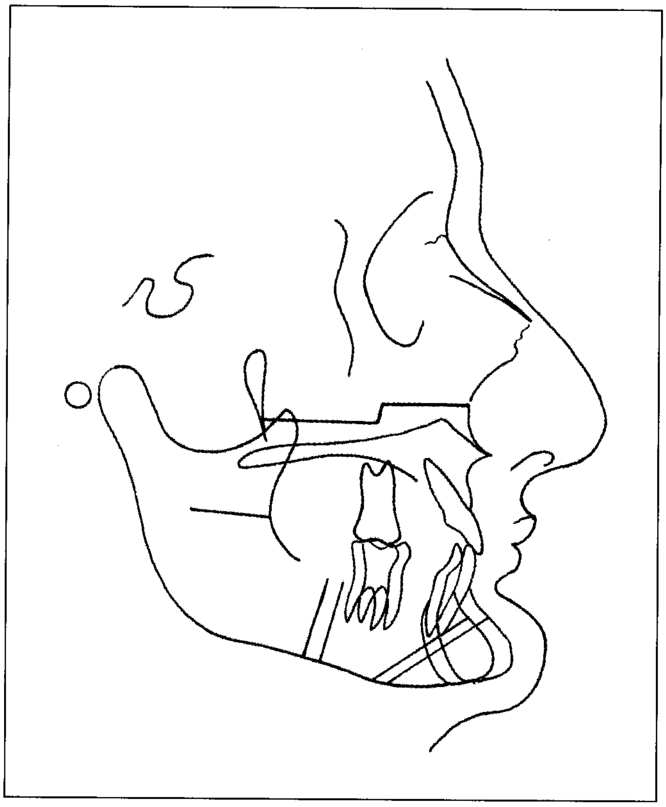

Fig 4d The maxillomandibular complex tracing (MMCT) is developed by first tracing the bone and dentition of the maxilla below the Le Fort I osteotomy line. The tracing is then moved to the left (in this case) to achieve an ideal occlusion between the maxillary teeth of the MMCT and the teeth on the OT. The mandibular teeth and bone anterior to the vertical osteotomy line are traced. The genioplasty line is also indicated on this tracing.

the ideal anteroposterior position of the anterior tooth surface relative to the upper lip. The desired anteroposterior position of the chin should also be indicated by a vertical line. Helpful guidelines in determining this line are the angle of facial convexity,[7] the 0-degree meridian,[1,8] as well as the clinician's judgment (Fig 4c).

Step 3 (Fig 4d): The PT is removed from the OT, and a new acetate paper is placed over the OT. The part of the maxilla below the Le Fort I maxillary osteotomy line is traced. The acetate paper is then moved (to the left in this case) to achieve the optimal occlusal relationship between the traced maxillary teeth and the mandibular teeth on the OT, and the mandibular teeth and the distal part of the mandible anterior to the vertical osteotomy line are traced. The osteotomy line for the genioplasty at the symphysis is retraced. The maxillomandibular complex tracing (MMCT) should be kept in this position on the OT. The MMCT is demonstrated in Fig 4e.

Step 4 (Fig 4f): The PT is overlaid on the OT. The MMCT can now be moved between the OT and PT. In this case this tracing is rotated in a *clockwise direction,* advancing the maxilla and rotating the mandible posteriorly using the box for the maxillary incisor tip and the vertical line for the chin as guidelines. A reduction genioplasty is indicated to correct the macrogenia and to increase the vertical height of the symphysis. After a satisfactory position has been achieved,

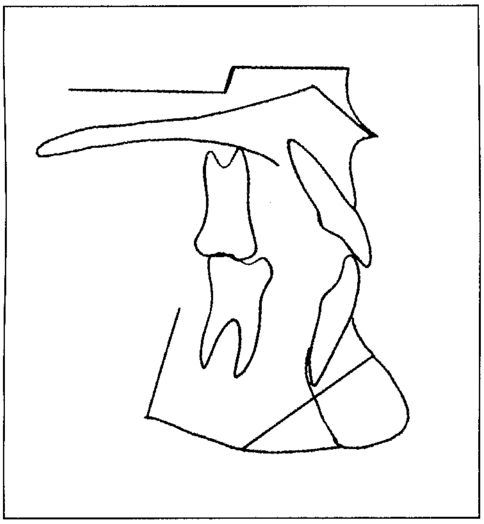

Fig 4e The maxillomandibular complex tracing.

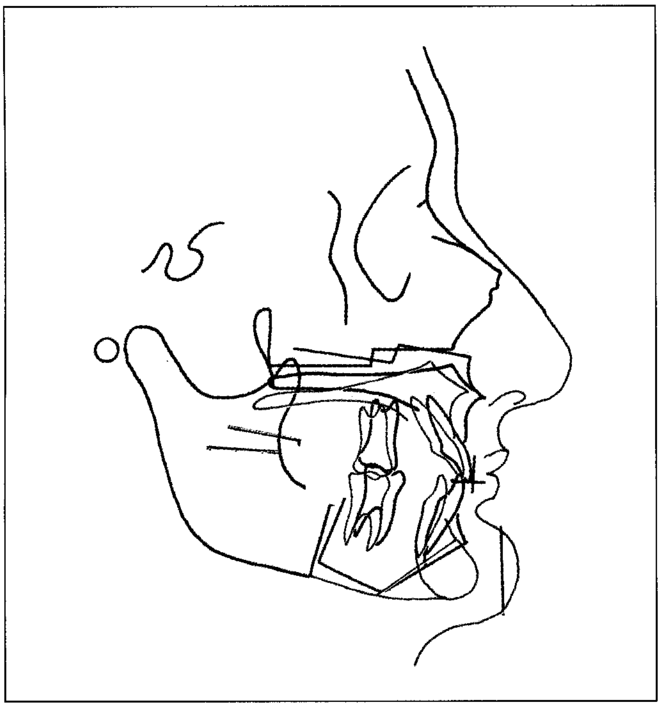

Fig 4f The MMCT is placed between the superimposed PT and the OT and rotated in a clockwise direction, guided by the "box" (indicating the incisor position) and the vertical line (indicating the chin position). The best possible position is obtained, keeping in mind that a reduction of the chin is indicated in this case. The hard tissue of the maxilla and mandible is traced. The chin below the genioplasty osteotomy line is not traced at this stage.

the maxillomandibular complex is traced on the PT. The part of the symphysis below the genioplasty osteotomy line, however, is not traced now.

Step 5 (Fig 4g): The MMCT is removed, and the PT is superimposed on the OT. Soft tissue prediction is drawn using the same principles as for conventional prediction of soft tissue response to hard tissue change.[1,2] The prediction tracing is completed by tracing the ideal soft tissue of the chin and the required reduction genioplasty (Fig 4h). In this instance a much smaller reduction is indicated than in the conventional prediction (see Fig 3), resulting in a better soft tissue chin contour.

Step 6 (Fig 4i): The predicted esthetic and functional result is evaluated. If the result is not satisfactory, changes may be indicated to improve the result. In the case demonstrated, the magnitude of the chin reduction can be reduced by increasing the rotation of the maxillomandibular complex, keeping in mind the effect of the increased advancement of the maxilla. Surgical prediction tracing, however, should always stay within the limitations of sound surgical technique.

Step 7: The point (R) where the Le Fort I osteotomy lines of the OT and PT cross each other (Fig 4i) is the point around which the maxillomandibular complex will be rotated during surgery. The exact position of the rotation point should be noted and used during the model surgery as well as during the actual surgical procedure. All jaw movements should be measured on the PT and model surgery and recorded as in conventional treatment.

A comparison of the PT of conventional treatment planning and the PT implementing rotation of the maxillomandibular complex demonstrates superior esthetics achieved by the latter (Fig 4j).

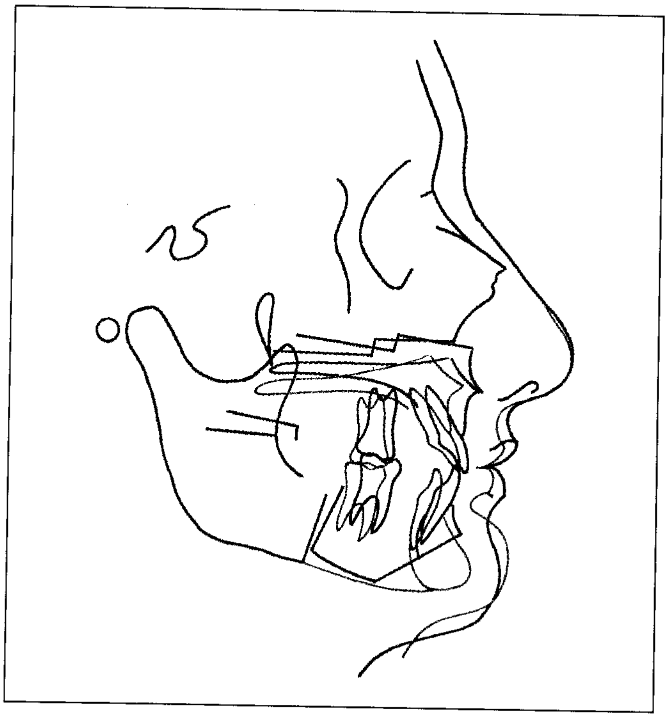

Fig 4g The PT is superimposed on the OT. The expected soft tissue change, including the ideal soft tissue position of the chin, is drawn.

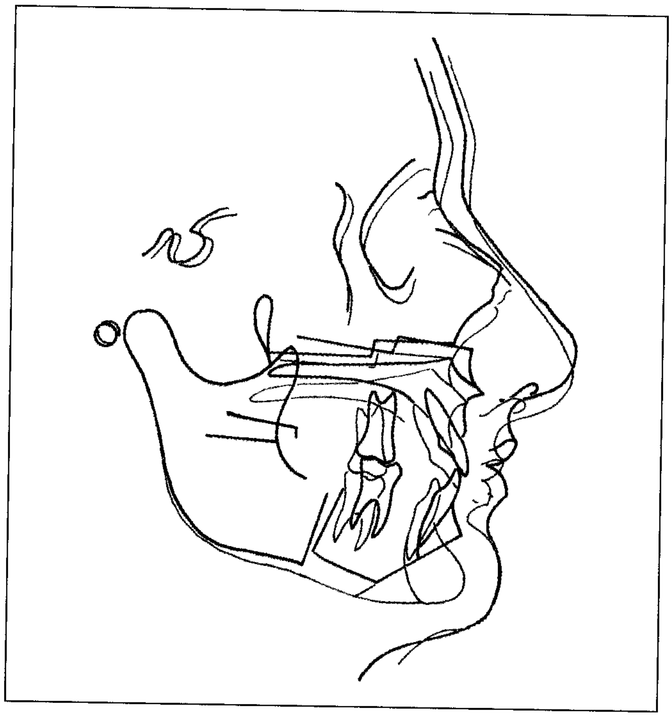

Fig 4h The PT is moved to the right to establish the required chin reduction to achieve the predicted soft tissue result.

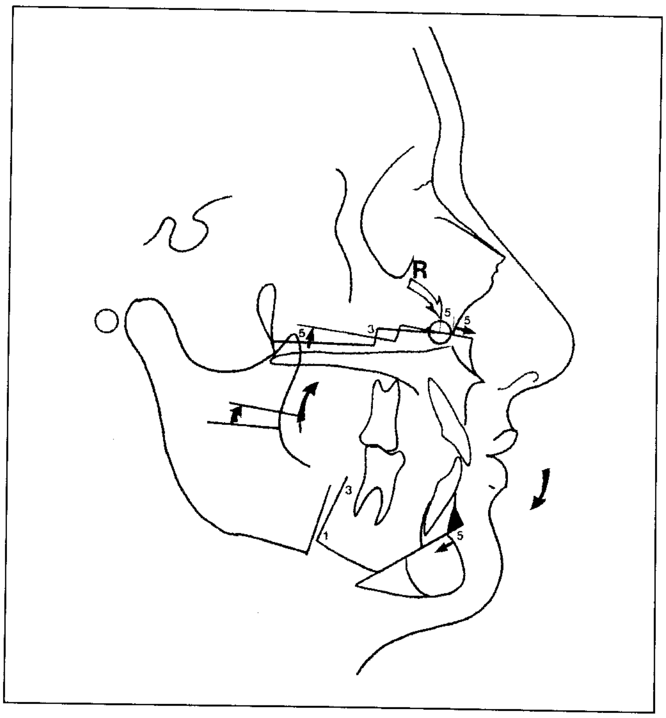

Fig 4i The completed surgical prediction tracing for Patient 1. The rotation point (R) is located at the point where the Le Fort I osteotomy lines cross, in this case 5 mm posterior to the piriform rim.

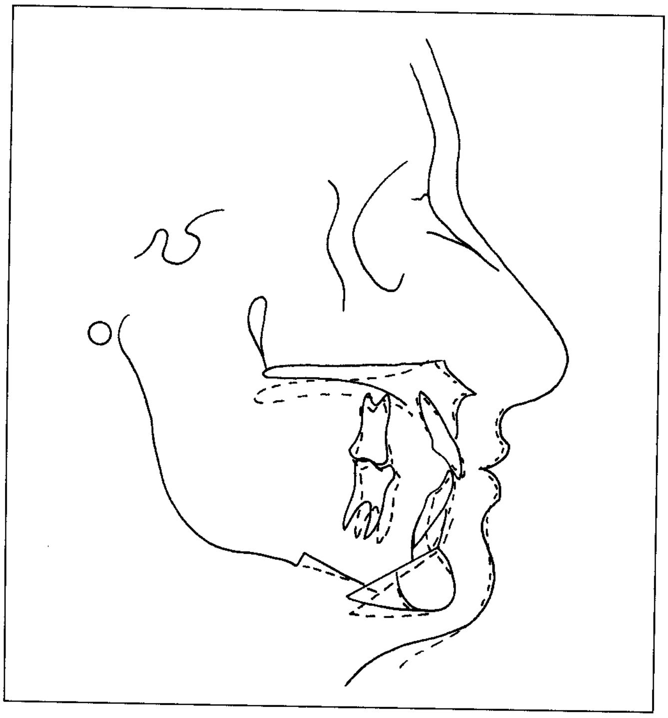

Fig 4j A composite tracing of the conventional prediction tracing *(dotted line)* and the prediction tracing involving clockwise rotation of the maxillomandibular complex *(solid line)* demonstrates improved soft tissue contour achieved with the latter.

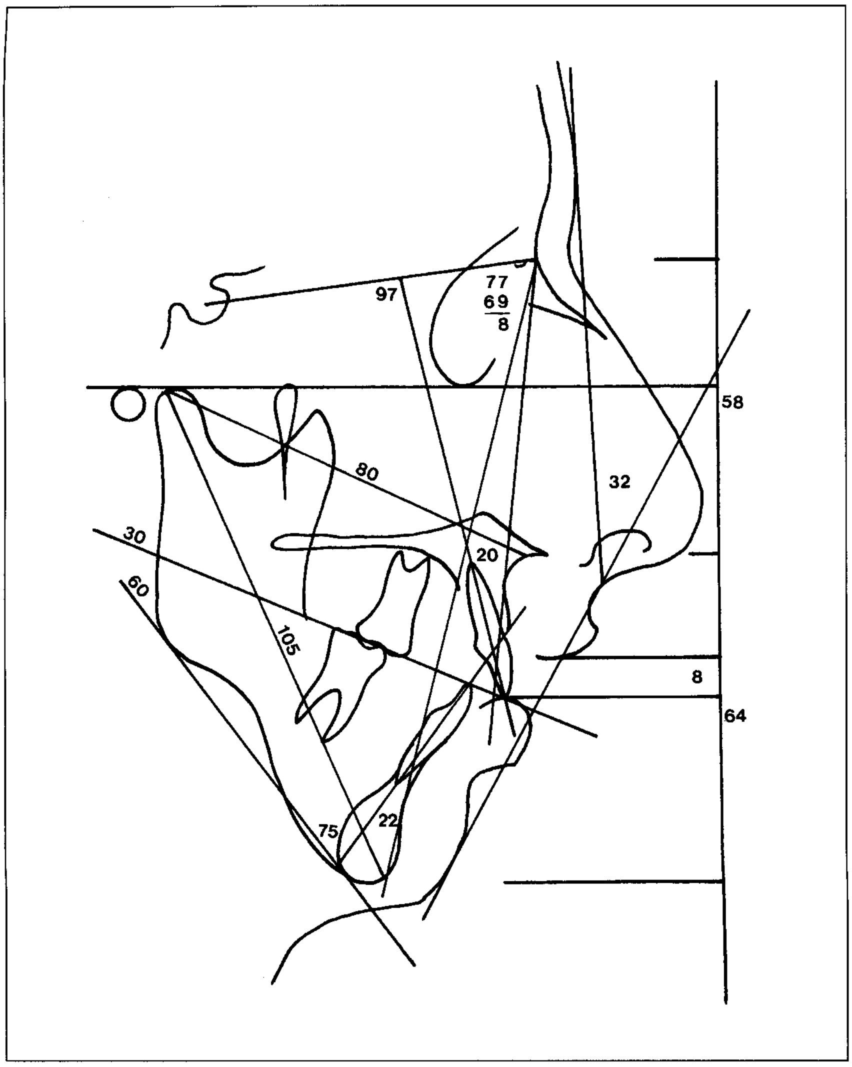

Fig 5a The presurgical cephalometric analysis of Patient 2.

Patient 2

The presurgical cephalometric analysis of Patient 2 is seen in Fig 5a. The diagnosis is *(1)* Class II occlusion; *(2)* mandibular anteroposterior deficiency; *(3)* vertical maxillary excess; and *(4)* microgenia. Treatment for this patient will involve **counterclockwise rotation** of the maxillomandibular complex.

Figure 5b illustrates the conventional surgical prediction involving maxillary superior repositioning and mandibular autorotation and advancement combined with an advancement genioplasty. For ideal chin position, the chin needs to be advanced more; however, further advancement by means of genioplasty will cause poor esthetic chin contour. The alternative of rotation of the maxillomandibular complex in a counterclockwise direction is tested by means of a surgical prediction. An improved esthetic result can be achieved, as illustrated in Fig 5c. The rotation point (R) in this case is at posterior nasal spine. The difference in results in surgical outcome is demonstrated in a composite tracing in Fig 5d.

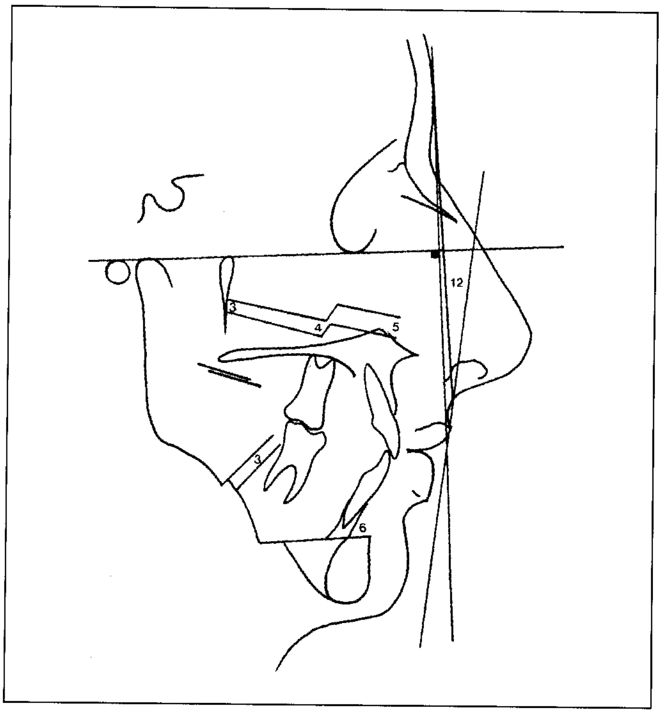

Fig 5b The surgical prediction tracing according to conventional principles. Surgery involves maxillary superior repositioning. The mandible will autorotate around a point at or just posterior to the condyle and is then advanced. The chin is advanced by means of a sliding genioplasty. The profile is still convex, and the chin is positioned too far posteriorly. Any further advancement of the chin by means of a genioplasty, however, will lead to an unesthetic chin contour.

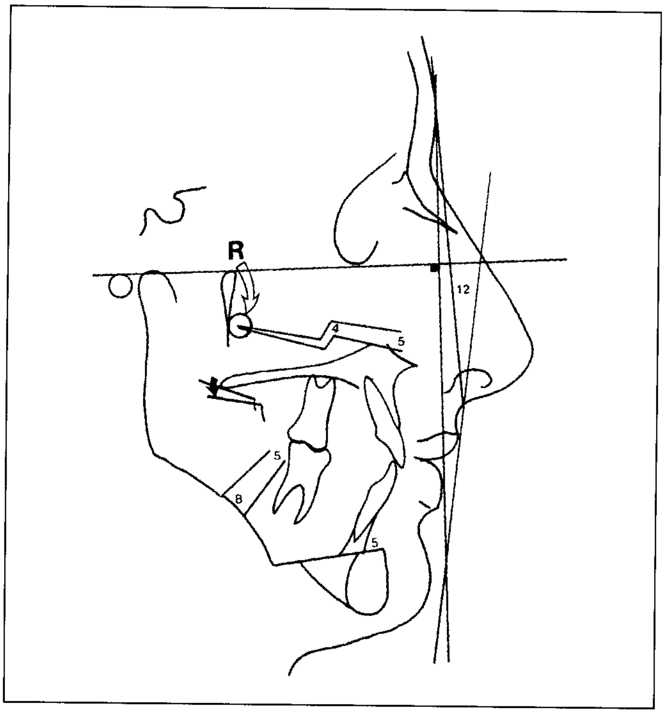

Fig 5c The surgical prediction tracing demonstrates counterclockwise rotation of the maxillomandibular complex around a point (R) at posterior nasal spine. The rotation of the maxilla enables the surgeon to advance the mandible further than with conventional planning. The anteroposterior position of the chin is acceptable and allows good soft tissue contour.

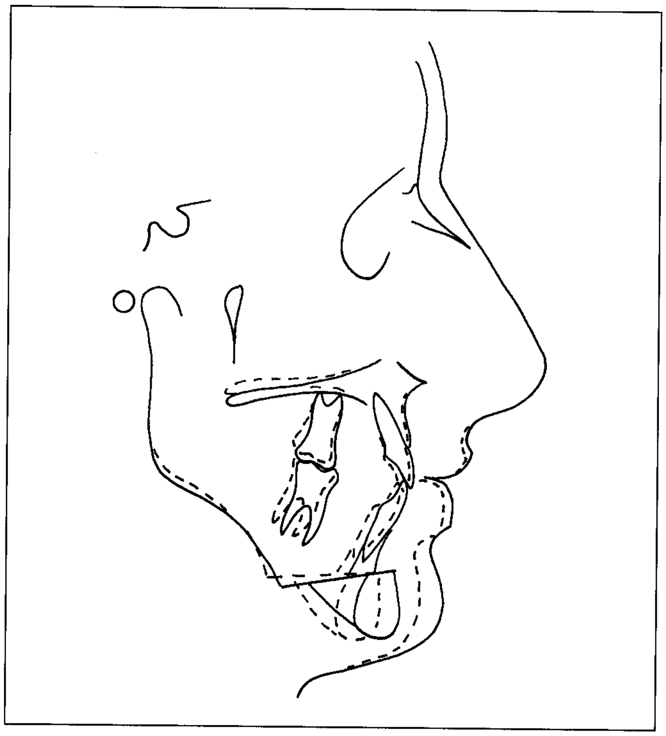

Fig 5d The difference in results is demonstrated by the composite tracing. Conventional prediction tracing *(dotted line)* is compared to the prediction tracing using rotation of the maxillomandibular complex in a counter-clockwise direction *(solid line)*.

Discussion

Although the rotation of the maxillomandibular complex is mostly indicated in patients with extreme low or high occlusal plane angles, small esthetic improvements can be made in other patients.

In double-jaw surgery where the conventional PT indicates a too strong or weak chin, a reduction genioplasty or advancement genioplasty will be indicated. Often, however, the chin contour is satisfactory and the labiomental curve ideal and will be unfavorably altered by genioplasty. A small rotation of the maxillomandibular complex may render genioplasty unnecessary, and the existing esthetic chin contour could then be maintained.

The manipulation of the occlusal plane,[5] alteration of the occlusal plane,[6] and rotation of the occlusal plane[9] are most probably misnomers, and this principle in surgical correction of dentofacial deformities should rather be called *rotation of the maxillomandibular complex*. This surgical design is by no means an attempt to correct the "abnormal" occlusal plane to a more "normal" or "average" occlusal plane angle to sella-nasion. It is also not an arbitrary change of the occlusal plane, but rather carefully planned to achieve an esthetic result that cannot be achieved by the conventional planning technique. This technique should be considered only if conventional surgical cephalometric planning fails to achieve satisfactory results.

Although the final position of the maxillomandibular complex tracing (MMCT) is guided by the desired maxillary incisor position and final chin position, paranasal esthetics should also be kept in mind during the development of the surgical visual treatment objective. It is evident that in patients with a low mandibular plane angle, the MMCT will be rotated clockwise, while in patients with a high mandibular plane angle, it will be rotated counterclockwise. The rotation of the MMCT could take place around any point on a line from anterior nasal spine to pogonion,[5] (anteriorly) or from anterior to posterior nasal spine (posteriorly). By changing the rotation point and/or the direction of rotation, different esthetic results can be achieved depending on the functional and esthetic requirements of each patient.[10] The point at which the Le Fort I osteotomy lines on the PT cross is, however, of technical importance to the surgeon, as this would be the major reference point during surgery. It is essential to record the postion of this point and maxillary movements around this point to facilitate accurate reproduction at model surgery and ultimately during surgery.

The method of cephalometric prediction tracing presented enables the surgeon to determine the point of rotation and the direction of rotation, as well as the expected esthetic and functional results.

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