

SLEEP DISORDERS

Which cephalometric analysis for maxillo-mandibular surgery in patients with obstructive sleep apnoea syndrome?

Quale analisi cefalometrica per la chirurgia maxillo-mandibolare in pazienti con sindrome delle apnee ostruttive notturne?

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SUMMARY

Maxillo-mandibular advancement MMA is considered an efficacious treatment for patients affected by severe obstructive sleep apnoea syndrome (OSAS). Even though OSAS improvement is the main goal of MMA, excessive maxillo-mandibular protrusion should be avoided to guarantee pleasant postoperative facial aesthetics. In order to attain such a result, the amount of MMA should be planned preoperatively by both aesthetic and cephalometric analyses. Steiner and Delaire cephalometric analyses are commonly used in the preoperative planning of orthognathic surgery for dentofacial deformities, however controversies still exist about the basis and postoperative aesthetic results of such cephalometric analyses in OSAS patients candidate for MMA. Forty-eight patients affected by severe OSAS were submitted to MMA. Pre- and post-operative Steiner and Delaire cephalometric tracings were assessed in each subject. For Steiner analysis, the variation in the SNA and SNB angles was measured, while for Delaire tracings the variation in the C3/FM-CPA and C3/FM-Me angles was assessed. Mean MMA was 6.9 + 3.8 mm for the maxilla and 13.6 + 5 mm for the mandible. After surgery, an improvement of the apnoea-hypopnoea index was recorded (40.47 + 7.64 preoperative vs. 12.56 + 5.78 postoperative). In all patients, both cephalometric analyses showed pre-surgical bimaxillary retrusion. After surgery, the mean value of Steiner's SNA angle increased from 78.18° to 85.58° ($p < 0.001$), while mean Delaire's C3/FM-CPA angle increased from 81.19° to 89.71° ($p < 0.001$). The mean value of Steiner's SNB angle increased from 74.33° to 80.73° ($p < 0.001$), while Delaire's C3/FM-Me angle increased from 80.10° to 87.29° ($p < 0.001$). Postoperatively, both the maxilla and mandible were in a more protrusive position ($p < 0.001$) according to Steiner analysis compared with Delaire tracing. Basing MMA on Delaire cephalometric analysis leads to an increased advancement of the maxillo-mandibular complex than Steiner tracing. The consequences of this aspect on facial aesthetics should be considered during surgical planning and preoperative informed consent in OSAS patients candidate for MMA.

KEY WORDS: Cephalometry • OSAS • Maxillo-mandibular surgery • Steiner analysis • Delaire analysis

RIASSUNTO

L'avanzamento maxillo-mandibolare (AMM) è un trattamento efficace per pazienti affetti da sindrome delle apnee ostruttive notturne (OSAS) di grado severo. Sebbene il miglioramento dell'OSAS sia l'obiettivo principale di tale chirurgia, è necessario evitare un avanzamento maxillo-mandibolare eccessivo per garantire un gradevole risultato in termini di estetica facciale. A tale scopo, è necessario programmare preoperatoriamente l'entità dell'AMM mediante un'analisi estetica e cefalometrica. Le analisi cefalometriche di Steiner e Delaire vengono comunemente impiegate nella programmazione della chirurgia ortognatica per deformità dentofacciali, tuttavia resta controverso il ruolo di tali analisi nei pazienti con OSAS candidati a AMM. Quarantotto pazienti con OSAS severa sono stati sottoposti a AMM. Abbiamo effettuato le analisi cefalometriche di Steiner e Delaire in tutti i soggetti. Per il tracciato di Steiner, abbiamo misurato la variazione degli angoli SNA e SNB, mentre per l'analisi di Delaire, abbiamo misurato la variazione degli angoli C3/FM-CPA e C3/FM-Me. L'AMM medio è stato di 6,9 + 3,8 mm per il mascellare superiore e 13,6 + 5 mm per la mandibola. Dopo l'intervento abbiamo riscontrato un miglioramento dell'Indice di Apnea-Ipopnea (40,47 + 7,64 preoperatoriamente vs. 12,56 + 5,78 postoperatoriamente). In tutti i pazienti, entrambe le tecniche cefalometriche hanno dimostrato una retrusione bimaxillare preoperatoria. Dopo l'intervento, l'angolo SNA medio è aumentato da 78,18° a 85,58° ($p < 0,001$), mentre l'angolo C3/FM-CPA medio è aumentato da 81,19° a 89,71° ($p < 0,001$). Il valore medio dell'angolo SNB è aumentato da 74,33° a 80,73° ($p < 0,001$), mentre l'angolo medio C3/FM-CPA è passato da 80,10° a 87,29° ($p < 0,001$). Postoperatoriamente, sia il mascellare superiore che la mandibola risultavano in una posizione più protrusa ($p < 0,001$) se analizzati secondo l'analisi di Steiner rispetto al tracciato di Delaire. L'utilizzo dell'analisi cefalometrica di Delaire nella programmazione dell'AMM in pazienti con OSAS comporta un avanzamento maxillo-mandibolare superiore rispetto al tracciato di Steiner. È opportuno considerare le conseguenze di tale risultato sull'estetica facciale durante la programmazione chirurgica e nel consenso informato preoperatorio in pazienti con OSAS candidati a AMM.

PAROLE CHIAVE: Cefalometria • OSAS • Chirurgia maxillo-mandibolare • Analisi di Steiner • Analisi di Delaire

Acta Otorhinolaryngol Ital 2015;35:332-337

Introduction

Maxillo-mandibular advancement (MMA) surgery is often indicated for the correction of dento-facial deformities. The ability of MMA to produce an increase in pharyngeal diameters is the anatomic-physiologic rationale of MMA for the surgical treatment of severe obstructive sleep apnoea syndrome (OSAS)¹⁻⁷. In such cases, the surgical goal is to attain the maximal advancement of the maxillo-mandibular complex – and therefore improvement of the apnoea-hypopnoea index (AHI) – while preserving pleasant postoperative facial aesthetics¹⁻³.

Patients affected by OSAS usually display a class II malocclusion and a retrusive profile^{4-5, 8}. In these subjects, MMA surgery is usually well-accepted from an aesthetic viewpoint, since the advancement of the maxillo-mandibular complex also leads to improvement of the retrusive profile. In selected situations, such as the aging face, a mild degree of skeletal overprotrusion (with respect to the theoretical cephalometric position) is usually well tolerated. Nevertheless, if the final protrusion is excessive, especially in Caucasian patients, the facial aesthetics may be less pleasing. In general, it is difficult to predict the post-surgical soft tissue profile and decide the limit that should not be exceeded to avoid unpleasant aesthetic results.

Several authors have suggested the need for cephalometric analysis in OSAS patients to provide comprehensive information regarding the postoperative harmony of the facial skeleton^{1-5, 8-16}. However, even harmonious skeletal support does not always result in an aesthetically

desirable profile of facial soft tissues¹⁴⁻¹⁶. Despite these limitations, the use of cephalometric analyses in surgical planning for OSAS patients is common^{1-5, 8-11}. Most plannings use the planes and angles derived from Steiner cephalometric analysis^{1, 2, 9, 11, 17-19}, whereas other authors suggest using Delaire analysis²⁰⁻²³. Even though both Steiner and Delaire cephalometric analyses describe the ideal relationship of the facial skeleton in the sagittal and vertical dimensions, some differences between them exist: in Steiner analysis, the sella-nasion (SN) line is used as the reference plane, while SNA and SNB angles are measured to assess the maxillary and mandibular anterior positions (Fig. 1). In Delaire cephalometric analysis, the C3 plane is used as the horizontal reference, while maxillary and mandibular anterior positions are assessed by FM-CPA and FM-Me (with respect to C3 plane) (Fig. 2). Even though the cephalometric principles of Steiner and Delaire analyses in orthognathic surgery for dentofacial deformities are well known, controversies still exist about the basis and postoperative aesthetic results of such cephalometric analyses in OSAS patients who are candidates for MMA.

The aim of this prospective study is to compare the outcomes of these two methods of analysis based on a broad sample of surgical OSAS cases. This paper addresses the following questions: do Steiner and Delaire preoperative cephalometric analyses provide the same skeletal and soft tissue facial assessment? Do they lead to any difference in surgical planning and results? And if so, which analysis is advisable when planning MMA surgery in OSAS patients?

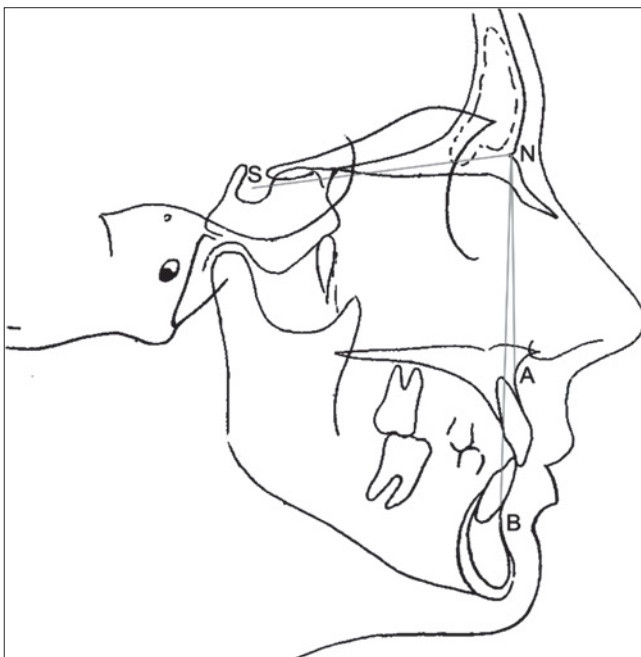


Fig. 1. Steiner cephalometric analysis: maxilla and mandible evaluations.

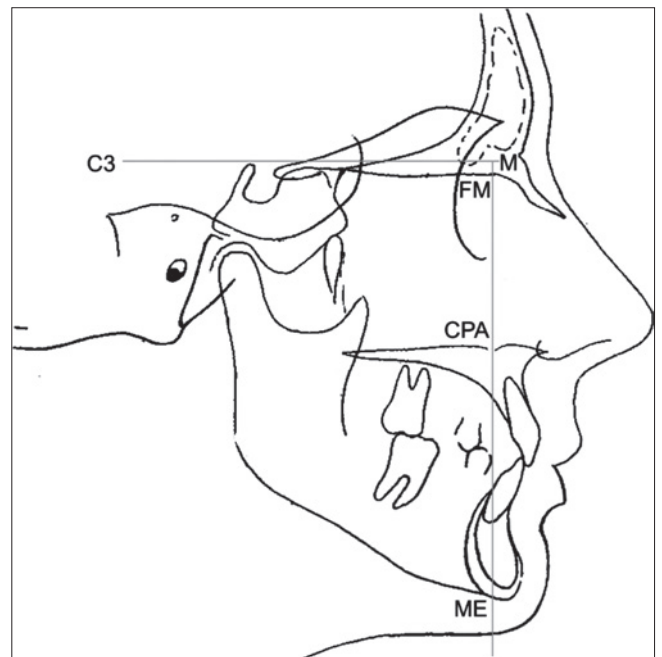


Fig. 2. Delaire cephalometric analysis: maxilla and mandible evaluations.

Materials and methods

A prospective analysis of 48 consecutive OSAS patients submitted to maxillo-mandibular surgery between 2000 and 2013 was carried out. All patients were male and had a mean age of 45.7 years (range: 21-67). The patients were submitted to MMA for severe OSAS at the Department of Maxillofacial Surgery, Parma University Hospital. Inclusion criteria were: 1) preoperative severe OSAS (AHI \geq 30) diagnosed by polysomnography; 2) availability of good quality pre- and post-surgical lateral telerradiographies of the cranium; 3) patients' ability to understand and sign a written informed consent to be submitted to MMA.

The updated version of AASM Manual for Scoring Sleep and Associated Events was used to correctly assess the AHI index. According to the AASM, an apnoea/hypopnoea event is defined as a decrease in airflow of \geq 30% (by a valid measure of airflow) lasting \geq 10 sec, associated with either \geq 3% desaturation from the pre-event baseline or an arousal²⁴⁻²⁸.

The aesthetic balance of facial profile was evaluated according to Rosen's criteria²⁹. In Rosen's surgical strategy, when a final biprotrusion is necessary, an acceptable aesthetic outcome is defined as the appropriate balance among the relative projection of subnasal, upper and lower vermilions and chin points²⁹.

All patients were submitted to MMA. Preoperative antibiotic prophylaxis (amoxicillin/clavulanate 2.2 g i.v.) was administered. Analgesic therapy (ketoprofen) and steroids (dexamethasone) were administered as needed. The amount of MMA surgery was planned preoperatively in agreement with the aesthetical considerations of facial skeletal expansion criteria proposed by Rosen²⁹.

Anatomical tracings of the pre- and post-surgical (6 months postoperatively) radiographs were drawn by an expert operator. All anatomical tracings were digitised and differences in image magnification, when present, were eliminated using appropriate software (Corel Photo-paint 11.0). On the magnification-normalised anatomical tracings, the same expert tracer carried out measurements according to Steiner and Delaire analyses to assess the antero-posterior positions of the maxilla and mandible.

For Steiner analysis, we measured:

- Maxilla. SNA: the angle between the sella/nasion plane and the nasion/A plane (normal value at the end of growth $82 \pm 2^\circ$). This angle assesses the antero-posterior position of the maxilla relative to the upper cranial structures.
- Mandible. SNB: the angle between the sella/nasion plane and nasion/B plane (normal value at the end of growth $80 \pm 2^\circ$). This angle assesses the antero-posterior position of the mandible relative to the upper cranial structures.

For Delaire analysis, we measured:

- Maxilla. The angle between C3 and FM-CPA line. In this analysis, C3 represents the ideal horizontal plane: it is drawn between M point (nose-fronto-maxillary suture point) and posterior clinoid apophysis, and is parallel to the ethmoid's lamina cribra. The fronto-maxillary (FM) point is located along C3 plane immediately above the anterior lacrimal crest and under the bony crest in the frontal sinus floor. The CPA point is located at the anterior edge of the upper limit of the nose-palatal foramen. Normally, at the end of growth, this angle is 90° in males and 85° in females. This angle assesses the position of the maxilla and the pre-maxilla in relation to the upper cranial structures.
- Mandible. The angle between C3 and FM-Me line. The Me point is located at the junction between the image of the symphysis and mandibular body. Normally, at the end of growth, this angle is 90° in males and 85° in females. This angle assesses the position of the mandible relative to the upper cranial structures.

Statistical analyses were performed using the Statistical Package for Social Sciences Software (SPSS 10.0 for Windows; SPSS, Inc., Chicago, IL) and STATA 7 (Stata Corp., College Station, TX). Data are shown as mean and standard deviation (SD). Parametric (Student's t-test) test was used to compare different values. Statistical significance was considered when $p < 0.05$ (two tailed).

Results

All 48 patients submitted to MMA were discharged 3 to 5 days after surgery. No complications (i.e. bleeding, plate fractures, etc.) were noticed. In our sample, the mean MMA was $6.9 + 3.8$ mm for the maxilla and $13.6 + 5$ mm for the mandible. After surgery, we observed statistically significant ($p < 0.001$) improvement of the AHI index vs. preoperative conditions with a final score under 20 in all patients.²³ In particular, mean AHI decreased from $40.47 + 7.64$ preoperatively to $12.56 + 5.78$ postoperatively. When comparing Steiner and Delaire cephalometric analyses, several differences between pre- and post-surgical assessment and skeletal balance were noted.

Pre-surgical analysis

- Maxillary position.* In our sample, the mean pre-surgical value of SNA according to Steiner analysis was 78.18° . The 3.82° difference with regards to mean normal value ($82 \pm 2^\circ$) reveals a maxillary displacement of approximately two standard deviations behind the ideal position. The mean value of CPA-FM to C3 angle according Delaire analysis was 81.19° : an 8.81° difference with regards to normal values (90°), indicating severe maxillary posterior displacement.
- Mandibular position.* Among our patients, the mean pre-surgical SNB value was 74.33° . The 5.67° differ-

Table I. Pre- and post-surgical position of the maxilla and mandible assessed with Steiner and Delaire analyses. According to Steiner tracing, maxillary and mandibular positions were determined with SNA and SNB angles, respectively. Basing on Delaire analysis, maxillary and mandibular positions were determined with C3/FM-CPA and C3/FM-Me angles, respectively. The statistical (t-test) comparison between pre- and post-operative maxillary and mandibular position is reported for each cephalometric analysis.

	Steiner analysis			Delaire analysis		
	Preoperative (degrees)	Postoperative (degrees)	p	Preoperative (degrees)	Postoperative (degrees)	P
Maxilla	78.18 + 2.75	85.58 + 3.79	< 0.001*	81.19 + 3.59	89.71 + 3.49	< 0.001*
Mandible	74.33 + 4.73	80.73 + 3.89	< 0.001*	80.10 + 4.86	87.29 + 4.46	< 0.001*

* Statistically significant.

ence compared with mean normal value ($80 \pm 2^\circ$) reveals severe mandibular posterior displacement. The mean value of Me-FM to C3 angle was 80.10° : a 9.90° difference with regards to normal values (90°), indicating severe mandibular posterior displacement (Table I).

Post-surgical analysis

- a) *Maxillary position.* After surgery, the mean value of Steiner's SNA angle increased from 78.18° to 85.58° , with a 7.40° increase. Mean Delaire's CPA-FM to C3 angle increased from 81.19° to 89.71° , with an 8.52° angular advancement. A statistically significant increase was seen according to both cephalometric analyses (Table I). When comparing postoperative maxillary position with respect to the ideal parameters according to Steiner and Delaire analyses, the maxilla is in a more protrusive position ($p < 0.001$) with Steiner analysis than with Delaire tracing (Table II).
- b) *Mandibular position.* After surgery, the mean value of Steiner's SNB angle increased from 74.33° to 80.73° , with a 6.4° advancement. Delaire's Me-FM to C3 angle increased from 80.10° to 87.29° , with a 7.19° advancement. A statistically significant increase was seen by both cephalometric analyses (Table I). When comparing postoperative mandibular position with respect to the ideal parameters according to Steiner and Delaire analyses, the mandible is in a more protrusive position ($p < 0.001$) according to Steiner analysis with respect to Delaire tracing (Table II).

Table II. Evaluation of postoperative maxilla and mandible position with respect to the ideal parameters according to Steiner and Delaire analyses. Maxillary and mandibular positions were determined with SNA and SNB angles, respectively, for Steiner tracing. For Delaire analysis, maxillary and mandibular positions were determined with C3/FM-CPA and C3/FM-Me angles, respectively. The difference between postoperative maxillary/mandibular position and their ideal location according to the different cephalometric analysis was calculated (t-test). Notice the postoperative more protrusive position of the maxilla and mandible according to Steiner analysis compared with Delaire tracing; * statistically significant.

	Steiner analysis (degrees)	Delaire analysis (degrees)	p
Maxilla	3.58 + 3.79	-0.29 + 3.49	< 0.001*
Mandible	0.73 + 3.90	-2.71 + 4.46	< 0.001*

Discussion

Maxillo-mandibular advancement has proven to be effective for surgical treatment of severe OSAS thanks to its ability to produce tongue advancement and an increase in pharyngeal diameters¹⁻⁷. In these patients, the surgical goal is to attain the maximal advancement of the maxillo-mandibular complex while preserving pleasant facial aesthetics¹⁻³.

Despite the efficacy of MMA to improve the AHI, controversies still exist about the amount of advancement required and preoperative planning in OSAS patients. In our common practice, the MMA surgical planning is generally based on Rosen's aesthetic criteria, since no cephalometric analysis has been shown to constantly predict postoperative aesthetical outcomes of soft tissues³⁰⁻³³. According to this approach, the amount of MMA is determined on the basis of the maximal biprotrusion attainable while preserving a pleasant facial soft tissue profile according to Rosen's criteria²⁹. Since the definition of a pleasant profile as a surgical target can make preoperative planning difficult and subjective, in our study we drew pre- and post-operative Steiner and Delaire cephalometric tracings in all our patients submitted to MMA to compare the results with aesthetic planning based on Rosen's criteria. No significant difference between Steiner and Delaire analyses was found in pre-surgical diagnoses: both Steiner and Delaire tracings revealed a class II biretrusive starting position in our patients. The defect was evaluated as slightly more severe for Delaire than for Steiner analysis for both the maxilla and mandible. When examining post-surgical maxilla position, Steiner analysis showed a mean maxillary overcorrection by 3.56° , while according to Delaire analysis it was within the normal range. The final position of the mandible, in contrast, was normal for Steiner analysis, while according to Delaire tracing, the chin could have tolerated a mean further advancement of 2.71° with respect to normal values. These results suggest that the final position of the maxillo-mandibular complex was judged as slightly protrusive by Steiner and retrusive for Delaire analysis. Therefore, when related to Rosen's aesthetical criteria, the surgical limit suggested by Steiner tracing was more protrusive than that obtained with Delaire cephalometry. These different results may be relat-

ed to the fact that, even though both Steiner and Delaire cephalometric analyses describe the ideal relationship of the facial skeleton in the sagittal and vertical dimensions, their cultural bases were different^{1 2 9 11 17-23}:

- a) Steiner and Delaire published in different times and environments: Steiner in the USA between 1950 and 1960, while Delaire worked in France between 1970 and 1980. The concept of the aesthetically ideal face was slightly more protrusive in the 70-80s than in 50-60s. Therefore, they adopted different normal values.
- b) Steiner's and Delaire's professional backgrounds were different: Steiner was an orthodontist, whereas Delaire was a maxillofacial surgeon. This may explain the difference in key points, angles and planes considered by the two authors. In particular, they used different horizontal ideal planes (SN for Steiner vs. C3 for Delaire) and measured maxillary/mandibular positions by analysing different points (surface points A and B for Steiner vs. deeper areas CPA and Me for Delaire).

These differences do not affect the ability of either cephalometric analysis to provide diagnostic and treatment support in OSAS patients, although Steiner analysis is more adherent to the final aesthetic balance proposed by Rosen²⁹. In MMA surgery, the risk consists in excessive bimaxillary advancement. According to our results, the adoption of Delaire analysis leads to a higher risk to attain this undesirable result than Steiner tracing. For this reason, we suggest avoiding Delaire analysis in preoperative planning for MMA. On the contrary, our results suggest that basing MMA planning on Steiner cephalometry offers more predictable results from an aesthetic viewpoint and can simplify the surgeon's decisions. Finally, our experience confirms the efficacy of MMA in attaining improvement in the AHI in severe OSAS patients. It also underlines the close connection between aesthetics and function in OSAS subjects submitted to MMA surgery. As already shown by three-dimension cephalometry, the posterior airway space (PAS) is related to maxillomandibular position, which influences the aesthetic appearance of the face as well: function and aesthetics are concomitant consequences of the same surgical procedures in these subjects³²⁻³³. Maxillomandibular advancement surgery in OSAS patients causes both a PAS volume increase and variations of facial profile³⁴. This aspect should be considered by the physician and patient when planning OSAS surgery.

Conclusions

Basing MMA preoperative planning on Steiner tracing leads to more predictable and desirable postsurgical facial aesthetics than Delaire analysis. Therefore, Steiner tracing is preferable to Delaire analysis when planning MMA in OSAS patients.

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Received: September 19, 2014 - Accepted March 8, 2015