A "Forced Symmetry": Surgical Planning Protocol for the Treatment of Posterior Facial Asymmetries

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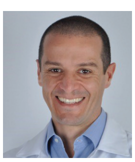

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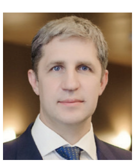

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Abstract

Dentofacial deformities are usually treated surgically and virtual hard tissue simulation has been advised for increasing the accuracy of hard tissue repositioning. However, asymmetric patients in addition to different lateral projections of hard tissues (i.e. gonial angles or parasymphyseal areas) may also exhibit a noticeable difference in surrounding soft tissue thickness that may be underdiagnosed. Consequently, symmetrical positioning of the hard tissue framework will not guarantee postoperative soft tissue symmetry. In this paper we introduce a new surgical planning protocol called "forced symmetry" that allows us to predict final soft tissue symmetry by mimicking facial symmetry using clinical rotation of the mandible in unoperated patients. Double cone-beam CT scanning allows surface-based superimposition of virtual head models in centric relation and in forced relation. The resultant composite head model reveals the target lateral projection of proximal fragments that guarantees the best soft tissue symmetry in the gonial areas.

Keywords
facial asymmetry, orthognathic surgery, three-dimensional virtual planning, gonial angle

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BACKGROUND

Studies usually only take the chin and nose areas into consideration for the measurement and correction of facial asymmetry[1,2]. *Zhanga et al.*[3] observed that a deviation of 2 mm or more from the facial midline makes females less attractive than their peers. Facial imbalance due to mandibular asymmetry is difficult to plan when there is a difference in lateral projection of hard tissues, e.g., gonial angles. A difference in the lateral projection of the gonial angles may be obvious and perceived as asymmetry and was observed to be quite noticeable in asymmetric patients[4].

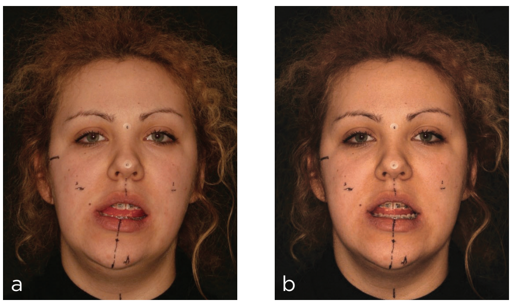


Figure 1: A 21-year-old female patient with Class III occlusion and hemimandibular elongation in: (a) centric relation with wax-bite registration, and (b) a forced symmetry position (note correction of posterior facial asymmetry).

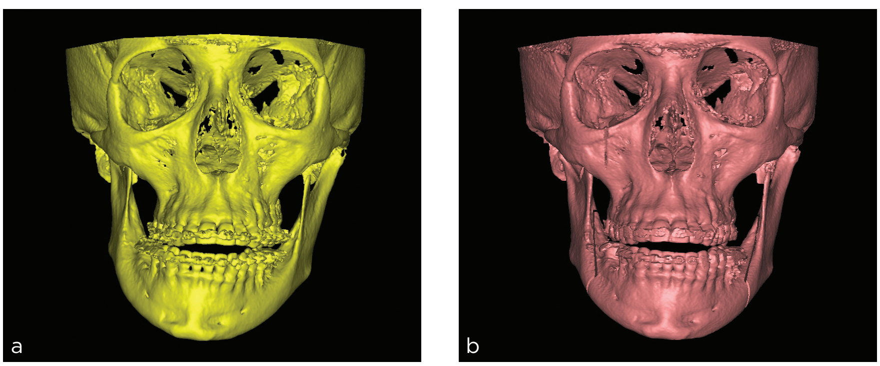
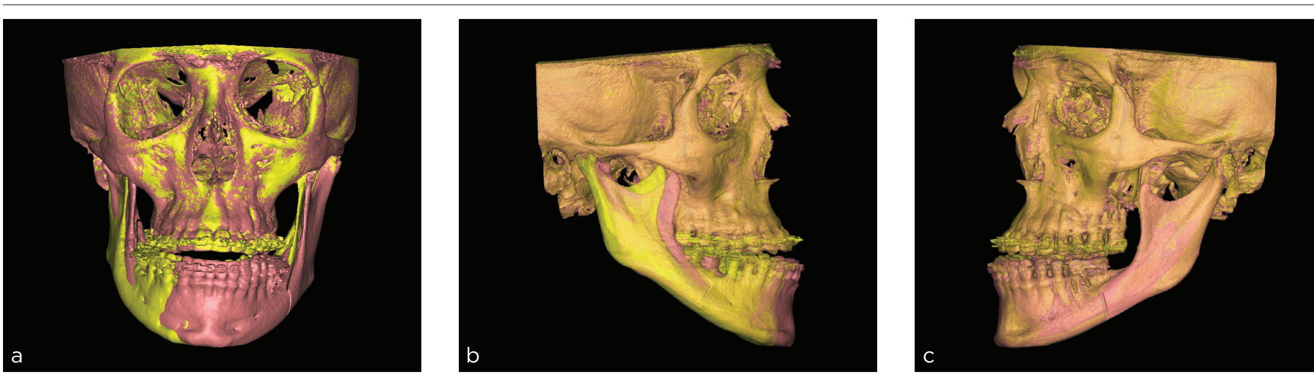


Figure 2: Virtual skull model: (a) centric relation, (b) forced symmetry position.

Hard tissue three-dimensional (3D) virtual treatment planning is common in contemporary orthognathic surgery, mainly due to its accuracy compared to two-dimensional (2D) cephalometric measurement[5,6]. In some asymmetric patients, hard tissue 3D simulation and virtual centering to the midsagittal plane may be insufficient if soft tissue thickness on both sides varies. *Gao et al.*[7] reported that the main difference in asymmetric patients is located at the level of the bone, with soft tissue thickness being more symmetrical than the bone. Consequently, hard tissue repositioning around the face midline should be followed by good soft tissue adaptation. However, if soft tissue thickness is not equal bilaterally, a residual soft tissue asymmetry may be noticed. *Kwon et al.*[8] determined the bilateral difference in muscle volume in asymmetric patients with mandibular prognathism compared to symmetric patients. Data on soft tissue thickness changes in gonial areas after orthognathic surgery are sparse, although according to *Lee*[1], soft tissue thickness does not change during long-term follow-up.



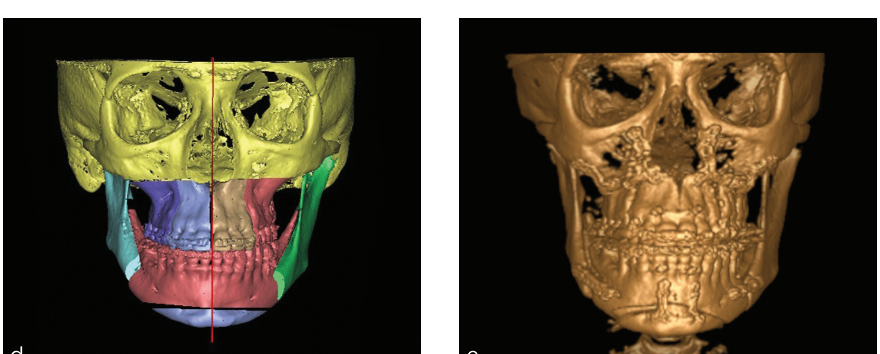


Figure 3: Virtual treatment planning: (a) superimposition of two virtual skull models rendered from centric relation (yellow) and forced symmetry (purple) cone-beam computed tomography (CBCT) scans; (b) transparent right profile view (note the amount of movement required for correction and right condyle displacement from the mandibular fossa); (c) transparent left profile view, with the left condyle remaining in the glenoid fossa; (d) virtual 3D plan; (e) actual CBCT outcome.

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Figure 4: Surgery outcome: (a,b) facial front photographs before and 4 years after surgery; (c,d) occlusal photographs before and 4 years after surgery.

If a noticeable residual asymmetry at the gonial angles remains after orthognathic surgery, additional interventions may be required to enhance the weaker side[9] or reduce the stronger side[10,11] through either surgical[12-14] or non-surgical[15-19] methods.

Soft tissue asymmetry can be corrected either by non-surgical or surgical modification of soft tissue thickness, or by positioning the hard tissue without altering the soft tissue using 'reverse soft tissue treatment planning'.

METHODS

The 'forced symmetry' protocol

Planning the correction of facial asymmetry can be simplified by clinical simulation to minimize or correct posterior facial asymmetry. The mandible is rotated in the axial plane and a new starting point for the planning procedure is established. The patient is asked to rotate their jaw in order to move the chin to the facial midline and make the soft tissue gonial angle areas appear as symmetrical as possible. It does not matter if the chin deviation is corrected, undercorrected or overcorrected, as the objective of this simulation is the correction of soft tissue symmetry in the posterior face. The non-centric forced symmetry (FS) position is recorded and serves as a starting point for the entire planning procedure.

Indications:

- Any posterior asymmetry in gonial angle areas that can be simulated into symmetry through rotation of the mandible in the axial plane.

Contraindications:

- Small posterior asymmetries, in which small transverse changes are needed, allowing clinical decisions to be made with high accuracy.
- Anterior facial asymmetries without asymmetry in the posterior area, when any rotation of the mandible in the axial plane to correct the anterior asymmetry results in worsening of the posterior asymmetry.

Workflow:

1. The patient is positioned in an upright position in front of the examiner. Gradual rotation of the lower jaw in the axial plane is actively performed by the patient until the soft tissue in gonial angle areas acquires the most symmetric position. The interrelationship of the dental midlines is noted and will later be reproduced during the bite registration procedure.
2. The patient is positioned in the supine position. Two bite registers are created. First, bite registration in centric relation (CR) with first tooth contact is performed *(Fig. 1a)* using bimanual manipulation of the mandible as advocated by *Dawson*[20].
3. Second, an FS position is reproduced by rotating the relaxed mandible passively until the lower dental arch achieves an interrelation with the upper dental arch recorded in step 1. A new registration wax-bite is used to register this position *(Fig. 1b)*.
4. Two cone-beam computed tomography (CBCT) scans are performed (I-Cat Next Generation; Imaging Sciences International, Hatfield, USA). The first scan is a high definition scan that is routinely performed for all patients before orthognathic surgery with CR wax-bite registration (16 × 22 cm scan, voxel size 0.3 mm, tube voltage 120 kVp, tube current 5 mA). This scan must include the entire maxillofacial area from the glabella to the hyoid bone and from the nasal tip to the middle cranial base. The second scan is a low radiation exposure scan with FS wax-bite registration (13-22 cm scan, voxel size 0.3-0.4 mm, tube voltage 120 kVp, tub current 5 mA). This scan must include the upper and lower jaws, and preferably the zygomatic arches and zygomatic bones - anatomical structures that do not change position are at a distance from each other and from the mandible and may be used for superimposition of the two scans. A low dose scan is performed because all that is needed from this scan is information on the macro-anatomy and the transverse position of the lower jaw in forced relation. Virtual head models are created for both CBCT scans using Simplant Pro software (Version 14.0; Materialise Dental, Leuven, Belgium) or any other 3D planning software. In the CR head model, posterior facial asymmetry and well-seated condyles can be observed, whereas in the FS head model, the posterior facial asymmetry has been compensated for by jaw rotation, but one of the condyles has been displaced from the glenoid fossa because the mandible has been rotated.
5. Upper and lower model casts are scanned separately as are the CR and FS wax bites (3Shape D700; 3Shape, Copenhagen, Denmark). Two pairs of STL files are exported from the optical scanner

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software (OrthoAnalyzer; 3Shape, Copenhagen, Denmark).

6. Models scanned in FS are imported into Simplant software and superimposed on the virtual head model in FS. Models scanned in CR are imported into Simplant software and superimposed on the virtual head model in CR. CBCT teeth are replaced with scanned teeth in both files *(Fig. 2a,b)*.
7. FS and CR virtual head models are superimposed on the skull and upper teeth m*(Fig. 3a-c)*. This is achieved by loading 3D objects from the forced relation head model into the CR head model in the software. It must be emphasized that one of the condyles is displaced from the glenoid fossa in the forced relation CBCT scan. This displacement is associated with the jaw registration process in the symmetric position only and in the virtual planning process, but does not occur at surgery. When surgery is initiated on the lower jaw first, the mandible is split on both sides, and the teeth-bearing (distal) segment is put into an intermediate splint and wired to the upper dentition, while both condyle-bearing (proximal) segments are seated in the glenoid fossae and plated to the teeth-bearing fragment.
8. The position of the gonial angles on the FS virtual head model is used as a template for transverse positioning of the proximal fragments on the CR virtual head model. The position of the teeth-bearing segment is defined by a CAD/CAM intermediate splint that is rendered between the initial position of the upper teeth and the repositioned lower teeth. During surgery, the positions of proximal segments are reproduced free hand from the 3D virtual plan based on the exact relationship of the distal and proximal segments and contact points or gaps that must be maintained between the segments. However, there is often not much freedom at this point since the transverse positions of the proximal segments are controlled by the transverse position of the distal segment that is in turn determined by the CAD/CAM splint.

RESULTS

Figs. 1-6 demonstrate the workflow of the 'forced symmetry' planning technique that has been used for more than 50 patients in our practices. The post-treatment radiological data and clinical photographs can be used to assess the results obtained with this technique.

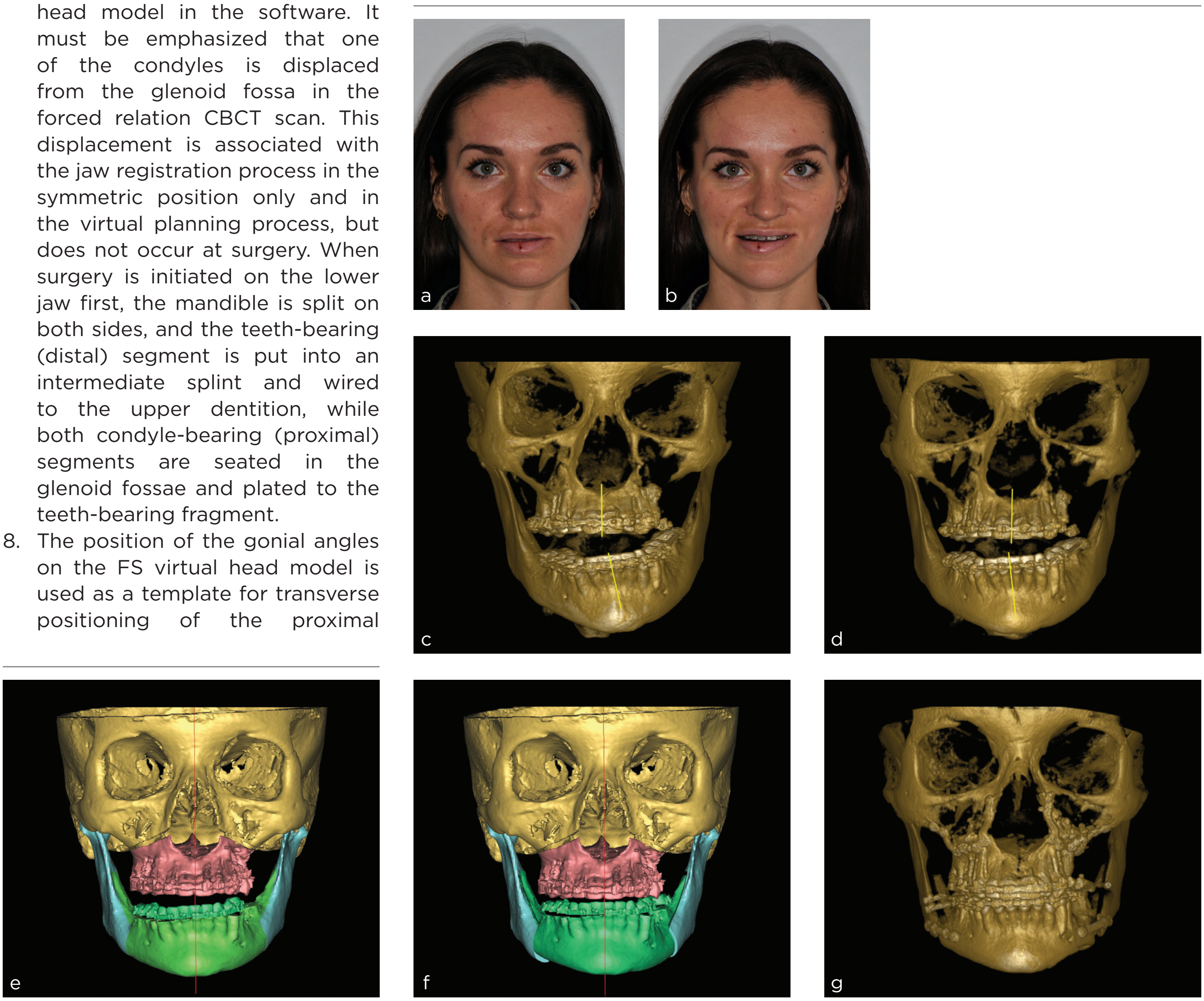

Figure 5: A 27-year-old female patient with Class III occlusion, partial adentia and hemimandibular elongation: (a,b) facial front view of the patient in centric relation and forced symmetry positions (note the improved facial symmetry at gonial areas in the forced symmetry position); (c,d) cone-beam computed tomography (CBCT) scans performed in centric relation and forced symmetry positions; (e) virtual planning: the mandible in the forced symmetry position allows osteotomy to be planned; (f) distal fragment moved to the planned position and proximal fragments maintained in the forced symmetry position; (g) CBCT scan after surgery.

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DISCUSSION

Orthognathic surgery can considerably improve facial asymmetry but further technique refinement is still required[21]. 3D virtual planning provides valuable information that helps errors common during face-bow transfer to be avoided or an intermediate splint in the articulator to be constructed[22].

A recent study on the perception of facial asymmetries concluded that orthodontists, maxillofacial surgeons and laypersons are able to notice a 2 mm side deviation at the tip of the nose and a 4 mm side deviation at the chin level in a frontal view[23]. However, chin and gonial angle differences are the most significant factors affecting assessment of facial asymmetry[24]. The masticatory muscles play an important role in facial asymmetry as they may present differences in thickness when both sides are compared. *Kwon et al.*[8] showed that asymmetric patients have a wider gonial angle and greater hemimandibular volume on the longer side with less pterygoid muscle volume, reflecting differences in the spatial anatomy of a skeletal structure. *Goto et al.*[25] reported that patients with mandibular laterognathism have a smaller ipsilateral masseter muscle as compared to a control group, suggesting that latero-deviation initiates an adaptive process in the entire jaw system, resulting in extensive atrophy of the jaw muscles. Data on soft tissue thickness changes in gonial areas after orthognathic surgery in asymmetric patients are sparse. Many studies on asymmetric patients do not include soft tissue alteration at the gonial angle, and only consider soft tissue around the nose, chin[1,2,26], lip and incisor teeth. A study by *Hagënsli et al.*[27] found that treatment results were positively ranked by more than 50% of patients even if asymmetry had not been completely corrected. This finding is controversial, although *Vasconcelos et al.*[28] stated that the patient's perception of their condition must be taken into account. Soft tissue changes after surgery are not always as expected[29]. *Lee* and *Yu*[30] investigated the masseter muscles of Class III asymmetric patients after orthognathic surgery and reported that muscle measurements showed no significant differences compared with a control group during a 4-year follow-up period. This suggests that soft tissue thickness does not adjust when the hard tissue framework is centered. Consequently, hard tissue symmetry may not always guarantee soft tissue symmetry if soft tissue thickness is different between the two sides of the face.

Differences were observed in the responses of thick and thin soft tissue at the midline (lips, nose and chin) after bimaxillary procedures[31], while soft tissue was reported to respond favorably to hard tissue correction in asymmetric patients[1]. *Gao et al.*[7] stated that simultaneous surgery to correct soft tissue and bone should be avoided as soft tissue is more symmetrical bilaterally than bone (i.e. bone is more asymmetrical than soft tissue). Similarly, *Yañez-Visco et al.*[32] concluded that the angulation of the mandibular ramus in the frontal and lateral planes determines apparent facial asymmetry, but did not evaluate soft tissue at the mandibular angle so their findings are restricted to hard tissues as usual[33-35].

It should be noted that small rotations of the mandible in the axial plane if not controlled during surgery cause changes in projections of the gonial angles and can cause asymmetry. Subsequently, when properly controlled, restitution of the symmetry of gonial angle areas can return symmetry to the face[36].

The FS protocol facilitates reverse treatment planning, where soft tissues dictate the position of hard tissues. It requires two CBCT scans: one in CR and the other in FS. The FS scan in our study provided data on the transverse position of the bones that make soft tissue appear symmetrical; however, one of the condyles is displaced from the glenoid fossa due to the forced relation of the

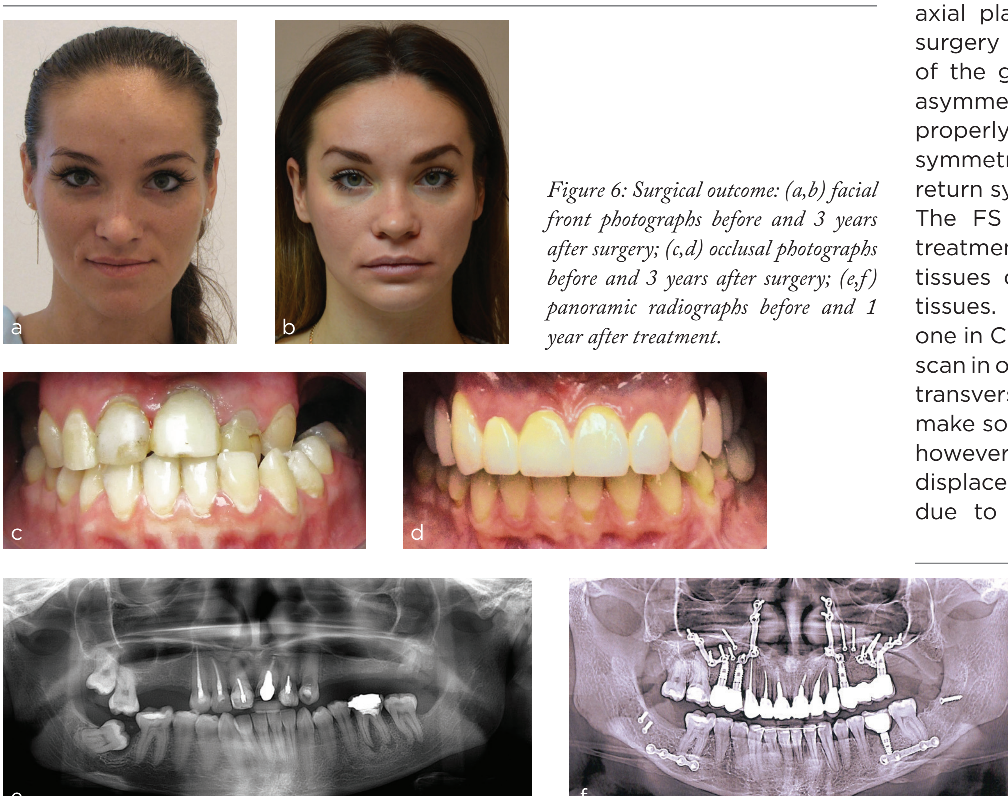

Figure 6: Surgical outcome: (a,b) facial front photographs before and 3 years after surgery; (c,d) occlusal photographs before and 3 years after surgery; (e,f) panoramic radiographs before and 1 year after treatment.

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mandible. Displaced condyles make a "maxilla-first" surgical approach impossible and so a "mandible-first" approach is mandatory if the main virtual planning is performed using a forced relation scan. A second CBCT scan in CR reveals the true position of the condyles in CR and facilitates both surgical protocols. Once superimposed on the cranial base and maxilla, the composite virtual head model provides all necessary information: the original condylar position (in the CR CT scan) and the desired transverse position of the proximal fragments (in the forced relation CT scan). The possibility of a perfect surgical outcome to an extensive surgical procedure justifies the double exposure. Although the effective CBCT dose must be considered and carefully controlled, it is important to remember that during a full skull scan CBCT effective doses range from 87 to 206 QSv as compared to multi-slice CT where they range from 474 to 1160 QSv[37,38]; in addition, the effective dose is continuously decreasing with the new generation of CBCT scanners. It is important to note that the forced relation scan can be performed in low dose mode and with a smaller volume since only the transverse position of gonial angles to be superimposed on the CR virtual head model is required. Our technique is based on clinical evaluation of the patient before surgical planning and on simplification of the planning process achieved by reducing facial asymmetry through clinical simulation of symmetry, thus allowing all surgical planning to be initiated from a new starting point. As far as we know, this is the first time that surgical planning based on a non-CR of the mandible has described in the literature.

Advantages:

- The forced symmetry protocol guarantees posterior facial symmetry provided symmetry can be successfully simulated by the patient through rotation of the lower jaw in to the middle of the face.

Disadvantages:

- Two cone-beam computed tomography scans are required for this protocol, however the risk-benefit ratio justifies the use of this protocol provided that the surgical procedure is planned and accurately performed from the very beginning.
- Planning using the forced symmetry protocol takes approximately 20% more time than regular virtual planning.

Future research:

- The behavior of asymmetric soft tissues in the gonial areas following orthognathic surgery has not be clarified.
- The forced symmetry planning protocol was developed under the assumption that the soft tissue thickness ratio between the sides remains the same after surgery.
- It is also not known if the technique could be limited to a single cone-beam computed tomography scan in forced symmetry relation while the centric relation (CR) position of the bones is reproduced from optical scans of dental models put into CR.
- The accuracy of the described technique should be validated.

CONCLUSIONS

The "forced symmetry" protocol may serve as a useful tool for planning the correction of posterior facial asymmetries. It can be used for patients with posterior asymmetries with different hard tissue projections and soft tissue thicknesses between the two sides of the face.

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