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Soft tissue response and facial symmetry after orthognathic surgery

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ABSTRACT

Objective: In orthognathic surgery aesthetic issues and facial symmetry are vital parameters in surgical planning. Aim of this investigation was to document and analyze the results of orthognathic surgery on the base of a three-dimensional photogrammetric assessment, to assess the soft tissue response related to the skeletal shift and the alterations in facial symmetry after orthognathic surgery.
Patients and methods: In this prospective clinical trial from January 2010 to June 2011, 104 patients were examined who underwent orthognathic surgery due to mono- or bimaxillary dysgnathia. The standardized measurements, based on optical 3D face scans, took place one day before orthognathic surgery (T1) and one day before removal of osteosynthesis material (T2).
Results: Soft tissue changes after procedures involving the mandible showed significant positive correlations and strong soft tissue response ($p < 0.05$). The midfacial soft tissue response after maxillary advancement was only of minor extent ($p > 0.05$). The facial surfaces became more symmetric and harmonic with the exception of surgical maxillary expansion, but improvement of facial symmetry revealed no statistical significance.
Conclusion: Soft tissue response after orthognathic surgery and symmetry are only partially predictable, especially in the maxillary and midfacial region. Computer programs predicting soft tissue changes are not currently safely reliable and should not be used or with caution to demonstrate a patient potential outcome of surgery.

1. Introduction

In the planning of skeletal orthognathic correction, aesthetics and matters of attractiveness are of vital importance to the patients. A retrospective analysis of 299 patients at the University Hospital Muenster showed that for 49.5% of the women and for 34.7% of the male patients aesthetics and looks were one of the determinative reasons for surgical intervention (Wesseling, 2004).

To allow for optimal functional and visual results the surgical planning should be based on reliable prognostic methods (Aboul-Hosn Centenero and Hernández-Alfaro, 2012; Donatsky et al., 2009; Falter et al., 2012). So far the diagnosis and surgical preparation are based on techniques that come with restrictions in terms of detailed imaging and depth of focus. In general they are associated with radiologic diagnostics and radiation exposure (Kim et al., 2013; Park et al., 2013, 2012; Yáñez-Vico et al., 2011).

The current three-dimensional measurement systems have not gained acceptance for routine use yet due to either enormous technical charges or a high radiation.

The aim of this investigation was to enhance the prognostic predictability of the outcomes of orthognathic surgery. The analysis of the soft tissue response to skeletal movement was the underlying technique. A three-dimensional optical measurement system was applied, that is based on the fringe projection technique and does not depend on an X-ray technique.

In general symmetry is assessed by portrait photography, symmetrical deviations in all three dimensions can thus be not analyzed.

Another tool used to analyze symmetry and to make a prognosis of soft tissue response of patients' faces is based on a laser technique (Shimomatsu et al., 2012). Holberg et al. compared laser-

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based profile predictions to an established 2D-technique relying on cephalometric data. Whereas laser-based prognosis came with a mean variation of 0.32 mm regarding the horizontal plane the 2D prediction showed a mean deviation of 0.75 mm and thus was clearly inferior (Holberg et al., 2005).

Comparable investigations underlined the fact that a calculation of soft tissue response is extremely difficult and highly unreliable. Joss et al. see the problems in poor study designs and a lack of standardized measurement techniques. Another crucial point is the enormous individual variability of the soft tissue response depending on different morphology, thickness and elasticity of the tissues (Joss et al., 2010).

In this study a three-dimensional symmetry index (3D-SI) was established to objectively compare facial symmetry before and after orthognathic surgery. The relevant questions were:

Is there a significant correlation between sagittal soft tissue response and skeletal movement based on the orthognathic planning?
Is orthognathic surgery able to increase and improve facial symmetry?

2. Material and methods

2.1. Patients and investigations

For this prospective study orthognathic patients with planned surgical correction of dysgnathia over a one and a half year period (from January 2010 to June 2011) were recruited consecutively, including all forms of dysgnathia and operative procedures. Exclusion criteria were age below 18 years, unwillingness to participate in the study and those with orthognathic operations prior to the newly planned procedure. All patients gave their informed written consent for participating in this study and the study was performed in accordance with the guidelines for good clinical practise (GCP).

In addition to general health status and characteristics of the dysgnathia, the planned translocation was assessed with The University of Muenster model surgery system for orthognathic surgery (KD-MMS)", as described below. One day before operation a preoperative face scan was performed and the preoperative three-dimensional (a-)symmetry index (3D-SI) was calculated (see description below). Postoperative assessment by face scan took place one day before removal of osteosynthesis material to prevent confounding due to swelling, and the postoperative 3D-SI was calculated. For 12 distinct facial points, change (distance in mm) was measured between pre- and postoperative face scan. All these procedures are described in more detail in the following section of the paper.

2.2. Assessment of dental and skeletal jaw movement

The distance of movement of the jaws through the orthognathic procedure was planned according to KD-MMS (Ehmer et al., 2013; Wiechmann et al., 1997). With the use of plaster casts, exact three-dimensional positioning of maxilla and/or mandible was planned preoperatively and formed the basis for the splints used intraoperatively. Philosophy and procedures of this system were previously described in detail (Ehmer et al., 2012).

As a result of the KD-MMS tool, exact planned movement of distinct points of the upper and lower dental arch and jaw can be measured. For the purposes of this study, only the sagittal changes of the following 5 points in each jaw (10 points in total) were considered for further analysis: right first molar, right cuspid, centre (midline, between incisors), left cuspid and left first molar. Negative distances mean a setback procedure, positive values represent forward movements/advancement.

2.3. 3D scanning system

The 3D scanning system is based on the fringe projection technique and has been developed at the Department of Prosthetic Dentistry and Biomaterials at the Westfalian Wilhelms University of Muenster and its technique and principles were described previously in detail (Bischoff et al., 2007; Dirksen et al., 2002; Westhäuser et al., 2008). The system enables a three-dimensional face scan with accurate skin colour assessment (true colour rgb model) using only normal visible light without any type of ionizing radiation. Over 1.5 s 200,000 to 800,000 3D-points can be assessed. Measurement accuracy of these 3D-coordinates is approximately 0.6 mm in *X*-axis and 0.2 mm in *Y*-axis within a field of 600 mm × 450 mm.

2.4. Calculation of the 3D-symmetry index (3D-SI)

For objective assessment and measurement of asymmetry, a special three-dimensional Symmetry Index (3D-SI) was calculated on the basis of the optically acquired data as follows:

The procedure is based on the proposals of a research group at the University of Erlangen (Hartmann et al., 2007; Nkenke et al., 2006). First the original 3D-dataset ("original cloud") is mirrored automatically at the median–sagittal plane to generate a "mirrored cloud". Afterwards, the original and mirrored cloud are matched. Registration is performed automatically by the software, using an iterated-closest-point-algorithm that matches both clouds with the lowest achievable distance from each other. The 3D-SI is calculated from the mean of all distances between original and mirrored cloud (a) and the cross-section dimension of the face (d) to overcome differences between smaller and greater faces, using the following formula: $\mathbf{3D\text{-}SI = (a/d) \times 1000}$.

In a perfectly symmetric face, the 3D-SI would be 0. The greater the value of the 3D-SI is, the more asymmetric is the face. This easy to calculate symmetry index therefore enables an objective assessment of facial symmetry. In previous studies we proved a good correlation of the 3D-SI with perceptually judged symmetry and attractiveness (Krückemeier, 2013).

For visualization of asymmetries, a false-colour image can be generated, showing the asymmetric regions of the face in warmer colours (yellow and red, see Fig. 1).

2.5. Measurement of profile changes

To assess profile changes of the facial soft tissue after the orthognathic operation, pre- and postoperative face scan clouds were also matched to each other. A rough overlap was made manually by marking 7 corresponding points (medial and lateral canthus of both eyes, nasal tip and left and right angle of mouth). For fine adjustment, areas assumed not to be affected by the operation (orbita and eyes, brows and forehead) were matched to each other for minimal distance between each other by a computed iterative algorithm. Different section planes were generated: 3 vertical section planes perpendicular to the bipupillary plane (through the left pupil, through the median–sagittal plane in the half of the bipupillary distance and through the right pupil) and 4 horizontal planes parallel to the bipupillary plane (and therefore perpendicular to the vertical planes) through the mediansagittal points *Subnasale* (SN, junction between nasal columella and upper lip), *Upper Lip* (UL, most anterior point of the upper lip), *Lower Lip* (LL, most anterior point of the lower lip) and *Pogonion molle* (PM, most anterior point of