3D cephalometry: a new approach for landmark identification and image orientation

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Abstract— **Cephalometry is the scientific study of the measurement of the head in relation to specific reference points. In 3D CT cephalometry, these points are identified on three-dimensional surface models generated from computed tomography scans. In this study a new approach for 3D cephalometry is presented, which should improve reproducibility of the technique and allow accurate comparison of pre- and postoperative data.**

I. INTRODUCTION

Cephalometry is the scientific study of the measurement of the head in relation to specific reference points. Based on these points various distances, angles, lines and planes are calculated. The technique is mainly used for diagnosis, treatment planning and outcome evaluation in orthodontics and craniofacial surgery.

Traditionally, lateral (and frontal) radiographs have been used to identify the reference points (also called landmarks). However, since these are 2D representations of a 3D structure, it is not straightforward to study complex abnormal anatomies such as asymmetrical cases. Therefore, interest for 3D CT cephalometry has risen over the last two decades. Using this technique, landmarks are identified on three-dimensional surface models generated from computed tomography scans.

The most common way to do this is by manual point-picking. Orientation of the skull can be done either by manual alignment of anatomic structures or by automatic set-up of a reference system based on previously determined landmarks [1]. Consequently, reproducibility depends on the judgement and experience of the examiners. To compensate for this drawback, we investigated a new method for landmark identification and image orientation.

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II. MATERIAL AND METHODS

Two sets of CT scans of the same patient were obtained. One set was taken before surgery was performed, while the other one was taken six months after the operation. Interslice resolution of the scans was 0.6 mm and intra-slice resolution was 0.48 mm. Segmentation and 3D reconstruction of the skull was performed using Mimics (Materialise NV, Leuven, Belgium). Then the model was transferred to pyFormex [2], an open-source program under development at IBiTech, where tools for landmark identification and image orientation were implemented.

A. Landmark identification

Landmark identification is done by calculating the extreme point in a specified direction of a certain region, according to the landmark definition. This is illustrated in figure 1 for the point Orbitale Right (OrR). First, the examiner picks the surface region (figure 1 a). Then this region is automatically refined and smoothed to allow interpolation between the original vertices of the model. Finally, a line region is automatically determined and the lowest point is calculated (figure 1 b).

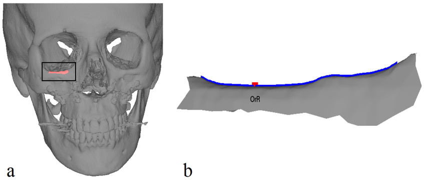

Figure 1. Example of landmark determination

B. Image orientation

Image orientation is done based on eight landmarks. To orientate the skull, four transformations (three rotations and one translation) suffice. Therefore, four orientation requirements are taken into account. Since all requirements are based on previously determined landmarks, orientation can be performed automatically. Furthermore, because after rotating the skull the extreme points may have changed, an iterative procedure is used. During each iteration the skull is re-orientated and the landmarks are recalculated. The orientation procedure stops when all requirements are fulfilled.

To evaluate the method, the reference systems of the orientated pre- and postoperative models were matched. Since the procedure orientates the skull in a standardized way, both models should show a good overlap where surgery did not change the geometry of the skull.

III. Results

Figure 2 shows an orientated skull model. Orientation of the preoperative model was finished after 6 iterations, while for the postoperative model 5 iterations took place. Deviation between the two models was calculated as the distance between pre- and postoperative landmarks. The maximum, minimum and mean deviation was 2.84 mm, 0.07 mm and 0.56 mm. In figure 3 both the pre- and postoperative skull model (black and red) and landmarks (yellow and green) are visualized. In the upper part of the skull, where geometry was not changed during surgery, a good overlap between both models can be observed.

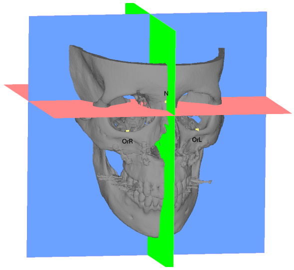

Figure 2. Orientated skull model

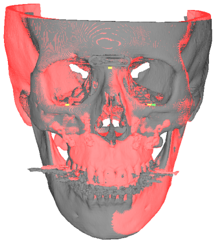

Figure 3. Orientated pre- and postoperative models show a good overlap

IV. Conclusions

In this study a new approach for 3D cephalometry is presented. Concerning landmark determination, the examiner identifies the landmark region rather than the landmark itself. We believe that this operation is less user-dependent and therefore reproducibility will be higher. Furthermore, an iterative procedure is used to orientate the skull. By recalculating the landmarks, deviations due to rotating the model are eliminated, improving accuracy of the method. Taking these improvements into account, the technique should allow accurate comparison of pre- and postoperative data. In future, reproducibility tests will be performed to validate the new approach.

References

[1] Swennen et al., *A new method of 3-D cephalometry Part I: the anatomic Cartesian 3-D reference system*, J Craniofac Surg, 17:314-325, 2006.

[2] pyFormex website: *http://pyformex.berlios.de*