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# Assessing symmetry of zygomatic bone through three-dimensional segmentation on computed tomography scan and "mirroring" procedure: A contribution for reconstructive maxillofacial surgery

Daniele Gibelli [a, *], Michaela Cellina [b], Stefano Gibelli [c], Antonio Giancarlo Oliva [b], Giovanni Termine [c], Valentina Pucciarelli [a], Claudia Dolci [a], Chiarella Sforza [a]

[a] Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, Milano, Italy
[b] Reparto di Radiologia, Ospedale Fatebenefratelli, ASST Fatebenefratelli Sacco, Milano, Italy
[c] Reparto di Otorinolaringoiatria, Ospedale Fatebenefratelli, ASST Fatebenefratelli Sacco, Milano, Italy

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ABSTRACT

*Purpose:* Surgical reconstruction of zygomatic bones in cases of traumatic injuries is a frequent event: assessment of symmetry is mandatory for a correct restoration of zygomatic shape, but the literature is discordant about its quantification. The purpose of this study is to show a novel method for assessing symmetry of zygomatic bone through mirroring of 3D models segmented on CT-scan.

*Materials and methods:* A total of 100 patients (50 male and 50 female), divided into two age groups (18–49 years and 50–92 years) were selected from the computed tomography (CT) scan database of a hospital in northern Italy. Zygomatic bones from each patient were segmented, and the left bone was automatically mirrored and registered on the right one according to the least point-to-point distance between the two surfaces. The mean and root mean square (RMS) distance between the two models was then calculated. Statistically significant differences according to sex and age groups were assessed through two-way analysis of variance ($p < 0.05$). In addition, the effect size of differences was calculated.

*Results:* The method proved to be repeatable, with inter- and intraoperator errors lower than 5%. Overall, mean and RMS point-to-point distances were respectively 0.01 mm and 0.84 mm, without statistically significant differences according to sex or age ($p > 0.05$), and with negligible effect size.

*Conclusion:* This study provides an innovative method for assessing the symmetry of the zygomatic bone based on surface analysis. Results may provide useful indications for the reconstruction of zygomatic bones in maxillofacial surgery.



## 1. Introduction

The zygomatic bone is quadrangular in shape and located in the midface, linked to the frontal bone through the frontozygomatic suture, the maxillary bone through the zygomaticomaxillary suture, and the temporal bone through the zygomaticotemporal suture. It has a strict relation with the sphenoid bone through the zygomaticosphenoidal suture (Markiewicz et al., 2013). Zygomatic bones contribute to overall facial morphology, thanks to the anterior projection of the cheek region (Gong et al., 2014). Therefore, their integrity and symmetry are of great interest in the field of reconstructive maxillofacial surgery, especially if one considers that the zygomatic bone is the second most frequently fractured facial bone (Covington et al., 1994).

The assessment of zygomatic bone symmetry in healthy people may provide important advantages for surgical reconstruction in the case of trauma: yet the morphological assessment of these structures is problematic for many reasons, including the lack of precise anatomical landmarks, the presence of irregular contours, and difficulties in determining a reference midsagittal plane (Gong et al., 2014). In addition, traditional anthropometric methods involving manual and digital analysis of the facial surface are affected by the variability of soft tissues and subjective evaluation;

* Corresponding author. Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, V. Mangiagalli 31, Milan, Italy.
*E-mail address:* daniele.gibelli@unimi.it (D. Gibelli).

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therefore, only methods based on bone surface are considered reliable according to some authors (Furst et al., 2001).

In addition, most of the approaches proposed in the literature have the limits of giving an incomplete assessment of zygomatic bone asymmetry, as they are based on the dislocation of cranial landmarks; however, the symmetry of facial bones is mainly due to variations of the entire surface rather than changes in localization of generic reference points. Therefore, a valid method for assessing the symmetry of the zygomatic bone should pass through a whole-surface assessment of differences between the right and left sides.

Thanks to modern three-dimensional (3D) image acquisition systems and elaboration software, the assessment of the entire bone surface is now easy to obtain: procedures of 3D segmentation on computed tomography (CT) scans have already been used in surgery to obtain "mirrored" 3D models from the healthy portion of the face, useful for the reconstruction of the fractured one (Feng et al., 2011). In addition, 3D models of zygomatic bone are used also in cases of delayed zygomatic fractures with dislocation of bone fragments (He et al., 2013).

However, although 3D methods for assessing the morphology of the zygomatic bone already exist, no study has so far analyzed the asymmetry between the right and the left side according to the entire surface.

This study aims at providing an innovative contribution to the topic of the assessment of asymmetry of the zygomatic bone through the registration and evaluation of point-to-point distances between the 3D model of the right side and the mirrored left side. A group of CT scans from a selected population was assessed, and their symmetry was computed to provide a practical application of this method.

## 2. Materials and methods

The procedure is based on 3D models of the zygomatic bone acquired through segmentation on CT scans. The CT scans were assessed through ITK-SNAP open-source software, which allows operators to perform semi-automatic segmentation of volumes according to the gray levels of the selected areas (Yushkevic et al., 2006). A two-step segmentation procedure was applied: first, the bone surface from the visceral cranium, including also zygomatic bones, was acquired (Fig. 1); secondarily, the obtained 3D model was elaborated through a 3D elaboration software (VAM®, Vectra Analysis Module, version 2.8.3, Canfield Scientific Inc.) to manually select the zygomatic bone according to sutures and to delete the portions belonging to the other bones from the 3D model (Fig. 2).

Once the two zygomatic bones were acquired, the left bone was mirrored: this procedure was automatically performed by VAM® software according to the sagittal plane. Once the left side was changed into the right one, it was registered onto the true right one according to the least point-to-point distance between the two models (Fig. 3). This procedure was automatically performed by the VAM® software through the reconstruction of a biunivocal relation between all the points belonging to the two 3D models. The final registration was reached once the mean point-to-point distance for all the pairs of points reaches the least value. In addition, the software calculated the point-to-point mean and root mean square (RMS) distances between the two models, together with a graphical sheet representing in green and other colors respectively the constant and variable areas between the two surfaces (Fig. 4).

In order to test this method, 100 patients (50 male and 50 female) between 18 and 92 years of age who had previously undergone a head CT scan in a hospital in Milan (northern Italy) were selected.

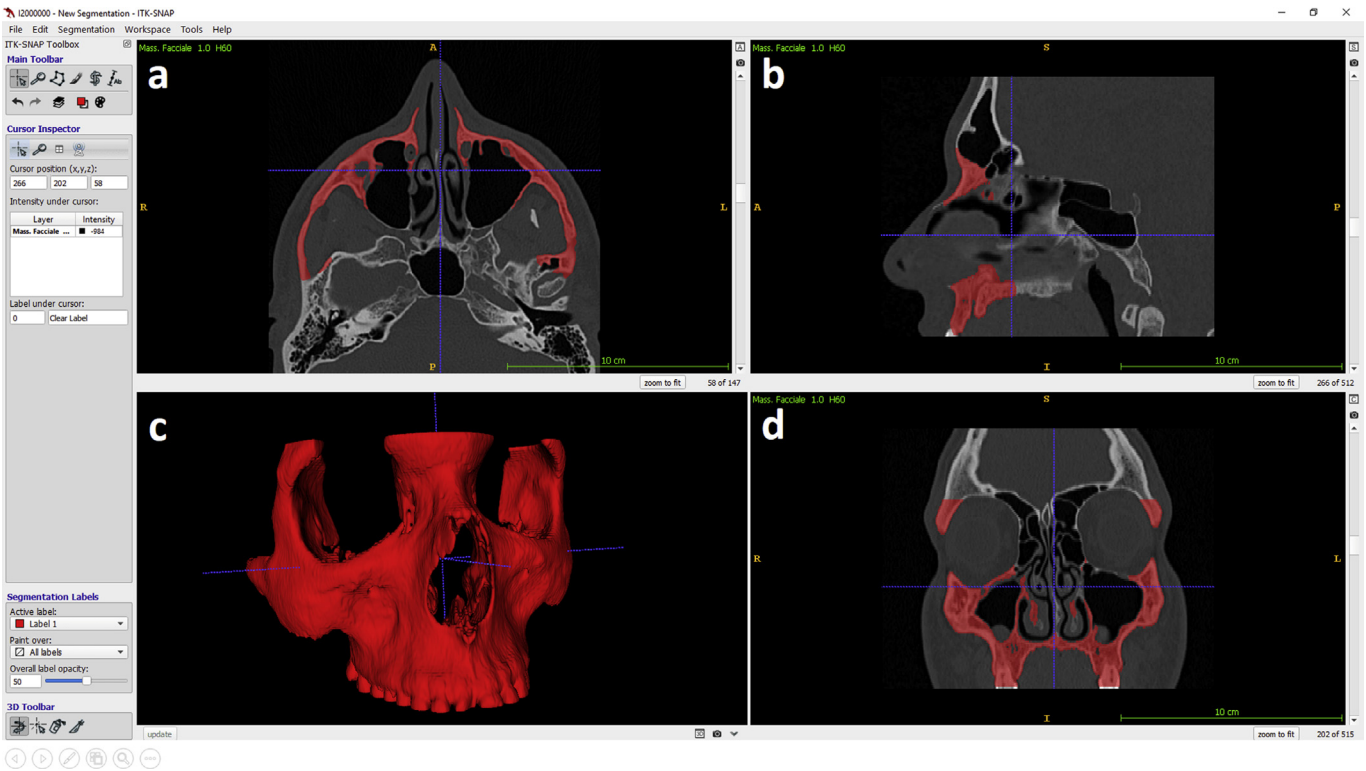


**Fig. 1.** Procedure of segmentation of 3D models of zygomatic bone (a, b, d) Images of the cranium according respectively to transversal, sagittal and coronal axes; (c) 3D model of segmented visceral cranium.

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