



# The Postoperative Morphometrics of Orbital and Maxillary Area for Craniosynostosis

Lijun Shi, MD, Weimin Shen, MD, Qingwen Gao, MD, and Liangliang Kong, MD

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**Purpose:** One of the most characteristic features in premature craniosynostosis is fronto-orbital retrusion. The standardized surgical technique of fronto-orbital advancement (FOA) can treat this (some) deformity, such as bilateral coronal synostosis. The purpose of the study is to investigate an available method to assess the postoperative outcome of the craniofacial surgery.

**Methods:** From 2010 to 2015, 6 pediatric patients were taken the FOA in the Department of Burn and Plastic Surgery in the Children's Hospital of Nanjing Medical University. All the patients were performed the computed tomography (CT) scan preoperatively and postoperatively. The CT databases were processed by DICOM files into MIMICS 16.0 software, which were automatically calculated into orbital volume and orbital roof and base surface area. *T*-test was used to compare measured values before and after surgery.  $P < 0.05$  was considered statistically significant.

**Results:** The average preoperative orbital volume was  $13930.70 \text{ mm}^3$ , and the postoperative was  $18578.67917 \text{ mm}^3$ . After operation, the volume of orbital was significantly increased ( $P < 0.05$ ). The mean area of the orbital roof surface was  $753.989025 \text{ mm}^2$  preoperatively, and the postoperative was  $1122.074583 \text{ mm}^2$ . The difference was statistically significant ( $P < 0.05$ ). The average area of the orbital base (*S2*) was  $334.94 \pm 91.76 \text{ mm}^2$ . After the FOA, the orbital base was  $356.99 \pm 114.21 \text{ mm}^2$ .  $P(S2) = 0.6072 > 0.05$ , there was no significant statistical difference.

**Conclusions:** Fronto-orbital advancement can successfully improve morphological orbital deformities in children with premature craniosynostosis, but much less for maxillary. The computer-assisted technique can present a measurement of FOA preoperatively and postoperatively, which make the evaluation intuitive.

**Key Words:** Craniosynostosis, fronto-orbital advancement, orbital cavity and maxillary area, three-dimensional measurement

From the Department of Plastic Surgery, Children's Hospital of Nanjing Medical University, Nanjing, China.

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Address correspondence and reprint requests to Weimin Shen, MD, Children's Hospital Affiliated to Nanjing Medical University, Nanjing, Jiangsu, China; E-mail: swmswmswm@sina.com

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Fronto-orbital advancement (FOA) is a traditional craniofacial surgery, which has already been one of the most useful techniques in craniosynostosis which can depend on the volume of the anterior cranial and also improve the brain development via reducing intracranial pressure. The deformity of orbital area and the influences after surgery. From now on, there has been no systemic evaluation for FOA.

A common indicator for measuring skull is the cranial vault asymmetry index, which is an indicator for assessing the severity of the oblique head deformity. For most patients, improved cranial asymmetry is the most preliminary improvement indicator. Forte et al reported orbital dysmorphology in untreated Crouzon and Apert syndrome patients.<sup>1</sup> They compared the difference with bony orbit, orbital soft-tissue volumes, and volume of the globe.

A lot of paper reported the effect of craniofacial surgery on the development of anterior cranial but few of them were available to discuss changes of orbital cavity and maxillary.

The purpose of this study was to study the morphometrics of orbital cavity area and the development of maxillary through three-dimensional (3D) reconstruction techniques before and after FOA to evaluate the outcome of the operation.

## METHODS

### Patients

In this retrospective study, 6 children underwent surgery with standardized surgical technique of FOA in the Department of Burn and Plastic Surgery at Children's Hospital of Nanjing Medical University were selected between 2010 and 2015. The standardized FOA is a coronal incision from the scalp, and then the forehead flap is turned over the periosteum and the cap is placed under the aponeurosis, reaching the ankle, and the soft tissue separation sites on both sides reach the tibia. The periosteum was cut at 1.5 cm from the upper edge of the orbital and separated under the periosteum. The vascular bundle of the orbital should be protected. After the forehead was cut off, the upper wall of the orbital and the lateral wall of the orbital were cut off. The eyeball and soft tissue are separated to the rear, and the upper eyelid is released. After the advancement, it is fixed with a titanium plate and a titanium nail. Four of them suffered from Crouzon syndrome, and 2 of them with Apert syndrome. Ages were in a range from 3 months to 11 years. In this self-control method, where the inclusion criteria were patients had the bilateral coronal suture synostosis. So we can observe the changes of the postoperative. The exclusion criterion was unilateral coronal suture synostosis. The total  $n = 12$

Some premature craniosynostosis patients had eyeball convex, visual dysfunction, strabismus, and diplopia. The preoperative and postoperative 3D computed tomography (CT) was finished.

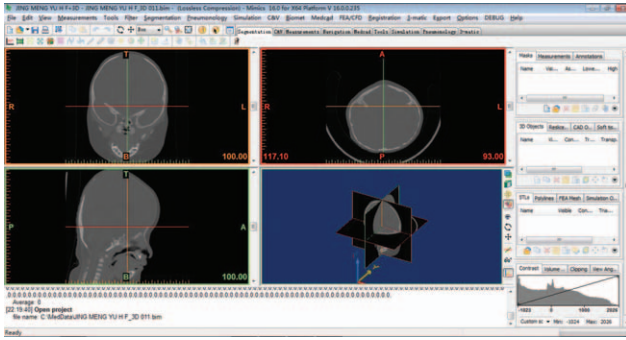


FIGURE 1. Photograph showing the three-dimensional software computed tomography data processed by DICOM files into MIMICS 16.0.

### Orbital and Maxillary Space and Three-Dimensional Reconstruction Computed Tomography Scan

All the patients used craniofacial 3D CT scan (Philips), 1.0 to 2.0 mm contiguous slice thickness, and the scanning time was 20 seconds.

#### Reconstruction and Measurement

The CT data processed by DICOM files into MIMICS 16.0 were automatically reconstructed into 3D models, which can calculate into orbital area and maxillary space (Fig. 1).

Established a 3D system, the center of the system is saddle point (S).<sup>2</sup> The reference plane takes the level of the epicondyle (ectocochlion) of the eye socket and the lacrimal dens (medial orbit) at the same level. The sagittal plane is passing through the saddle point S and perpendicular to the horizontal plane. Coronal plane is through the saddle point S, perpendicular to the horizontal plane and sagittal plane. A reference/control plane is set up to facilitate the errors when cutting 3D reconstructed images.

Each measurement was measured 3 times and averaged. And finished in the same time by the same person under the same condition.

#### Data Analysis

Preoperative and postoperative data were expressed as  $x \pm s$  in the experiment. Paired *t*-test was used to measure the data with SPSS software. The difference was statistically significant ( $P < 0.05$ ) (Fig. 2).

## RESULTS

### Orbital Volume

The average preoperative orbital volume was  $13930.70 \text{ mm}^3$ , and the average postoperative orbital volume was

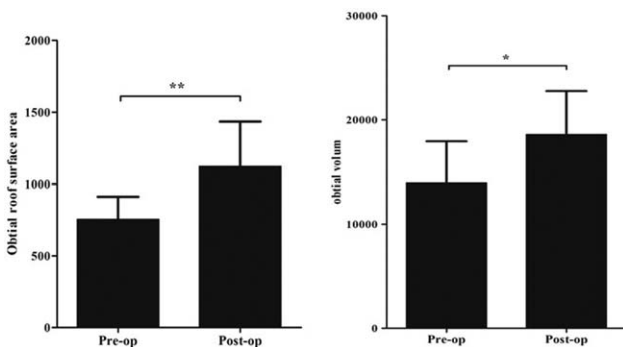


FIGURE 2. Preoperative and postoperative data analysis about orbital volume and orbital roof area. *T*-test was used to measure the data.

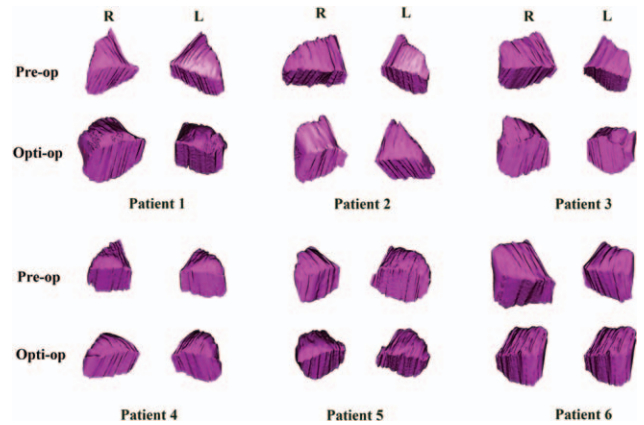


FIGURE 3. Average preoperative and postoperative orbital volume was been reconstructed.

$18578.67917 \text{ mm}^3$ . After operation, the volume of orbital was significantly increased ( $P < 0.05$ ) (Fig. 3).

### Orbital Roof Area (S1)

The mean area of the orbital roof surface (S1) was  $753.989025 \text{ mm}^2$  preoperatively, and the average orbital roof surface area was  $1122.074583 \text{ mm}^2$  postoperatively. The difference was statistically significant ( $P < 0.05$ ) (Fig. 4).

### Orbital Base Area (S2)

The average area of the orbital base (S2) was  $334.94 \pm 91.76 \text{ mm}^2$ . After the FOA, the mean area of the orbital base was  $356.99 \pm 114.21 \text{ mm}^2$ . Set  $P = 0.05$ , using paired *t*-test for statistical analysis,  $P(S2) = 0.6072 > 0.05$ , no significant statistical difference. Orbital base area is the top of the maxillary, which area change can reflect the change of the maxillary.

## DISCUSSION

Fronto-orbital dysmorphism is a common manifestation of craniofacial malformations, both in the syndrome or nonsyndromes. Severe patients may have some serious complications, such as increased intracranial pressure, exposed, optic nerve compression, vision loss, strabismus, diplopia, and other visual dysfunction.<sup>3</sup> FOA was originally described by Tessier in 1971. For infants, this method has been the conventional surgical approach since 1980.<sup>4</sup>

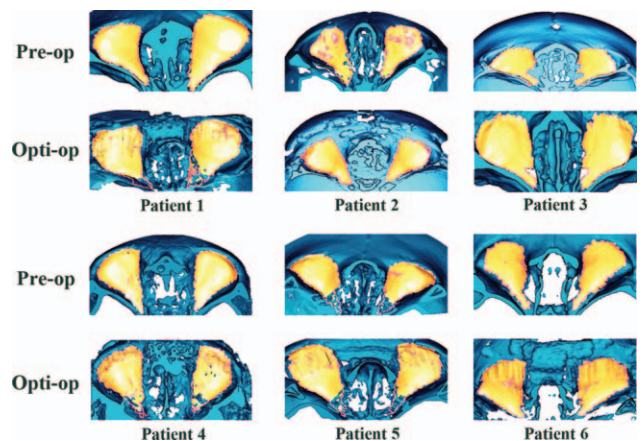


FIGURE 4. The picture shows that the average preoperative and postoperative orbital roof area was been marked.

The evaluation of postoperative including the volume of the brain and the anterior cranial fossa. Three-dimensional measurement brings a revolutionary leap to the evaluation preoperative and postoperative.

With the development of digital techniques, there are a variety of 3D digital measurement technologies. In craniomaxillofacial surgery, 3D photography was widely used recently. However, for the pediatric patients, too much CT scan will increase the possibilities of induced malignant tumors. New studies have shown that 3D photography techniques can be used to measure and track changes in cranial volume in patients with craniotomy. McKay et al<sup>4,5</sup> first demonstrated the use of a linear regression model equation to analyze the strong correlation between CT and 3D photography, which can be used to measure and track varying cranial volume while avoiding radiation exposure. It is easy to determine the absolute volume of the cranial fossa using 3D images, and the ability to measure cranial volume from 3D photographs adds an important method to provide a complete and objective means of analysis for skull growth and postoperative changes.

In the perioperative period, the use of 3D photogrammetry can be an objective display of craniotomy before and after surgery changes.

In perioperative period, 3D photogrammetry makes it available to simulate craniotomy so that we can predicate the outcome of our procedure.

Wilbrand et al<sup>5,6</sup> used the 3D camera to measure the periapical malocclusion index, closed forearm symmetry rate, unilateral human cheek posterior closed skull symmetry rate, and triangular head deformity of the anterior cranial volume changes the 3D photogrammetric method is widely used in all nonsyndromic craniosynostosis.

Rodriguez-Florez et al<sup>7</sup> quantitatively evaluates the aesthetic outcome of FOA by comparing to the control group before and after surgery using a hand-held scanner to scan the forehead

Different from Handheld 3D Scanners, traditional CT scans are used by ionizing radiation, which needs general anesthesia while it works for children. Handheld 3D scanners are advantageous. To the evaluation of postoperative efficacy, Maik Tenhagen et al measured head index (cephalic index), head circumference, skull volume, sagittal length, and Coronary width and other indicators, for 9 patients with traumatic malformations at 3 weeks postoperatively by observing in the 3D imaging and CT between the no significant difference.

Three-dimensional hand-held scanning was proved to be an effective and useful assessment method in statistical modelling.<sup>8</sup>

According to these reports, we found that 3D photography technology has the advantages of low radiation, but in the measurement indicators, through the 3D photography technology to rebuild the model, most of the body surface for the measurement. And for the orbital volume and area, has not been reported. So we still use CT data reconstruction measurement for its accuracy.

Orbital volume is a common indicator in midface measurement in children. Comparing to the ordinary method, 3D measurement has obvious advantages. So it has great practical value. Ezaldein et al<sup>9</sup> used 3D measurement method to assess the 23 pairs of triangular head deformities children and control group with high depth and width of the eye socket and the orbital volume, the difference of orbital plane angle. Smektala et al<sup>10</sup> using 3D reconstruction method, measured midface deformity after the LeFort III osteotomy about the orbital volume to evaluate the postoperative effect. These children are mostly syndromic craniosynostosis, accompanied with midface disorder. The diversification of the orbital area and the promotion of the maxilla development haven't been reported.

We measured the orbital area and orbital volume, to assess the effect of FOA surgery and detect development of orbital cavity postoperatively. At the same time you can measure the expansion of anterior cranial volume, to evaluate the development of anterior cranial indeed. In these patients we concluded that the upper orbital area and orbital volume increased after surgery it shows that surgery can improve orbital development, but also improve brain development. Orbital volume measurement can be an intuitive assessment of the improvement of the surgery. The improvement of orbital volume can also be used as one of the indicators of evaluation in FOA. With the orbital volume increasing, we can obviously recognize the improvement of the fronto-orbit. The shape of the orbital roof was also changed before and after the surgery. Therefore, the reconstructed orbital area could assess the morphological changes of the orbital roof area. After supraorbital wall osteotomy, the supraorbital wall can reunion as it own morphology. Then the orbital coverage of the eye surface area increased, it can improve the symptoms such as corneal exposure and so on. Reconstruction of the orbital roof area and orbital volume was performed to evaluate the outcome of FOA surgery by using 3D digital reconstruction. The complex orbital anatomy of the craniofacial malformations has a more intuitive way, and provides a method and basis to individual treatment.

## CONCLUSIONS

In this study, the 3D measurement analysis by MIMICS 16.0 software for FOA surgery preoperatively and postoperatively for orbital deformity shows the orbital morphological changes clearly and directly. FOA surgery increased the upper orbital area but it did not play a role in development of maxillary and the base area of orbital cavity. We consider that computer-assisted surgery can be an intuitive evaluation of FOA preoperatively and postoperatively.

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