Frontoorbital advancement in coronal suture craniosynostosis: a quantitative preoperative assessment

Alaa Nabil El-Sadek

Background **Surgical therapy of coronal craniosynostosis in the modern era has evolved with the adoption of frontoorbital advancement and forehead reshaping to correct the supraorbital rim recession and the abnormal form of the cranium. The aim of this study was to evaluate the efficiency of quantitative preoperative planning for the degree of frontoorbital advancement in treatment of coronal craniosynostosis.**

Patients and methods **Fourteen patients (eight bilateral and six unilateral cases) who presented with simple nonsyndromic coronal craniosynostosis were treated surgically at the Plastic Surgery Unit in Zagazig University Hospital. The degree of the needed frontoorbital advancement was determined preoperatively using longitudinal orbital projection. Standard surgical correction was performed in all cases including frontoorbital advancement and forehead reshaping. Follow-up was based on clinical examination, computed tomography, and longitudinal orbital projection.**

Results **The preoperative and postoperative longitudinal orbital projection documented significant improvement in the relationship between the supraorbital rim and the cornea in all cases, with normalization of the relationship between the supraorbital rim and the cornea in eight patients (five patients were bilateral, and three patients were unilateral).**

Conclusion **Frontoorbital advancement and forehead reshaping for treatment of bilateral and unilateral coronal craniosynostosis achieve excellent functional and aesthetic results. Quantitative preoperative planning to determine the degree of frontoorbital advancement is highly recommended to achieve significant improvement and normalization of the relationship between the supraorbital rim and the cornea.** ***Ann Pediatr Surg*** **7:139–145 © 2011 Annals of Pediatric Surgery**

Annals of Pediatric Surgery 2011, **7**:139–145

Keywords: coronal craniosynostosis, frontoorbital advancement, forehead reshaping

Plastic and Reconstructive Surgery Unit, Faculty of Medicine, Zagazig University, Zagazig, Egypt

Correspondence to Alaa Nabil El-Sadek, MD, Plastic and Reconstructive Surgery Unit, Faculty of Medicine, Zagazig University, Zagazig, Egypt
Tel/fax: +0020105245613; e-mail: alaa_nabil_plastic@hotmail.com

Received 15 May 2011 **accepted** 3 June 2011

Introduction

Craniosynostosis is a premature fusion of one or more of the suture lines that form the living skull. It can occur as part of a syndrome or as an isolated defect (nonsyndromic). It is called simple when only one suture is involved and compound when two or more sutures are involved 1,2.

Craniosynostosis results in restriction of the growth of the cranium and deformity of both cranial and facial skeletons. If untreated, craniosynostosis may lead to cerebral atrophy (due to increased intracranial pressure), mental retardation (due to cerebral atrophy), ocular complications including optic nerve atrophy, and even death in severe cases 3,4.

Patients with bilateral coronal suture craniosynostosis demonstrated flattening of the forehead, recession and elevation of the superior orbital rim, anteroposterior shortening of the skull, temporal convexity, skull widening (brachycephaly), and elevation of the height of the skull (turricephaly) [5,6].

Unilateral coronal suture craniosynostosis, commonly referred to as anterior plagiocephaly, is characterized by flattening of the forehead and the frontoparietal region ipsilateral to the fused suture, with compensatory bulging of the contralateral frontoparietal region. The ipsilateral superior orbital rim is retracted and elevated. The temporal fossa ipsilateral to the fused suture is convex, and the ear ipsilateral to the fused suture is displaced anteriorly because of a forward orientation of the petrous bone. In addition, the glenoid fossa, which is located anterior to the petrous bone, is displaced further anteriorly, resulting in the articulation of the mandible being displaced forward; thus, the chin point of the mandible is displaced to the contralateral side. The nasal radix is deviated toward the fused suture; thus, the tip of the nose is deviated to the contralateral side [5–11].

Although the diagnosis of craniosynostosis can be made on clinical examination, computed tomography (CT) can confirm the clinical impression of craniosynostosis [12]. The newer generation of CT scanners allows reconstruction of images in coronal, sagittal, and oblique planes from a single set of axial scans. These computer-generated images are described as reformatted. Marsh and Gado [13] described an oblique image reformatted along the plane connecting the apex of the orbit and the center of the globe and have named this image as longitudinal orbital projection. Normally, the corneal surface is tangent to a line extending between the midpoint of the superior and inferior orbital rims. The longitudinal orbital projection can demonstrate the relationship of the eyes to the orbital rims [13].

Surgical therapy of coronal craniosynostosis in the modern era has evolved with the use of frontoorbital advancement and forehead reshaping to correct the supraorbital rim recession and abnormal form of the cranium [5,7,14].

As frontoorbital deformity represents the central area of dymorphology in patients with coronal craniosynostosis, a quantitative method for preoperative and postoperative evaluation is preferred to a qualitative one [15].

Traditionally, the degree of advancement of the frontoorbital complex in bilateral and unilateral coronal craniosynostoses depends usually on the surgeon's experience. The aim of this study was to evaluate the efficiency of quantitative preoperative planning for the degree of frontoorbital advancement in the treatment of bilateral and unilateral coronal craniosynostosis. The degree of advancement of the frontoorbital complex was quantitatively evaluated before the operation on the basis of CT and longitudinal orbital projection. The operation was performed in accordance with the preoperatively planned degree of advancement, the efficiency of which was evaluated postoperatively.

The aim of this study was to evaluate the efficiency of quantitative preoperative planning for the degree of frontoorbital advancement in the treatment of coronal craniosynostosis.

Patients and methods

All patients selected for this study were treated at the Zagazig University Hospital. This study included 14 patients who presented with simple nonsyndromic coronal craniosynostosis (eight bilateral and six unilateral cases). The diagnosis, age at surgery, and length of follow-up are shown in Table 1.

Diagnosis was based on history, clinical examination, and CT, including a three-dimensional reconstruction. Signed permission to publish preoperative and postoperative images was obtained from the parents. Patients who presented with hydrocephalus or other cranial or cerebral abnormalities were excluded from this study.

Using the longitudinal orbital view, a line is drawn tangential to the ventral margin of the infraorbital rim and the ventral cornea surface. The supraorbital rim lag is the linear distance between the ventral surface of the supraorbital rim and the cornea-inferior rim line. It is annotated as either positive or negative to indicate the anteroposterior relationship between the supraorbital rim and the cornea-inferior rim line [14]. In bilateral coronal craniosynostosis, the supraorbital rim projection was determined quantitatively from the longitudinal orbital projection, and the degree of the needed advancement of the frontoorbital complex was quantitatively evaluated before the operation. The operation was performed in accordance with the planned degree of advancement, the efficiency of which was evaluated postoperatively. In the unilateral coronal cases, there was recession of the supraorbital rim at the synostosed side and compensatory protrusion in the contralateral side. The recession and protrusion were quantitatively assessed preoperatively and were corrected intraoperatively. The projection difference between the ipsilateral and contralateral supraorbital rims was compared preoperatively and postoperatively.

Table 1 Preoperative diagnosis, number of patients, age at surgery, and length of follow-up

Diagnosis	Number of patients	Mean age at surgery (months)	Mean length of follow-up (months)
Bilateral coronal craniosynostosis	8	7.43	21.71
Unilateral coronal craniosynostosis	6	6.33	30.83

Preoperative assessment was carried out immediately before surgery and included pediatric clinical evaluation, blood coagulation tests, hemogram, urea and electrolyte estimations, and blood cross-matching.

Operations were carried out under endotracheal general anesthesia. A warming mattress was used in all cases to avoid hypothermia. Intravenous third-generation cephalosporin was administered at the time of induction of anesthesia and was continued postoperatively.

Standard frontoorbital advancement and forehead reshaping were performed in all cases, with only minor variations undertaken to accommodate individual patients' differences. The goal of the surgical procedure was to remove the restriction to the growth of the brain and to normalize the frontoorbital osseous deformity. The operative procedures used were resection of the synostosed suture and complete supraorbital bar mobilization and forehead reshaping.

Surgical procedures

Marking for bicoronal incision was performed (Fig. 1). The anterior scalp flap was dissected epiperiostealy up to a position of 2 cm above the upper orbital margin. The temporalis muscle was dissected laterally in a subperiosteal plane. Bilateral circumferential subperiosteal

Fig. 1

Marking for bicoronal incision in a 7-month-old boy with bilateral coronal craniosynostosis.

orbital dissection followed, with release of the lateral canthi, but with preservation of the integrity of the medial canthi and the nasolacrimal apparatus. The subperiosteal dissection continued along the lateral orbital rims to below the frontozygomatic sutures. The posterior scalp flap was dissected epiperiostealy to a position between the coronal and lambdoid sutures. Bifrontal osteotomy was performed, which included removal of the synostosed coronal suture, leaving a 1-cm supraorbital bar. Extensive undermining of the dura was performed in the anterior cranial vault continuing to the lateral aspect of the cranial base. The frontal bone was then removed as indicated. The most lateral aspect of the coronal suture was radically removed with rongeurs, including a part of the greater and lesser wings of the sphenoid bone.

The frontal and temporal lobes of the brain were gently repositioned to allow for safe upper orbital osteotomies through the skull base. Care was taken to remain anterior to the olfactory bulbs. The supraorbital bar was isolated from the orbit by cutting from the pterion laterally, across the orbital roof, to the nasion medially (Fig. 2).

The supraorbital bar was realigned by thinning the bone on its posterior surface, especially near the superolateral orbital rim, to facilitate bending and reshaping (Fig. 3). The supraorbital rim was quantitatively advanced and lowered in bilateral coronal craniosynostosis. In unilateral coronal craniosynostosis, the recessed supraorbital rim at the synostosed side was quantitatively advanced and the protruded half in the contralateral side was quantitatively recessed to achieve symmetry. The supraorbital bar was

Fig. 2

Resection of the supraorbital bar and forehead craniotomy segment.

Fig. 3

Forehead and supraorbital bar after remodeling on a side table.

Fig. 4

Fixation of the supraorbital bar and forehead in an advanced position.

then affixed to the facial skeleton with polyglycolic acid sutures. Stabilization was achieved with temporary dynamic miniplates, which fixed the supraorbital bar to the corresponding parietal bone (Fig. 4).

The forehead craniotomy segment was modeled to create an appropriate anterior cranial vault volume and symmetric forehead shape. In summary, the technical strategy was parallelogrammic correction of the forehead and the supraorbital rim deformity. The modified frontal bone was fixed to the supraorbital rims with polyglycolic acid sutures. An osseous defect was left behind and above the frontoorbital region, which reossified slowly. The temporal muscles were advanced anteriorly and fixed securely to the lateral orbital rim with polyglycolic acid sutures. The wound was closed in two layers over a drain.

Fig. 5

Preoperative anterior view of a patient with bilateral coronal craniosynostosis showing flattening of the forehead and elevation of the supraorbital rim.

Fig. 6

Preoperative lateral view showing anteroposterior shortening of the skull and recession of the supraorbital rim.

The dynamic miniplate and screws were removed 1 month postoperatively through small incisions at the eyebrow and above the ear without the need for bicoronal incision. We believe that dynamic miniplates provide better stability than absorbable miniplates to keep the remodeled craniofacial skeleton, especially in unilateral coronal craniosynostosis in which everything was asymmetric before intraoperative remodeling. Our strategy was to provide sufficient stability for the function and form of the head and face without restriction of the rapidly enlarging brain, which acts as a natural moulding force for the mobilized craniofacial skeleton.

Postoperative care and follow-up

After extubation, the child was transferred to the Pediatric Intensive Care Unit for 24 to 48 h so that hemodynamic stability and level of consciousness could be monitored. Parents were informed about the considerable amount of swelling that had occurred around the scalp and periorbital areas and they were reassured that the swelling would subside after a few days. Drains were usually removed 2–3 days postoperatively, depending on the amount of output.

Further clinical follow-up was carried out at 3 weeks, 6 weeks, 3 months, 6 months, and 1 year postoperatively. A three-dimensional CT scan was performed 1 year after surgery. Long-term follow-up was also recommended to assess the child's neuropsychologic development and craniofacial growth.

Results

This study included 14 patients who presented with simple nonsyndromic coronal craniosynostosis. The sample consisted of eight patients with bilateral coronal craniosynostosis (five boys and three girls) and six patients with unilateral coronal craniosynostosis (two boys and four girls). The mean age at surgery and the mean length of follow-up are shown in Table 1. The length of follow-up depended solely on the date of entry of each patient into the study protocol. On the basis of the longitudinal orbital projection, the preoperative planned degree of frontoorbital advancement (that is, preoperative recession of the supraorbital rim) and postoperative correction data were compared and statistically evaluated.

At the time of the most recent clinical evaluation, 11 of 13 patients (84.6%) had achieved excellent functional and aesthetic results (Figs 5–10). Two patients (15.4%) out of 13 achieved good results in spite of minor complications: one patient (7.7%) showed minor bone irregularity in the forehead, and the other patient (7.7%) showed minor asymmetry of the forehead. The mortality rate in this series was one of 14 patients (one patient with bilateral coronal craniosynostosis) who developed pulmonary edema and heart failure 1 day after surgery most probably because of fluid overload. The deceased patient was excluded from the statistical analysis of this study. The mean value of preoperative and postoperative longitudinal orbital projection documented significant improvement ($P = 0.000$) of the relationship between the supraorbital rim and the cornea in all cases (13 patients), with normalization of the relationship between the supraorbital rim and the cornea in eight patients (five patients with bilateral coronal craniosynostosis and three patients with unilateral coronal craniosynostosis) (Tables 2 and 3).

Discussion

The term craniostenosis is used to indicate premature fusion of one or more of the cranial sutures. Technically, craniosynostosis is the process of premature sutural fusion; craniostenosis is the result. In fact, the terms

Fig. 7

Postoperative anterior view showing improvement of the forehead and the supraorbital rim.

Fig. 8

Postoperative lateral view showing improvement of the shape of the cranium and of the projection of the supraorbital rim.

have been used interchangeably, and craniosynostosis seems to be replacing craniostenosis as the more common term [16].

Craniosynostosis remains primarily a surgical disease. The goals of therapy are to provide adequate intracranial volume to allow space for brain expansion and to minimize cognitive sequelae and create an aesthetically normal skull shape [3,4]. The operative correction of coronal craniosynostosis has evolved from simple strip craniectomy to more complex bilateral frontoorbital advancement and forehead reshaping. Although simple craniectomy was the first method described for treatment of premature synostosis, poor results especially in moderate and severe deformities, have largely led to it being abandoned [11,12]. In this study, bilateral frontoorbital advancement and forehead reshaping were performed in all patients. This technique is accepted worldwide, and it is the most preferred by many surgeons as it facilitates global shaping through radial sections in the bone and also permits large reconstructions [5,7,10,12,17].

Traditionally, the degree of advancement of the frontoorbital complex depends usually on the surgeon's experience. As frontoorbital deformity represents the central area of dymorphology in patients with coronal craniosynostosis, a quantitative method for preoperative and postoperative evaluation is preferred to a qualitative one [15].

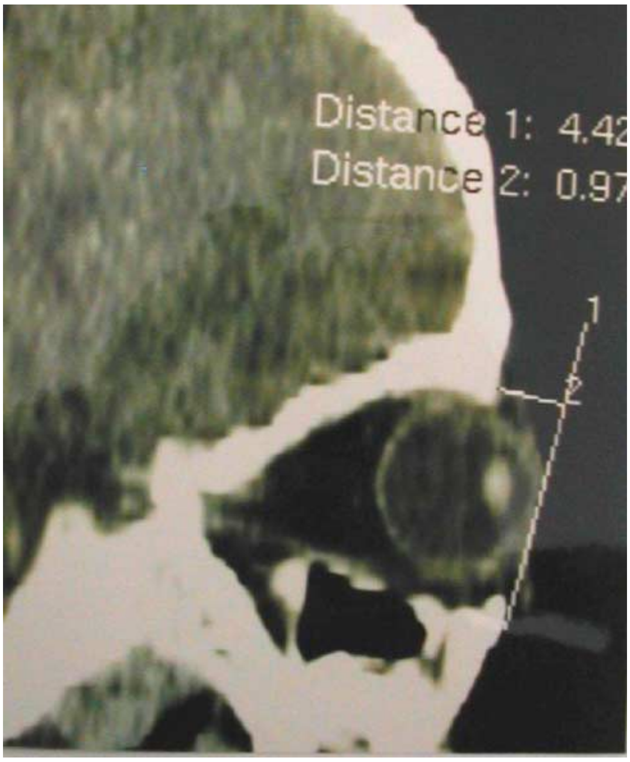
The abnormalities of the eye were previously determined in relationship to the orbital rims using the longitudinal orbital projection [13]. In this study, longitudinal orbital projection was used to determine the abnormalities of the superior orbital rim in relation to the eye. Longitudinal orbital projection was used to preoperatively measure the degree of recession of the superior orbital rim in relation to the cornea at the side of the coronal suture craniosynostosis.

In this study, the supraorbital rim recession was measured quantitatively using longitudinal orbital projection. Therefore, the degree of advancement of the frontoorbital complex was quantitatively evaluated before the operation. The operation was performed in accordance with the planned degree of advancement, the efficiency of which was evaluated postoperatively.

Most surgeons believe that frontoorbital advancement and forehead reshaping are best undertaken around 6 months of age because approximately 50% of skull growth is achieved by this period of life. Moreover, skeletal rigidity and secondary growth distortion, which make surgical correction more complicated if it is postponed, can be avoided by performing the procedures at this age. In addition, eye growth is most pronounced during the first year of life and the binocular vision of the infant develops at 3–6 months of age when the macula reaches maturity. Therefore, craniofacial reconstructive surgery is preferred to be performed at an early age (6 months of life) in order to allow for normal development of the eye and to avoid ocular complications [12,18]. In this study, the age at surgery ranges from 5 months to 11 months with a mean age of 6.92 months.

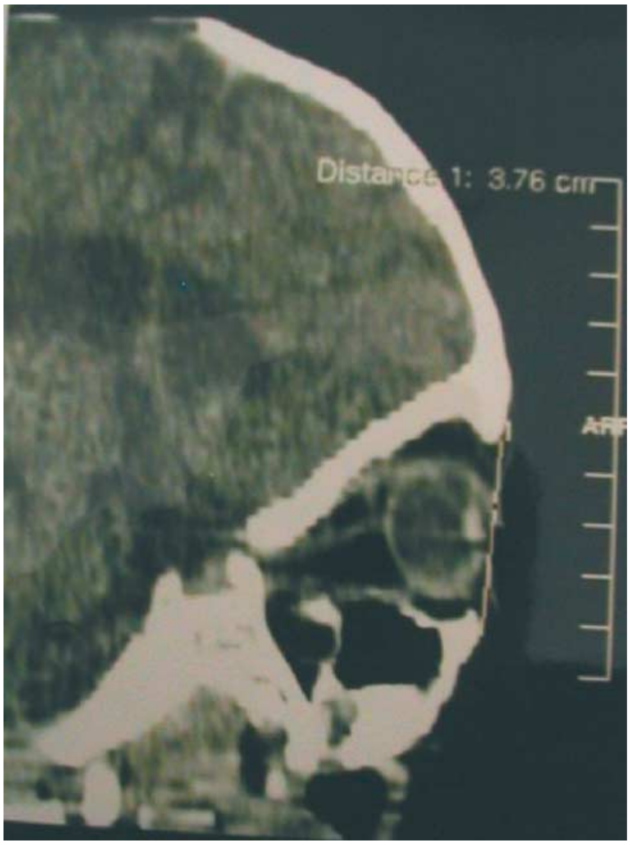
In this study, at the time of the most recent evaluation, 11 patients (84.6%) achieved excellent functional and aesthetic results. Two patients (15.4%) achieved good results in spite of minor complications; one patient (7.7%) showed minor bone irregularity in the forehead, and the other patient (7.7%) showed minor asymmetry of the forehead. The mortality rate in this series was one of 14 patients (one patient with bilateral coronal craniosynostosis) who

Fig. 9



Preoperative longitudinal orbital projection showing recession of the supraorbital rim to be measured.

Fig. 10



One-year postoperative longitudinal orbital projection showing normalization of the relationship between the supraorbital rim and the cornea.

developed pulmonary edema and heart failure 1 day after surgery most probably because of fluid overload. The deceased patient was excluded from the statistical analysis of this study.

Although the morbidity and mortality in this study were in agreement with those of Ferreira *et al.* [19] and Kadri and Mawla [20], Harrop *et al.* [21] reported a morbidity of 0.02% and no mortality in 40 consecutive cases.

Although Jimenez *et al.* reported minimally invasive endoscopic strip craniectomies and postoperative helmet molding therapy in the management of craniosynostosis, full correction cannot be achieved by such techniques [22].

Choi *et al.* in 2009 recommended the use of one-piece frontoorbital advancement with distraction but without a supraorbital bar for coronal craniosynostosis as an alternative surgical approach for treating noncomplex forms of single-suture coronal craniosynostosis. Although their aim was to reduce complications, no analysis of the frontoorbital advancement was performed to confirm significant improvement [23].

Koh *et al.* [12] described good results using a more complicated cranial remodeling procedure consisting of supraorbital bar advancement and the rotation-reposition of multiple frontoparietal bone flaps. However, no quantitative preoperative planning was described.

Teng *et al.* reported satisfactory results using frontoorbital advancement in patients with craniosynostosis, but their study was qualitative without any quantitative assessment [24].

Table 2 Preoperative and postoperative quantitative assessment of the supraorbital rim in relation to cornea-inferior rim line in patients with bilateral coronal craniosynostosis

Patient number	Preoperative projection	Postoperative projection
1	9 (recession)	2 (recession)
2	8 (recession)	0 (accurate correction)
3	11 (recession)	2 (recession)
4	9 (recession)	0 (accurate correction)
5	7 (recession)	0 (accurate correction)
6	8 (recession)	0 (accurate correction)
7	10 (recession)	0 (accurate correction)

Data are expressed in millimeters (normal = 0).
Patient number 8 died and was excluded from the statistical analysis.

Table 3 Projection difference between contralateral and ipsilateral supraorbital rims in patients with unilateral coronal craniosynostosis

Patient number	Preoperative recession	Postoperative projection
1	13	3
2	12	0 (accurate correction)
3	14	2
4	11	0 (accurate correction)
5	10	0 (accurate correction)
6	11	2

Data are expressed in millimeters (normal = 0).

Lo *et al.* [15] documented the use of quantitative three-dimensional CT to assess the stability of frontoorbital advancement in nonsyndromic bilateral coronal synostosis. They concluded that plate rigid fixation at the nasion provides superior stability for bandeau advancement compared with bone graft/suture fixation, but again no preoperative planning was performed.

Kovács *et al.* in 2008 studied the growth of the orbit after frontoorbital advancement using a nonrigid suture as against a rigid plate fixation technique. Although they used quantitative three-dimensional CT analysis, no preoperative planning was performed [25].

Although Kirschner *et al.* [26] reported repair of the immature craniofacial skeleton with a calcium phosphate cement and published quantitative assessment of craniofacial growth, no preoperative planning was performed.

In this study, quantitative assessment was performed and the quantitative preoperative planning was evaluated. The postoperative longitudinal orbital projection documented significant improvement in the relationship between the supraorbital rim and the cornea in all cases (13 patients), with normalization of the relationship between the supraorbital rim and the cornea in eight patients (five patients with bilateral coronal craniosynostosis and three patients with unilateral coronal craniosynostosis).

Limitations of this study must be underlined. Only a few patients with craniosynostosis were available for surgery at suitable age. This may be because of the low incidence of craniosynostosis and lack of early diagnosis or misdiagnosis of the available cases. This study must be extended to involve a larger number of patients to support the validity of such preoperative quantitative planning.

Conclusion

Bilateral frontoorbital advancement and forehead reshaping for treatment of coronal craniosynostosis achieve excellent functional and aesthetic results. Quantitative preoperative planning to determine the degree of frontoorbital advancement is highly recommended to achieve significantly better results and normalization of the frontoorbital complex.

Acknowledgements

The author is greatful to Professor Dr Khaled Abdel-Aziz, Assistant Professor of Radiology Department, Zagazig University, for computed tomography assessment.

Conflicts of interest

There are no conflicts of interest.

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