EVALUATION OF FRONTOORBITAL ADVANCEMENT IN CORONAL AND METOPIC CRANIOSYNOSTOSIS.

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Abstract

Background: Fronto-orbital advancement (FOA) is the corrective procedure for coronal and metopic craniosynostosis. The goal of the FOA is to expand cranial volume allowing brain growth thus, improve aesthetic and functional outcome. Traditionally, the degree of advancement of the fronto-orbital complex in bilateral and unilateral coronal craniosynostoses is a qualitative method and depends usually on the surgeon's experience. The aim of this study is to evaluate the efficiency of quantitative preoperative planning for the degree of fronto-orbital advancement in the treatment of bilateral and unilateral coronal and metopic craniosynostosis.

Patient and methods

Twelve patients (four metopic, five unilateral coronal and three bilateral coronal). The metopic and unilateral coronal cases are simple non syndromic craniosynostosis while, bilateral coronal cases are syndromic craniosynostosis. All cases treated surgically at plastic and reconstructive surgery department, Zagazig university hospitals. The degree of the needed fronto-orbital advancement was determined preoperatively using longitudinal orbital projection. Surgical correction was performed in all cases in the form of fronto-orbital advancement and forehead reshaping. Follow up based on clinical examination, computed tomography and longitudinal orbital projection.

Results

There was statistically significant improvement in the relationship between the supraorbital rim and the cornea in all cases, most of operated cases (metopic, unicoronal and bicoronal) showed excellent results with no statistically difference between them.

Conclusion

the current study showed that fronto-orbital advancement and fore head reshaping showed satisfactory outcome in the treatment of craniosynostosis. Fronto-orbital advancement resulted in significant improvement in supraorbital projection regardless of craniosynostosis type. Quantitative preoperative planning is highly recommended to achieve significantly better results and normalization of the fronto-orbital complex.

Keywords: Frontoorbital Advancement, Coronal And Metopic Craniosynostosis

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Introduction

Craniosynostosis, defined as the premature fusion of one or more cranial sutures, occurs in 1 in 2000 to 2500 live births and is one of the most common congenital craniofacial anomalies. Lack of growth perpendicular to the fused sutures and compensatory growth at normal ones result in patients presenting with a distorted head shape **(Azoulay,2020).**

The different types of craniosynostosis have traditionally been classified according to theetiology into primary (caused by a primary defect of ossification) or secondary to mechanical causes, systemic disorders. Also, according to the number of the involved sutures into simple (involving one suture) or complex (involving two or more sutures). In isolated forms, the condition is named according to the morphology of deformities consequent to the synostosis. These include dolichocephaly/scaphocephaly (synostosis of the sagittal suture), trigonocephaly (synostosis of the metopic suture), brachycephaly (bilateral synostosis of the coronal sutures), plagiocephaly (asymmetry of the neurocranium due to synostosis of a single coronal suture **(Badve et al.,2013).**

Bilateral coronal synostosis (brachycephaly) includes typical clinical features such as; a sagittally short and transversely wide skull shape, symmetrical occipital flattening, and elevation of the height of the forehead .These features can be explained by Virchow's law, which states that the bicoronal synostosis limits the growth in the forward and backward direction, resulting in occipital flattening and anteroposterior shortening of the skull. Compensatory growth occurs due to the open sagittal suture sideways and due to the open lambdoid sutures upward, resulting in parietal widening and increased forehead height **(Kronig et al.,2021).**

Unilateral coronal craniosynostosis results in anterior plagiocephaly, a phenotype characterized by an asymmetric forehead appearance. **(Robertson etal.,2020).**

Anterior plagiocephalic skull characterized by ipsilateral frontal and superior orbital retrusion , contralateral bossing of the forehead. In addition to the forehead, facial abnormalities are manifested in such patients.The middle and lower portions of the face are rotated toward the nonfused side. The nasal root generally points in the direction of the fused suture; whereas, the nasal tip points in the direction of the unfused suture. functional disturbances, such as elevated intracranial pressures, airway obstruction, and globe exposure, are rare **(Wu,2020).**

Metopic synostosis is easily recognized by the triangular shape of the forehead (trigonocephaly) when viewed from above. Trigonocephaly shows a male predominance of 75%. **(Veelen-Vincent et al.,2010). T**here is palpable midline ridge at the fused suture, and hypotelorism. It is associated with impaired neurocognitive ability **(Chandler et al.,2020).**

Physical examination is a very sensitive tool in the diagnosis of craniosynostosis. Pre-operative imaging can be helpful to confirm this clinical diagnosis. Computed tomographic scans permit excellent visualization of the underlying bony architecture, helping surgeons appreciate bony anomalies and plan surgical correction **(Engel et al.,2013).**

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** 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 cornea to the orbital rims **(Marsh and Gado,1983).**

The aim of this study was to evaluate the role of quantitative preoperative planning in determining the degree of fronto-orbital advancement in treatment of coronal and metopic craniosynostosis in Plastic and reconstructive surgery department, Faculty of Medicine, Zagazig University.

Patient and methods

All patients selected in this study were managed at plastic and reconstructive surgery departement in Zagazig University hospitals. Twelve patients with craniosynostosis were included in this study.
The inclusion criteria were Age (6 months to 18 months), Sex (both males and females), Cause (syndromic or non syndromic), type (Unilateral or bilateral coronal craniosynostosis and Metopic suture craniosynostosis).

The exclusion criteria were Age (> 18 months and < 6 months), type (sagittal and lambdoid craniosynostosis) and Patients who presented with

hydrocephalus & other cranial or cerebral abnormalities.
Types of craniosynostosis, number, syndromic or not are shown in table 1.

Some sociodemographic data among the studied group are shown in table 2.

Table 1: Types of craniosynostosis, number, syndromic or not.

Type	Number of patients	Syndromic or not
Metopic	4	Non syndromic
Unilateral coronal	5	Non syndromic
Bilateral coronal	3	Syndromic

Table 2: Some sociodemographic data among the studied group**.**

Variable	N=12	%=100
Age (months)	***Mean*** ± ***SD***:	9.9 ± 1.4
	Range:	9- 14
Weight:	***Mean*** ± ***SD***:	9.1 ± 0.93
	Range:	8- 11
Sex:		
• ***Male***	7	58.3
• ***Female***	5	41.7

Diagnosis of the patients was based on history and clinical examination which usually reveals the deformity associated with the sutures closed. Frequently ridges may be felt over a closed suture .The physical examination is performed with special attention to the hands and feet as well as arms and legs looking for deformities. Head computerized tomography with 3 dimensional reconstructions is helpful in determining which sutures are involved and to what degree. The brain may also be evaluated and any brain abnormality determined.

Preoperative assessment was carried out immediately before surgery and included paediatric clinical evaluation, blood coagulation tests, complete blood count, serum creatinin and electrolyte estimations, and blood cross matching.

Operative Technique

Standard fronto-orbital advancement and forehead reshaping were performed for all cases with some minor variations according to each patient skull deformity. Operations were carried out under general anaesthesia. Intravenous antibiotics, third generation cephalosporin were administered at the time of induction of anaesthesia and continued postoperatively. The patients were operated in supine position. After shaving and disinfection a solution of epinephrine (1: 200.000) was infiltrated prior to the incision.

The steps of surgery are illustrated in figures (1-4). A bicoronal incision was used and the anterior scalp flap was elevated epiperiostealy up to a position 2 cm above the supra orbital margin, the temporalis muscle was dissected laterally in a subperosteal plan. Bilateral circumferential subperiosteal orbital dissection with the release of the lateral canthi, but with preservation of integrity of the medial canthi and the nasolacrimal apparatus, the subperiosteal dissection continued laterally along lateral orbital rim till the fronto-zygomatic suture. The posterior scalp flap was dissected epiperiosteal to a position between coronal and lambdoid sutures. Bifrontal osteotomy was performed including removal of the coronal suture, leaving one centimetre above the supraorbital bar. Extensive dural undermining was done in anterior calvarial vault continuing to the lateral aspect of the cranial base then the frontal bone was 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 sphenoid bone in case of coronal craniosynostosis.

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

The supra orbital bar was realigned by thinning the bone on its posterior surface, especially near the superolateral orbital rim, to facilitate bending and reshaping according to the type of the deformity and the clinical type of craniosynostosis, our cases were coronal(unilateral and bilateral) and metopic synostosis . The supra orbital bar was advanced and then fixed to the facial skeleton by absorbable polyglycolic acid sutures. Stabilization was achieved by temporary titanium mini plates and screws to fix the supra orbital bar to each corresponding pareital bone.

The forehead craniotomy segment was modulated to create an appropriate anterior cranial vault volume and symmetric forehead shape. The modified frontal bone was fixed to supraorbital bar and to each other with polyglycolic acid sutures. An osseous defect was left behind and above the fronto-orbital region, which re-ossified slowly. The wound is closed in two layers over a suction drain. The miniplates and screws were removed three month postoperative through small incisions at the eye brow and above the ear.

Figure 1. markings of bicoronal incision in male patient with metopic craniosynostosis.

Figure 2. Resection of the supraorbital bar and forehead craniectomy segment.

Figure 3. Forehead and supraorbital bar on a side table.

Figure 4. Fixation of the supraorbital bar and forehead in an advanced position.

Postoperative care and follow-up

After extubation, the patients were transferred to the Intensive Care Unit for monitoring of hemodynamic stability and level of consciousness. Parents were reassured that the swelling of periorbital areas 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. The patients were examined for symmetry of the forehead and supra orbital rims, bone irregularities, skull shape, deformity improvement, scar condition.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 12 patients; 7(58.3%) males and 5 (41.7%) females. The age at time of operation was from 9 m to 12 m. The minimum weight found was 8 kg and the maximum was 11.5 kg as shown in table 2. Five patients with non syndromic unicoronal , four patients with non syndromic metopic and three patients with syndromic bilateral coronal craniosynostosis as shown in table1. The length of follow-up depended on the date of entry of each patient into the study protocol.

By using the longitudinal orbital projection, the preoperative planned degree of fronto-orbital advancement (that is, preoperative recession of the supraorbital rim) and postoperative correction data were compared and statistically evaluated. There was statistically significant difference between pre-operative and post-operative supra-orbital projection among all types as shown in figure (5-6) with P≤ 0.05as shown in table 3.

Table 3.Preoperative and postoperative quantitative assessment of the supraorbital rim in relation to cornea-inferior rim line.

the metopic group				
Variable	**Pre-operative**	**Post-operative**	**Paired t-test**	**P-value**
SOP (ml): • ***Mean ± SD*** ***Range***	6.8 ± 0.63 6-7.5	0.25 ± 0.5 0-1	13.2	**0.000* (HS)**
the unilateral coronal group				
Variable	**Pre-operative**	**Post-operative**	**Paired t-test**	**P-value**
SOP (ml): • ***Mean ± SD*** ***Range***	9 ± 0.83 8-10	0.22 ± 0.3 0-0.6	34.8	**0.000* (HS)**
the bilateral coronal group				
Variable	**Pre-operative**	**Post-operative**	**Paired t-test**	**P-value**
SOP (ml): • ***Mean ± SD*** ***Range***	9 ± 1 8-10	0.3 ± 0.26 0-0.5	13.9	**0.005* (S)**

HS: Highly significant

Figure 5. preoperative CT film of metopic craniosynostosis patient, longitudinal orbital projection view shows retruded superaorbital rim and the measurement of the retrusion distance

Figure 6. postoperative CT film of the same patient , longitudinal orbital projection view shows the advancement of the supra orbital rim and accurate correction of the deformity.

Most of the operated cases (Metopic, Unicoronal and Bicoronal) showed excellent results (75%, 60% and 50 %) respectively with no statistically significant difference between them, p>0.05. Aesthetic outcomes are shown in figure (7-10).

Figure 7. Preoperative top view of a patient with metopic craniosynostosis showing trigonocephaly deformity

Figure 8. Preoperative anterior view of the same patient .

Figure 9. Postoperative top view of the same patient shows improvement of trigonocephalic deformity.

Figure 10. Postoperative anterior view of the same patient shows improvement of trigonocephalic deformity.

Complications were observed in 6 patients (50 %): In 3 (25 %) patients, there were dural tear managed intra operatively by suturing of the tear with 6/0 poly glycolic acid. In one patient (8.3 %) there was haematoma at the incision line managed conservatively by intravenous antibiotics, this haematoma was resolved spontaneously. One patient (8.3 %) had infection in the wound; this patient was managed conservatively by intravenous antibiotics and repeated dressing until infection resolved.One patient (8.3 %) had CSF leakage in the form of rhinorria; this patient was managed conservatively by intravenous antibiotics until the patient was improved. Unfortunately 1 patient (8.3%) died; The patient died from inadequate assessment of blood loss and the inadequate blood or fluid replacement intra-operatively, manifested by hypotension and hypovolemia intraoperatively. The condition was complicated by irreversible hypovolemic shock in the early postoperative period.

Discussion

Fronto-orbital advancement remains a powerful technique for the correction of anterior cranial vault differences related to metopic (trigonocephaly) or unilateral coronal (anterior plagiocephaly) craniosynostoses. Traditional fronto-orbital advancement requires access to the forehead and superior 2/3 of the orbit via a coronal incision. The frontal bone and orbital segment (bandeau) are then separated from the skull and reshaped. In patients with metopic craniosynostosis, the bandeau and frontal bone will need to be advanced and widened. In patients with unilateral coronal craniosynostosis, the bandeau will need to be "untwisted" to address the supraorbital retrusion on the affected side, the affected orbit will need to be shortened and widened, and the frontal bone flap will need to be proportionately advanced on the affected side. Overcorrection of the affected dimension should be undertaken to account for growth and relapse **(Massenburg et al.,2022).**

The goals of operative correction for trigonocephaly are to normalize frontal contour and advance the superolateral orbital rims **(Shumkovski et al.,2021).** Unfortunately, bilateral frontotemporal depression and lateral supraorbital hypoplasia are often seen in the long term. These postoperative skeletal abnormalities are more likely in severe forms of trigonocephaly, wherein the deformity is progressive and worsens with age **(Patel et al.,2016).**
Treatment of bilateral coronal craniosynostosis includes the use of bilateral fronto-orbital advancement to increase the cranial volume, improve forehead aesthetics, and normalize the relationship of the supraorbital rim to the eye. Both syndromic and nonsyndromic patients are at risk for relapse and often need revision procedures **(Alex et al.,2019).**

The main aim of this study was to evaluate the role of quantitative preoperative planning in determining the degree of fronto-orbital advancement in treatment of coronal and metopic craniosynostosis.

This interventional study was conducted at Plastic and reconstructive Surgery department, Faculty of Medicine, Zagazig University. This study was conducted on 12 patients with coronal and metopic craniosynostosis.

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 **(El-Sadek,2011).**

The mean age ± SD of studied group was 9.9 ± 1.4 months with mean weight 9.1 ± 0.93 Kg.

Comparable with the current study **Patel et al.,(2016)** showed that the mean age at Fronto-Orbital Advancement repair was 10.2 ± 2.0 months of 16 pediatrics with Metopic Synostosis. Also, **Seruya et al.,(2012)** showed that the average age was 10.7±12.9 months and mean weight of 9.0 ± 7.0 kg among 90 infants underwent fronto-orbital advancement. The study also showed that patients treated at 6 to 12 months had the least need for any secondary surgery; however, patients older than 12 months had the lowest incidence of readvancement. These results indicate that frontoorbital advancement should be delayed until at least age 6 months to avoid relapse.
The current study showed that more than half of them were males (58.3%). This was similar to **Alford et al.,(2018)** who revealed that more than half of their patients were males (52%). Also, **Abraham et al.,(2018)** showed that most patients were male (65.93%). Also, **Bellew & Chumas,(2015)** showed that among 91 children with craniosynostosis there were 67% males.

Regarding types of craniosynostosis, the current study showed that 41.7 % of the studied patients were unilateral coronal, 33.3% were metopic and 25% of them were bilateral coronal. However, **Seruya et al.,(2012)** showed that fused sutures were metopic among 36/90(40%), unicoronal 32(35.5%) and bicoronal 22(24.5%). Also, **Bellew & Chumas,(2015)** showed that among 91 children with craniosynostosis there were 47 sagittal, 15 unicoronal, 13 metopic, 9 multisuture, and 7 bicoronal.

The current study showed that the majority of the studied cases (75%) were non-syndromic and 25% were syndromic. In line with the current study **Ahmed et al.,(2018)** showed that the patients with craniosynostosis were predominantly (90%) non-syndromic. Also, **Patel et al.,(2016)** revealed that the majority of patients (68.7%) were non-syndromic.

Regarding operative data, the current study showed that the mean ± SD operative time of studied group was 261.3 ± 13.8 minutes, the mean ± SD of blood transfusion was 215 ± 21.1 cc, and the mean total hospital stay was 13.6 ± 1.1 days.

Comparable with the current study **Esparza et al.,(2008)** revealed that the mean hospitalization time after fronto-orbital advancement in the whole series was 11.9 days, with an ICU stay of 3 days.
Also, **Seruya et al.,(2012)** showed that the average operative time of fronto-orbital advancement was 4.2 hours, the study revealed that there was significantly positive correlation between blood loss and operative time.

However, **Engel et al., (2013)** showed that the median average amount of blood loss during the operation was less than 188 ml, ranging from 80 to 400 ml. Blood was transfused in all cases.

Also, **Isaac et al.,(2019)** showed that fronto-orbital advancement group had median operative time 216 (177–245) minutes, length of stay 4 (3-4) days, blood loss 260 (180–330) cc.

Regarding the change in supraorbital rim projection (SOP), the current study showed that there was significant reduction in SOP postoperatively compared to the preoperative values among metopic, unilateral coronal and bilateral coronal groups ($p<0.05$ all).

In line with the current study **El-Sadek,(2011)** showed that Frontoorbital advancement and forehead reshaping for treatment of bilateral and unilateral coronal craniosynostosis achieve excellent functional and aesthetic results. 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).

The comparison between metopic, uni-coronal and bi-coronal patients revealed that there was no significant difference between them as regard satisfaction. Most of the operated cases (Metopic, Unicoronal and Bicoronal) showed excellent results (75%, 60% and 50 %) respectively with no statistically significant difference between them, $p>0.05$. Among the whole group 63% had excellent outcome, 18.2% were good and 18.2% were fair.

In agreement with the current study **Ahmed et al.,(2018)** showed that good satisfaction was achieved among 73% of the patients underwent Fronto-orbital Advancement. Also, **El-Sadek,(2011)** showed that post Fronto-orbital Advancement 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.

Regarding postoperative complications, the current study showed that 25% of cases had dural tear, 8.3% had hematoma, CSF leak & infection. 1 case (8.3%) was dead.

In agreement with the current study **Ahmed et al.,(2018)** showed that the most common complications that had been encountered during surgery was dural tear that necessitated immediate surgical repair with absorbable sutures in 6 patients (40%). CSF leak due to dural tear from bony dissection occurred in one patient (6.7%), and wound infection in 2 patients (13.3%).

Conclusion

The current study showed that fronto-orbital advancement showed satisfactory outcomes in the treatment of craniosynostosis. Fronto-orbital advancement resulted in significant improvement in supraorbital projection regardless of craniosynostosis type. Quantitative preoperative planning to determine the degree of fronto-orbital advancement is highly recommended to achieve significantly better results and normalization of the fronto-orbital complex

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