Reconstruction of unicoronal plagiocephaly with a hypercorrection surgical technique

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Object. Successful surgical repair of unicoronal plagiocephaly remains a challenge for craniofacial surgeons. Many of the surgical techniques directed at correcting the stigmata associated with this craniofacial deformity (for example, ipsilateral supraorbital rim elevation [vertical dystopia], ipsilateral temporal constriction, C-shaped deformity of the face, and so on) are not long lasting and often result in deficient correction and the need for secondary revision surgery. The authors posit that the cause of this relapse was intrinsic deficiencies of the current surgical techniques. The aim of this study was to determine if correction of unilateral coronal plagiocephaly with a novel hypercorrection surgical technique could prevent the relapse of the characteristics associated with unicoronal plagiocephaly.

Methods. The authors performed a retrospective analysis of 40 consecutive patients who underwent surgical repair of unicoronal plagiocephaly at their institution between 1999 and 2009. In all cases, the senior author (S.R.B.) used a hypercorrection technique for surgical reconstruction. Hypercorrection consisted of significant overcorrection of the affected ipsilateral frontal and anterior temporal areas in the sagittal and coronal planes. Demographic, perioperative, and follow-up data were collected for comparison. The postsurgical appearance of the forehead was documented clinically and photographically and then evaluated and scored by 2 independent graders using the expanded Whitaker scoring system. A relapse was defined as a recurrence of preoperative features that required secondary surgical correction.

Results. The mean age of the patients at the time of the operation was 13 months (range 8–28 months). The mean follow-up duration was 57 months (range 3 months to 9.8 years). The postsurgical hypercorrection appearance persisted on average 6–8 months but gradually dissipated and normalized. No patients exhibited a relapse of unicoronal plagiocephalic characteristics that required surgical correction. In all cases the aesthetic results were excellent. Only 3 patients required reoperation for the management of persistent calvarial bone defects (2 cases) and removal of a symptomatic granuloma (1 case).

Conclusions. Our study demonstrates that patients who undergo unicoronal plagiocephaly repair with a hypercorrection surgical technique avoid long-term relapse. Our results suggest that the surgical technique used in the correction of unilateral coronal synostosis is strongly associated with the prevention of postsurgical relapse and that the use of this novel method decreases the need for surgical revision. (DOI: 10.3171/2011.6.FOCUS1193)

Key Words • craniosynostosis • unicoronal plagiocephaly • frontal plagiocephaly • temporal constriction • surgical relapse
nal plagiocephaly have been described. Hoffman and Mohr\(^3\) have described the lateral canthal advancement technique for expanding the affected ipsilateral anterior cranial fossa by releasing the frontoethmoidal and frontosphenoidal sutures that were also believed to contribute the characteristics of unicoronal plagiocephaly. Long-term follow-up of this technique has shown that 7 (17.9%) of 39 patients experienced relapse of the original deformity warranting surgical reoperation.\(^{22}\)

One of the most common postsurgical deformities after unicoronal repair is ipsilateral temporal constriction.\(^{26,31}\) Hilling et al.\(^5\) published an article on a series of 53 patients who underwent unilateral coronal synostosis repair in which a bandeau advancement technique was used. Patients in whom this technique was used, however, commonly presented with residual postoperative temporal hollowing. Oh et al.\(^7\) showed that placement of calvaria bone graft along the osteotomized coronal suture could prevent temporal constriction. However, they did not adequately substantiate their claims as they had an insufficient number of patients to statistically support the reliability of the technique. Strikingly, Steinbacher and colleagues\(^8\) demonstrated that all patients who underwent unicoronal plagiocephaly repair in which a unilateral frontoorbital advancement bandeau technique was used presented with residual postsurgical temporal hollowing. Eppley et al.\(^9\) acknowledged that a significant number of patients who underwent craniosynostosis repair required hydroxyapatite-based cranioplasty to correct postsurgical deformities (relapse). These reports affirm that a current single surgical procedure is unable to successfully and predictably correct all the characteristics of coronal plagiocephaly.

Surgical repair of unicoronal plagiocephaly requires the correction of both the underlying bony deformity associated with the synostotic suture as well as the management of the overlying soft-tissue envelope. In line with the tenets of the law of Wolff as well as the functional matrix theory, we believe that surgical techniques that repair unicoronal plagiocephaly without addressing the postsurgical recoil of the soft-tissue envelope may be associated with a surgical relapse.\(^{25,26,34}\) We hypothesize that correction of unicoronal plagiocephaly with a hypercorrection technique (one that overstretches the soft-tissue envelope to counteract recoiling forces) is associated with a lower incidence of postsurgical relapse.

**Methods**

**Study Criteria**

This study was a retrospective analysis of patient charts in cases in which unilateral coronal synostosis repair was conducted at the University of Michigan Craniofacial Anomalies Program between 1999 and 2009. The study was performed in concordance with the institutional review board. Demographic data were recorded and included patient age at the time of surgery and at the last follow-up, surgical technique, estimated blood loss, and perioperative transfusion volume. Exclusion criteria included incomplete medical record, absence of follow-up clinical images, multisurgical synostosis, syndromic disease, and major concomitant medical conditions.

**Surgical Technique**

All surgical procedures were performed by the senior author (S.R.B.). A wavy bicoronal scalp incision was used. The anterior scalp flap was dissected in a subgaleal plane and reflected anteriorly. Dissection transitioned to the subpericranial plane 2 cm above the supraorbital rims to avoid damaging the supraorbital neurovascular bundles. Dissection was extended to expose the nasofrontal junction, the anterior orbital aspect of the bilateral supraorbital rim, and the bilateral frontozygomatic sutures. Bilateral temporalis muscles were exposed by dissecting superficially to the deep temporal fascia. A frontal craniotomy was performed by the neurosurgeon in a standard fashion.\(^2\) The supraorbital bar was harvested in a standard fashion without bandeau extensions.\(^3\) Bilateral temporalis muscles flaps were dissected off the temporal fossa subperiosteally to a level inferior to the zygomatic arch. The supraorbital bar was contoured with Tessier bone benders to achieve a smooth flattened contour. The inferolateral edge of the ipsilateral supraorbital rim was contoured with rongeurs to achieve a widened and arched shape that resembled the appearance of the contralateral unaffected side. Barrel stave osteotomies were performed in the ipsilateral temporal bone to widen the cranial vault and cross-strut stabilization was used to hold the correction out against the recoiling forces of the scalp.\(^20\)

The recontoured supraorbital bar is repositioned in a hypercorrected position both in the coronal and sagittal planes. To achieve this hypercorrected position, the supraorbital bar was placed in a declined position (higher on the unaffected side and lower on the affected side) in the coronal plane, with the unaffected side pivoting upon its frontozygomatic suture (Fig. 1 white arrow) and the affected side positioned in a relatively inferior position upon the corresponding frontozygomatic suture (vertical hypercorrection) (Fig. 1 right arrow). The supraorbital bar is also asymmetrically displaced anteriorly in the sagittal plane so that the unaffected side keeps pivoting at its corresponding frontozygomatic suture and the affected side is positioned significantly anterior to its corresponding frontozygomatic suture (horizontal advancement hypercorrection) (Fig. 1 yellow arrow). The hypercorrected frontoorbital bar is held in place at the level of the unaffected frontozygomatic suture side with Vicryl sutures. The frontal bar crosses the frontonasal junction, which helps to support the advanced bone and is also held with Vicryl sutures. Finally, a resorbable plate is used to support the significant advancement of the affected side to achieve hypercorrection. The desired hypercorrection is checked prior to welding the resorbable plate to its bony attachments by reflecting the anterior bicoronal flap and inspecting the degree of displacement. An interpositional bone graft obtained from the endocortical side of the frontal bones is then attached to the resorbable plate to reinforce and add durability to the hypercorrection (Fig. 1). The more malleable frontal bones are then reshaped to correct the ipsilateral flattening and contralateral frontal bossing. Finally, the frontal bone is reattached to the
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supraorbital bar with either resorbable plates or Vicryl sutures.

The temporalis muscle flap of the affected side is rotated anteriorly over the advanced lateral orbital rim to fill and recontour the anterior aspect of the reconstructed temporal fossa. The temporalis muscle is held in the desired place with Vicryl sutures often anchored to adjoining bone through tactically placed drill holes. The bicoronal flap is once again flipped back to check the contour of the anterior temporal fossa (Fig. 1). If there is clinical evidence of residual temporal undercorrection, the temporalis muscle can be reshaped and “sculpted” by applying Vicryl sutures within the muscle itself. Judicious use of bone grafts can also be used to achieve the desired contour. The temporalis muscle of the unaffected side was minimally repositioned to gain temporal fossa symmetry with the opposite side and secured in the same fashion using Vicryl sutures. The bicoronal incision is closed in layers, leaving the most distal 1–1.5 cm ends of the incision behind the ear open for fluid drainage in both sides. No drains are placed. The incision is covered with topical antibiotic ointment. The head is covered with a sterile head wrap dressing.

Study Data

Clinical progress notes were evaluated to determine complications, causes of reoperation, and postoperative assessment of the patient’s cranial vault and face. Preoperative and postoperative photographs were evaluated and scored by 2 independent graders (a senior plastic surgery resident and postgraduate student from the institution not related with the study) using the expanded Whitaker scoring system.3,32 The elements of the craniofacial evaluation included the position of the ipsilateral supraorbital rim (vertical dystopia), the shape of the ipsilateral and the contralateral forehead, the presence of ipsilateral temporal constriction, and the degree of residual C-shaped deformity. Data were analyzed using standard statistical tests.

Results

A total of 40 patients (16 boys and 24 girls) were included in the study. Thirty-five patients were nonsyndromic and 5 were syndromic. Left coronal synostosis (23 cases) was more common than right coronal synostosis (17 cases) in our cohort. The mean age at the time of surgery was 13 months (range 8–28 months). The average perioperative estimated blood loss was 164 ml (range 25–600 ml). In 18 patients (44%) perioperative blood transfusion was performed. The mean hospital length of stay was 5 days (range 4–6 days). The mean follow-up duration was 57 months (range 3 months to 9.8 years). Patients were routinely seen at the following postoperative intervals: 2 weeks, 2 months, and then every 1 to 2 years until reaching 10 years of age. In accordance with our hospital policy, patients did not undergo routine postoperative radiography or CT scanning.

Our results indicated an immediate intraoperative hypercorrection of the unicoronal plagiocephaly resulting in a lowered and anteriorly projected ipsilateral supraorbital rim and ipsilateral forehead and significant lateral projection of the anterior temporal area compared with the contralateral side and preoperative appearance (Fig. 1).

A hypercorrected appearance was present in all treated patients for an average of 6–8 months, but the hypercorrection gradually dissipated and normalized (Fig. 2).
were no acute perioperative complications such as infection, surgical wound dehiscence, or collapse of the hypercorrection. There were no deaths.

Review of the charts demonstrated that no patient required reoperation for correction of a surgical relapse (based on either the surgical team physical examination and/or patient’s parents’ assessment). Only 3 patients required reoperation for reasons not associated with relapse: 2 patients underwent bone grafting of persistent calvarial defects, and 1 patient required removal of a symptomatic scalp granuloma, thought to be secondary to a foreign body reaction of the underlying resorbable plate.

Clinical evaluation of the patients’ pre- and postoperative photographs using the expanded Whitaker scoring scale demonstrated that the majority of cases were Category I (no imperfections noted) for the following characteristics analyzed: supraorbital rim elevation (vertical dystopia) 80% (32 cases); shape of ipsilateral forehead (vertical dystopia) 82.5% (33 cases); shape of contralateral forehead 97.5% (39 cases); and ipsilateral temporal constriction 82.5% (33 cases) (Table 1). In the remainder of cases the appearance was Category IIA (minor imperfections noted, but no surgical revision performed or planned) for the same categories: supraorbital rim elevation (vertical dystopia) 20% (8 cases); shape of ipsilateral forehead (vertical dystopia) 17.5% (7 cases); shape of contralateral forehead 2.5% (1 cases); and ipsilateral temporal constriction 17.5% (7 cases) (Table 1). No patient had phenotypic characteristics classified as Category IIB (minor imperfections that required minor soft-tissue or bone contouring revisions), Category III (major bony or soft-tissue imperfections that required major alternative osteotomies for bone grafting), or Category IV (severe relapse that required repetition of the original surgery) (Table 1).

Clinical evaluation of the patients’ postoperative photographs for the appearance of the C-shaped deformity showed that this deformity improved in 57.5% (23 cases), remained unchanged in 5% (2 cases), and corrected in 37.5% (15 cases). No patient had worsening of a C-shaped deformity. These differences were statistically significant (Table 2).

Although our patients did not undergo routine postoperative radiography or CT evaluation due to our institution’s pediatric patient radiation exposure policy, one of the patients underwent head CT scanning for an unrelated medical condition. The 3D CT scans demonstrated that the affected left supraorbital rim, left forehead region, and left anterior temporal area resembled the appearance of the contralateral normal side (Fig. 3). Close evaluation of axial bone-window CT scans showed a slight difference in the anterior projection of the affected left supraorbital rim compared with the contralateral side but the configuration overlaying soft-tissue envelope resembled the radiological contour of the contralateral normal side (Fig. 4). Clinical evaluation of postoperative images showed no evidence of ipsilateral supraorbital rim or forehead retrusion compared with contralateral side (Fig. 4).

Discussion

Relapse after unilateral coronal synostosis repair is a common finding associated with multiple surgical techniques.22,23,31 Although surgical procedures to correct unicoronal plagiocephaly have evolved significantly, postsurgical deformities (relapse) that warrant secondary corrective surgical revisions are still common.10,28 Our proposed hypercorrection technique for unicoronal synostosis was not associated with a surgical relapse (Category IIB or above on the expanded Whitaker scale) that warranted a subsequent corrective reoperation (Fig. 2–4, Table 1).

Hoffman and Mohr13 introduced the lateral canthal advancement of the supraorbital margin as an alternative to strip craniectomies for the correction of unicoronal synostosis. Long-term follow-up of this technique in a se-

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**Fig. 2.** Progression of unicoronal plagiocephaly hypercorrection repair.  
A and D: Preoperative appearance at 3 months of age.  
B and E: Appearance 3.5 months postoperatively.  
C and F: Appearance 2 years postoperatively.
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<table>
<thead>
<tr>
<th>Condition of C-shaped Deformity</th>
<th>Incidence (no. of cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>worse</td>
<td>0.0% (0)</td>
</tr>
<tr>
<td>unchanged</td>
<td>5.0% (2)</td>
</tr>
<tr>
<td>improved</td>
<td>57.5% (23)</td>
</tr>
<tr>
<td>corrected</td>
<td>37.5% (15)</td>
</tr>
</tbody>
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TABLE 1: Clinical evaluation of photographic appearances after unicoronal plagiocephaly repair with the hypercorrection surgical technique

<table>
<thead>
<tr>
<th>Extended Whitaker Category</th>
<th>Supraorbital Rim Elevation</th>
<th>Ipsilateral Forehead</th>
<th>Contralateral Forehead</th>
<th>Ipsilateral Temporal Constriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>32 (80.0)</td>
<td>33 (82.5)</td>
<td>39 (97.5)</td>
<td>33 (82.5)</td>
</tr>
<tr>
<td>IIA</td>
<td>8 (20.0)</td>
<td>7 (17.5)</td>
<td>1 (2.5)</td>
<td>7 (17.5)</td>
</tr>
<tr>
<td>II B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>III</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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TABLE 2: Effects of the unicoronal plagiocephaly hypercorrection surgical technique on C-shaped deformity

Ries of 39 patients showed that even though the majority of the patients had good results after surgery (24 [65%] of 37 available for follow-up), a significant number of patients (7 [18.9%]) had postsurgical deformities that required reoperation. The characteristics of the relapse that warranted major reoperation were not described, making it difficult to assess the potential cause of such relapse.

McCarthy et al.23 in a report on their 23-year experience in the management of craniosynostosis, indicated that 6 (18.8%) of 32 patients who underwent unicoronal plagiocephaly in which the authors used the tongue-in-groove frontoorbital advancement technique had unchanged vertical dystopia. Bartlett and colleagues3 compared the surgical outcomes of the unicoronal plagiocephaly repair in which the hypercorrection surgical technique was used did not undergo reoperation for correction of surgical relapse. The majority of the postoperative photographs (> 80%) reflected a Category I result based on the extended Whitaker scale (Table 1). The remainder of the patients (approximately 20%) had minor imperfections (ipsilateral supraorbital rim [8 patients], ipsilateral forehead [7], contralateral forehead [1], and ipsilateral temporal constriction [7]) that did not warrant surgical intervention (Category II A). Among these minor imperfections, ipsilateral temporal constriction was not the most common finding, contrasting with previous published data (Table 1)12,21

Temporal hollowing is a common finding after unicoronal plagiocephaly repair.3,28,31 The cause of the temporal hollowing remains a matter of debate. Multiple reports have suggested the role of temporal muscle atrophy,3 temporal fat atrophy,30 and type of surgical technique2,15 in the causation of postsurgical temporal hollowing. Persing et al.29 described the temporalis musculo-osseous flap surgical technique as a method to prevent temporal hollowing after frontoorbital advancement in a patient with unicoronal plagiocephaly. However, because this report was based on a single case, it is difficult to assess the reliability of the technique. Steinbacher and colleagues31 found that all the patients who underwent unicoronal plagiocephaly repair with a unilateral bandeau frontoorbital advancement presented with bitemporal constriction due to both the relapse of the bony bandeau and constriction of the temporals muscle, but not to atrophy of the temporalis fat. Our study showed that the majority of the patients (82.5% [33 patients]) treated with the hypercorrection surgical technique resisted the development of bitemporal constriction (extended Whitaker Category I) (Fig. 3). In contradistinction to the findings of Steinbacher and colleagues all the temporal abnormalities found in our series were classified as extended Whitaker Category II A, and none of our patients were classified as Category II B. It is possible that the lateral hypercorrection of the temporal area on the affected side, in addition to the anterior hypercorrection of the ipsilateral frontal area, prevented the occurrence of the temporal constriction relapse commonly seen with other surgical techniques.31 These data suggest that the type of surgical technique has a strong influence on the aesthetic outcomes of unicoronal plagiocephaly repair, especially in regard to postsurgical temporal constriction.

Hansen et al.31 compared the outcomes achieved with 3 different surgical techniques in the management of
unicoronal plagiocephaly repair. Their report suggested that only surgical techniques that included the osteotomy of the nasal root significantly improved the nasal canthal associated with the C-shaped deformity of the face. Our hypercorrection surgical technique did not osteotomize the root of the nose. The reason behind not performing nasal osteotomies was to avoid instability of the hypercorrected frontoorbital bar at the nasofrontal junction (pseudobuttress). We did, however, see improvement in our patients. Clinical evaluation of the progression of the C-shaped deformity postoperatively showed that the 15 patients, or 37.5%, had a corrected deformity, 23 (57.5%) had an improved deformity, and 2 (5%) had an unchanged

Fig. 3. Clinical appearance of patients with unilateral coronal plagiocephaly preoperative (left column) and after correction with the hypercorrection surgical technique (right column).

Fig. 4. Tomographic and photographic appearance of the cranial vault and face after unicoronal synostosis repair with the hypercorrection technique. A and B: Three-dimensional CT scans. C: Axial CT scan. D and E: The patient’s preoperative clinical appearance. F and G: The patient’s postoperative appearance.
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deformity. Our results with regard to the nasal root deviation and C-shaped deformity are in concordance with reports of surgical techniques that also do not osteotomize the root of the nose.23

Split calvarial bone grafts are not routinely used for primary correction of unilateral coronal plagiocephaly.12,22,23,31 Hoffman and Mohr13 used calvarial bone graft to maintain the lateral canthal advancement, but their technique was not associated with hypercorrection. Our technique used bone grafts to primarily reinforce a dissolvable plate that maintains the hypercorrection of the frontoorbital bar in the synostotic side (preventing collapse of the construct as the resorbable plate resorbs/weakens with time). Additionally, split calvarial bone grafts are used when appropriate to correct minor imperfection of the hypercorrection that are seen once the anterior bicornal flap is repositioned over the hypercorrected framework. Because the ultimate goal of the technique is to achieve asymmetrical hypercorrection of the frontoorbital advancement with the soft-tissue envelope in place, any superficial contour irregularities (depressions, edges, and so on) are corrected by placing split calvarial bone grafts underneath the area of concern (“touch up”).

The mean age of patients at the time of surgery in our series was 13 months (range 8–28 months). Although our institution’s policy is to perform correction of unilateral coronal plagiocephaly when the patient is between 6 and 12 months of age, the timing of surgery was affected by the age of the patient at the time of referral, cancellations due to patient sickness (upper airway respiratory infections, for example), and/or scheduling issues. Performing surgery at ages less than 6 months is associated with very soft calvarial bone that may not be strong enough to withstand the desired hypercorrection. Cranial vault remodeling, performed at ages older than 16 months, could be associated with the persistence of calvarial bone defects due to decreased osteogenic potential of the dura. Additionally, advance age at the time of the operation may be associated with development of elevated intracranial pressure and subsequent developmental delays.29,33 Although 2 of our patients required reoperation for management of persistent calvarial bone defects, both patients underwent surgery at 12 months of age. Review of patient charts showed that no patient in our series developed clinical signs of elevated intracranial pressure pre- or postoperatively per clinical assessment and ophthalmological fundoscopic assessment. Neurological development after correction of unilateral coronal synostosis with the hypercorrection surgical technique was not assessed in this study.

Traditional 2D clinical pre- and postoperative photographs were assessed to evaluate the position of the ipsilateral supraorbital rim (vertical dystopia), shape of the ipsilateral and contralateral forehead, presence of ipsilateral temporal constriction, and degree of residual C-shaped deformity in our study. Two-dimensional photographs were evaluated using the expanded Whitaker scoring system.1 Two-dimensional photography has been widely used and validated to evaluate the characteristics of craniofacial malformations and to assess the effect of therapeutic surgical procedures in the correction of such conditions.1,3,10,11,22,23 Three-dimensional photography is a novel technology that allows us to capture a patient’s superficial craniofacial anatomy in 3 dimensions.34,19 This revolutionary imaging technology has the potential of quantifying volumetric changes of the facial soft tissues10,16,18 as well as cranial vault volume.24 Three-dimensional photography appears to be the ideal tool to assess and quantify the effect of surgical techniques in the correction of craniofacial malformations such as unilateral coronal plagiocephaly. Analysis and quantification of the effects of the hypercorrection surgical technique in the management of unilateral coronal synostosis, particularly in the forehead, could not be performed in our series because this technology was not readily available for clinical use at the time the majority of the patients underwent preoperative photographic documentation.

Our study did not include routine postoperative radiographic evaluation (radiography or CT scanning) of patients who underwent unicoronal plagiocephaly repair. Our Children’s Hospital policy strongly encourages the avoidance of radiation exposure in pediatric patients, especially during the phase of rapid brain growth (from birth up to 3 years of age).5,7,8,21 This policy is welcomed and practiced by our neurosurgery colleagues. Although valuable information could be obtained from postoperative CT scans to establish the potential structural causes of unicoronal plagiocephaly surgical relapse,31 the uncommon and minor postsurgical deficiencies observed with our hypercorrection surgical technique did not warrant routine evaluation of postoperative CT scans.

Multiple studies have suggested that the possible cause of surgical relapse associated with surgical techniques was the lack of overcorrection.11,12,22 We posit that the low incidence of relapse associated with our unicoronal plagiocephaly hypercorrection technique is due to the increased support of the hypercorrected bony framework design, which functions to counter and resist the soft-tissue recoil in patients with unicoronal plagiocephaly (functional matrix theory).2,25,34

Conclusions

Our results suggest that the type of surgical technique used in the correction of unilateral coronal synostosis has a strong effect on the occurrence of postoperative relapse. Our report demonstrates that patients who undergo unicoronal plagiocephaly repair with a hypercorrection surgical technique resisted long-term relapse and did not require secondary surgical correction.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Buchman, Mesa. Acquisition of data: Mesa, Fang. Analysis and interpretation of data: Buchman, Mesa, Fang. Drafting the article: Mesa. Critically revising the article: all authors. Statistical analysis: Mesa. Administrative/technical/material support: Buchman, Mesa, Muraszko. Study supervision: Buchman, Mesa.
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