Chapter

Telescoping with Multiple Revolution Cranial Osteotomies in Patients with Simple Craniosynostosis

Diego José Caycedo, Marcela Cabal Castro and Luís Fernando Santacruz

Abstract

Simple craniosynostosis is a cranial deformity that occurs secondary to a premature closure of one or more sutures, with a consequent alteration in cranial growth and cerebral expansion. The cranial alteration presents as flattening parallel to the compromised suture, with compensatory bulging in a perpendicular vector. The surgical treatment consists in cranial decompressions with suturectomies and simultaneous cranioplasties. Dynamic multiple revolution osteotomies allow the design of bone flaps that can help with decompression and correct secondary deformities caused by the synostosis. This multicenter descriptive case series study assessed 52 patients (12 plagiocephaly, 29 scaphocephaly, 7 brachycephaly and 4 trigonocephaly) operated in Cali, Colombia. In each case, suturectomy and telescoping with multiple revolution cranial osteotomies were designed to correct each particular deformity. No clinical complications were observed in the postoperative period (1, 90, and 180 days), and excellent outcomes with no re ossification of sutures and maintenance of the cranioplasty, based on clinical observation and findings in the 3D reconstruction scans.

Keywords: telescoping, osteotomies, cranioplasty, suturectomy, craniosynostosis

1. Introduction

Simple craniosynostosis is a cranial deformity that occurs secondary to a premature closure of one or more sutures, with a consequent alteration in cranial growth and cerebral expansion. It develops during the first years of life and affects 1 in every 2000 to 2500 births worldwide [1]. The cranial alteration presents as flattening parallel to the compromised suture, with compensatory bulging in a perpendicular vector [2, 3].

The surgical treatment consists in cranial decompressions with suturectomies and simultaneous cranioplasties. Dynamic multiple revolution osteotomies allow the design of bone flaps that can help with decompression and correct secondary deformities caused by the synostosis. This multicenter descriptive case series study assessed 52 patients (12 plagiocephaly, 29 scaphocephaly, 7 brachycephaly and 4 trigonocephaly) operated in Cali, Colombia. In each case, suturectomy and telescoping with multiple revolution cranial osteotomies were designed to correct each particular deformity. No clinical complications were observed in the postoperative period (1, 90, and 180 days), and excellent outcomes with no re ossification of sutures and maintenance of the cranioplasty, based on clinical observation and findings in the 3D reconstruction scans.

Craniosynostosis surgical techniques have evolved over time. Initially extensive craniotomies with or without the use of alloplastic substances between bone gaps were described to release de compromised suture and allow cerebral decompression. Uncertain and inconsistent results were observed, that usually required reoperations and ended in poor esthetic results [4–7]. Developing techniques included the addition of bone remodeling for the compensatory defects using cranial bone grafts (static remodeling) and the use of different osteosynthesis materials. Given the evidence around the rapid ossification during the first year of life, nowadays gradual osteogenic distraction is one of the preferred procedures associated to skull osteotomies and cranial bone flap remodeling [8]. Osteotomies that remove bone segments and relocate them as bone grafts for cranial remodeling, increase the possibility of complications due to dead space formation between dura mater and bone grafts [9].

Over time, distraction osteogenesis has become very important in the surgical treatment of craniosynostosis. In 1998, Lauritzen et al. [10] proposed the dynamic cranial remodeling technique with expansive springs, placed between the osteotomies (without dural dissection) thereby promoting expansive forces that prevented deformity recurrence. Salyer & Bardach [11] proposed, for the correction of scaphocephaly, posterior bi-parietal osteotomies molding bone grafts after separating them from the skull. Similar proposals were made by Tullous et al. [12] and Solís-Salgado & Anaya-Jara [13]. Cardim [14] presented excellent results with the use of springs and dynamic osteotomies (Nautilus), however, the maintenance of postoperative expansion was sometimes affected by the scalp flap or by positional effects.

The primary aim and motivation of our craniofacial surgery team in Cali, Colombia, is to find a stable maintenance option of the postoperative expanded shape. The proposal is to maintain the bone expansion achieved by telescoping (dynamic spiral) osteotomies with 2-center spirals, by placing absorbable plates at 180 degrees from each other, arranging them with a level-based organization according to each circumvolution (**Figure 1**).

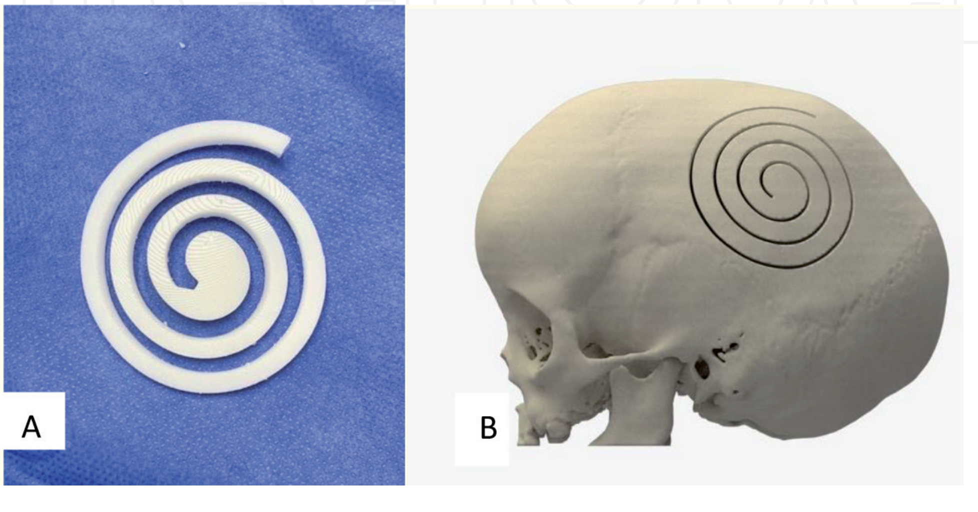
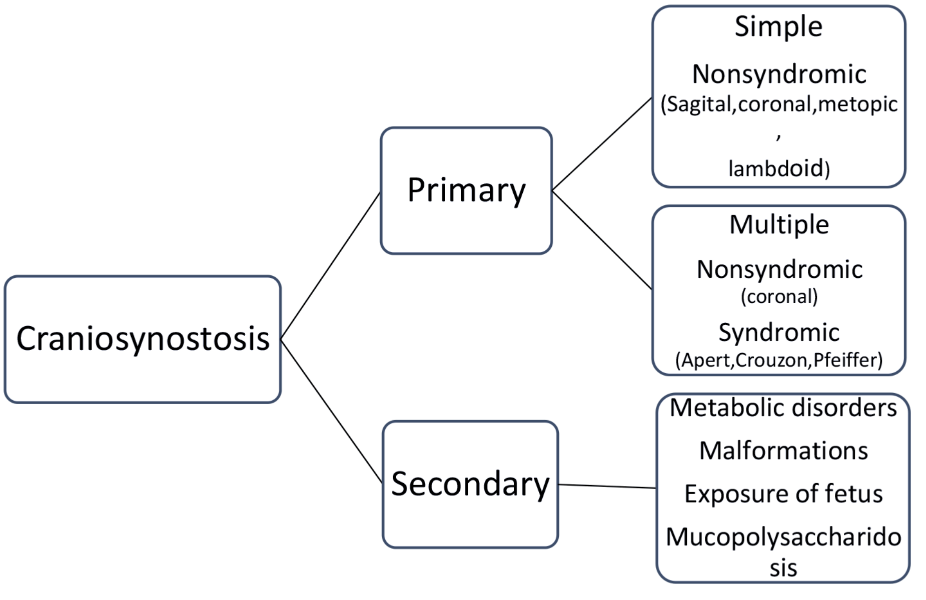


Figure 1.
(A) 2 centered spiral shape; (B) Representation of the spiral osteotomies.

2. Classification of Craniosynostosis

Two methods of classifications of craniosynostosis are used: anatomical and etiological. Anatomical classifications identify the fused cranial suture. There are four major sutures, and they can be altered as single metopic or sagittal sutures or as paired coronal and lambdoid sutures.

Single suture synostosis most commonly involve the sagittal suture (45%), followed by coronal (22%), metopic (22%), and lambdoid (5%). Alternatively, an etiological classification emphasizes the primary cause of craniosynostosis. The two most common causes of craniosynostosis are restriction of fetal head movement during pregnancy and single gene disorders that predispose to suture fusion. Bilateral coronal and multiple suture synostosis occur with disproportionate frequency in syndromic cases.



3. Presurgical preparation

The indications for surgery and inclusion criteria were patients diagnosed with simple craniosynostosis without previous surgical treatment and who had evident cranial deformity verified with X-ray and tomography. Children between 3 months and 4 years old. Excluded patients were those with syndromic craniosynostosis, children with previous surgical treatments, and patients with indication of minimally invasive cranial correction.

A multidisciplinary medical group consisting of a plastic surgeon, pediatric neurosurgeon and anesthesiologist asses all patients. To support the best surgical plan, 3D imaging Ct scans are performed. Its required to guarantee for all patients a strict monitoring of the anesthesia including colocation of central catheter, arterial route, bladder catheter ant temperature monitoring. It's also required to have guaranteed intraoperative blood transfusion. After the intervention all patients are transferred to intensive care unit. The first follow up of the patients are done every 3 months and then 3 more follow ups every 6 months until the second year after the interventions.

Patients that had cranioplasty surgery with a telescopic osteotomy, were divided in subgroups according to their alterations for surgical purposes. These subgroups are: Diagnosis of scaphocephaly, brachyophaly, plagiocephaly, and trigonecephaly. Patients with the scaphocephaly diagnosis are intervined with the "PI" technique and in the bi-temporoparietal regions, multiple- revolutions oseotomies were used to achieve the expansion and telescoping of osteotomies. Absorbable plates are staggered in three levels with a 180 degree in each circumvolution within the dynamic osteotomy. Patients with plagiocephaly, brachycephaly and trigonocephaly were treated with corticotomy surgeries for the liberation of the synostosed sutures and with dynamic osteotomies depending on the altered areas, fixing plates in the same alternating form as described previously for scaphocephaly

4. Surgical technique

Patients underwent general anesthesia, with endotracheal intubation and bilateral tarsorrhaphy, and placed in supine decubitus on the surgical table. A zigzag shape bitemporal coronal incision was made and a subsequent subperiosteally dissection was performed until the compromised suture was completely exposed.

In patients with scaphocephaly, the synostosis was managed with a "PI" technique osteotomy (**Figure 2**), removing the bone segments on each side of the sagittal suture. Then sub cranial dissection in the temporal regions was performed, as well as design of spiral osteotomies (**Figure 3**). With and without mechanical traction of the bone flaps of the spiral osteotomies, decompression was observed. (**Figure 4**). To maintain the expansion and telescoping of the osteotomies, at each level of the spiral absorbable plates were placed at each level of the spiral at 180 degrees from each other (**Figure 5**). This allows the lasting cranial decompression observed in the 3-d Computerized Tomography scan (**Figure 6**).

In plagiocephaly, brachycephaly and trigonocephaly cases (**Figure 7**), after the release of the compromised suture, spiral osteotomy was performed in the flattened areas of the skull. After checking the adequate release of the suture, the absorbable plate was placed to maintain telescoping (expansion) (**Figure 8**). The patients in the immediate postoperative period were transferred to the intensive care unit (ICU) for 2 days and then to a hospitalization room for 4 to 5 days.

5. Clinical evaluation

The patients that met the inclusion criteria were determined by a clinical evaluation. Out of the 52 diagnosed patients with simple craniosynostosis, 12 were plagiocenphaly, 29 scaphacephaly, 7 brachycephaly and 4 trigonocephaly. The average age of patients was 16.3 months. No mayor complications were observed in the intra operative and post - operative stage. No seromas, cerebrospinal fluid fistula or signs of infections. Only in two patients, the formation of granuloma was observed at the incisions and was resolved with the suture removal. In the neurological recurrent assessment, none of the patients showed any alteration and there was no suspicion of Intracranial Hypertension recurrence according to clinical charts. Furthermore, none of the patients had an increased hospitalization time in the intensive care unit or in the ward. .3D CT scans were requested to all patients for evaluation of the surgical procedure at different times (**Figure 6**). In all patients, correction of the cranial deformity in the immediate postoperative period was observed (**Figures 7–9**). Likewise, the results were maintained over time and they were assessed at the controls after 3 and 6 months of surgery (**Figure 9**).

The craniofacial surgery team and their families judged the results in follow ups that went from 6 to 25 months after surgery. Sixteen of the patients had an excellent aesthetical correction of their deformities. In 4 cases the family was pleased with the outcomes, but the craniofacial surgery team identifies mild residual deformity.

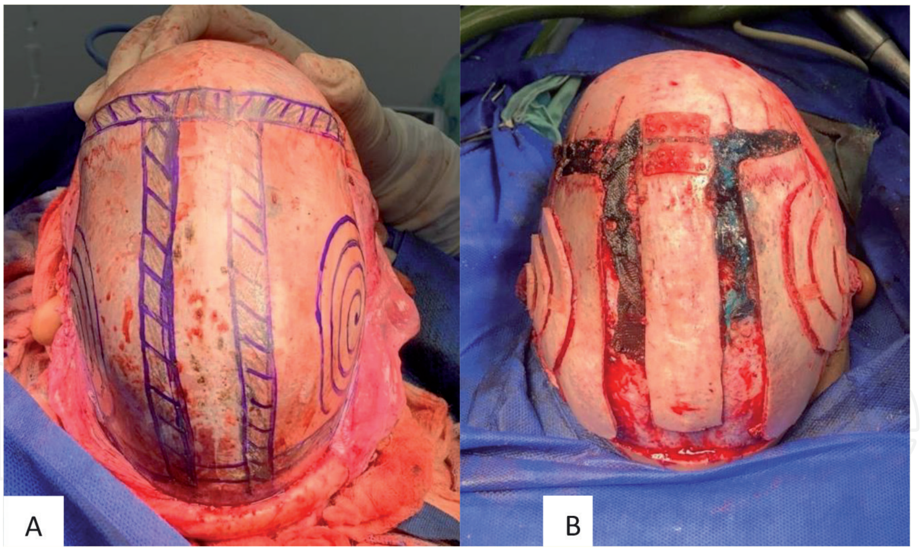


Figure 2.
Intraoperative images of a scaphocephaly correction; (A) Intrasurgical suturectomies design; (B) "PI" shape modification osteotomy.

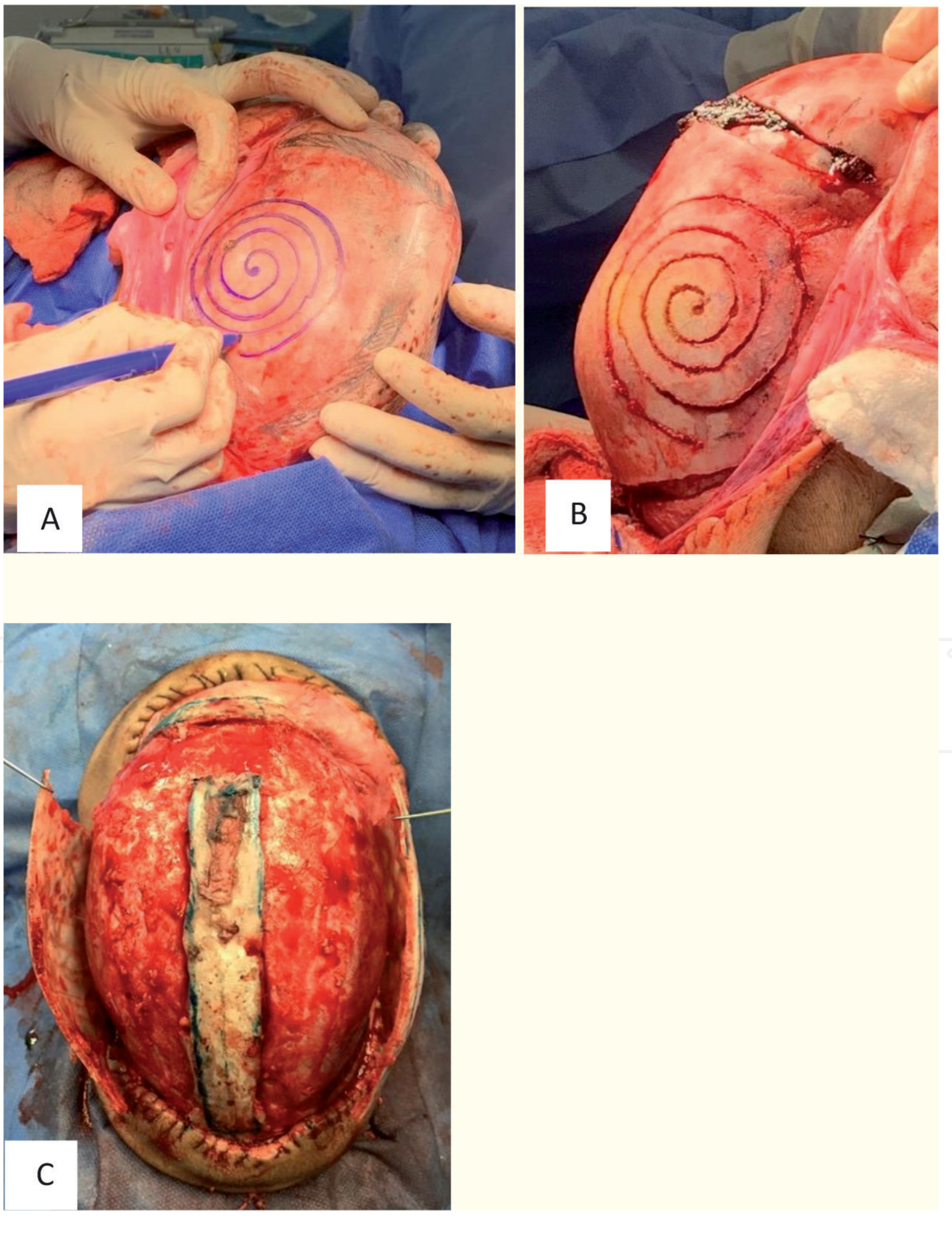


Figure 3.
Intraoperative images of a scaphocephaly correction. (A) Design of technique, (B) Spiral osteotomies, and (C) Sub-cranial dissection.

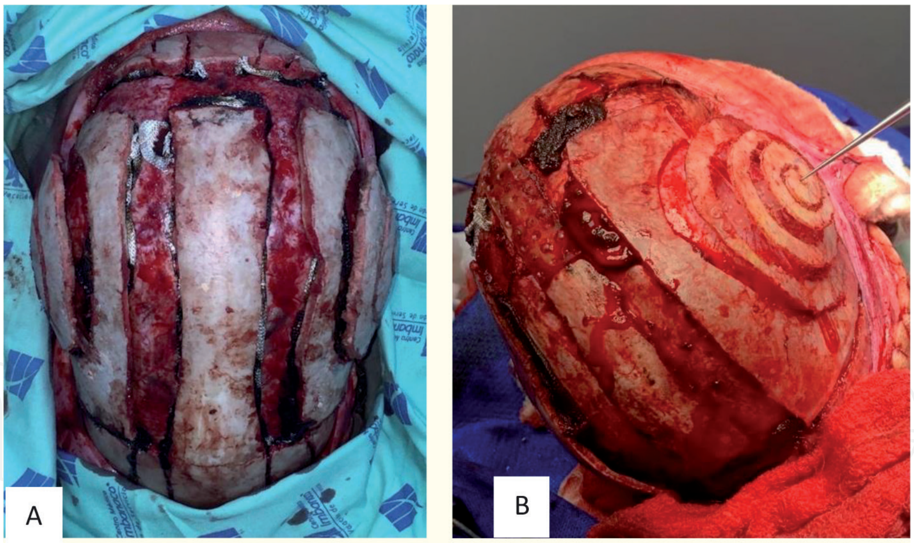


Figure 4.
Superior image view of the spiral osteotomy in a scaphocephaly correction. (A) Osteotomy without applied traction; (B) osteotomy with traction.

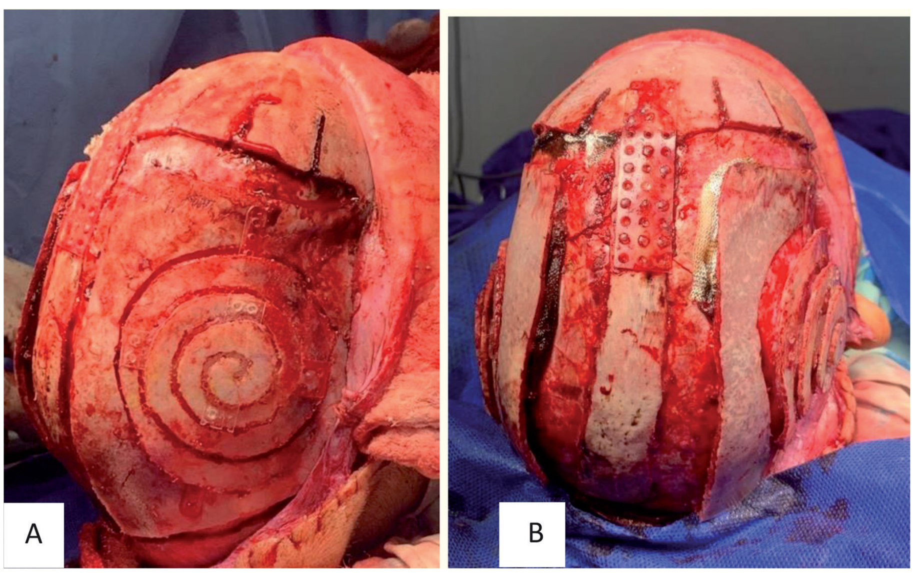


Figure 5.
Scaphocephaly correction. (A) View of the lateral intraoperative spinal osteotomy with absorbable plates places al 180. (B) Intraoperative superior view.

6. Discussion

In simple craniosynostosis, cranial alterations are the result of skull compensation to the premature closure of a suture. This deformity allows adequate brain growth to avoid neurological sequelae resulting from compression of structures. According to Virchow descriptions [2, 3], different cranial shapes can be found depending on the suture alteration.

The aim of the different surgical procedures described for the synostosis correction is to provide predictable and stable outcomes and the prevention of neurological changes, secondary to cerebral compression. All surgical plans including craniectomies, suturectomies, subsequent reconstruction procedures [4, 5] and the use of cranial expansion devices or any ostheosynthesis material [6, 7] need to consider the least traumatic choice for the patient and consider always that unexpected morbidities can present.

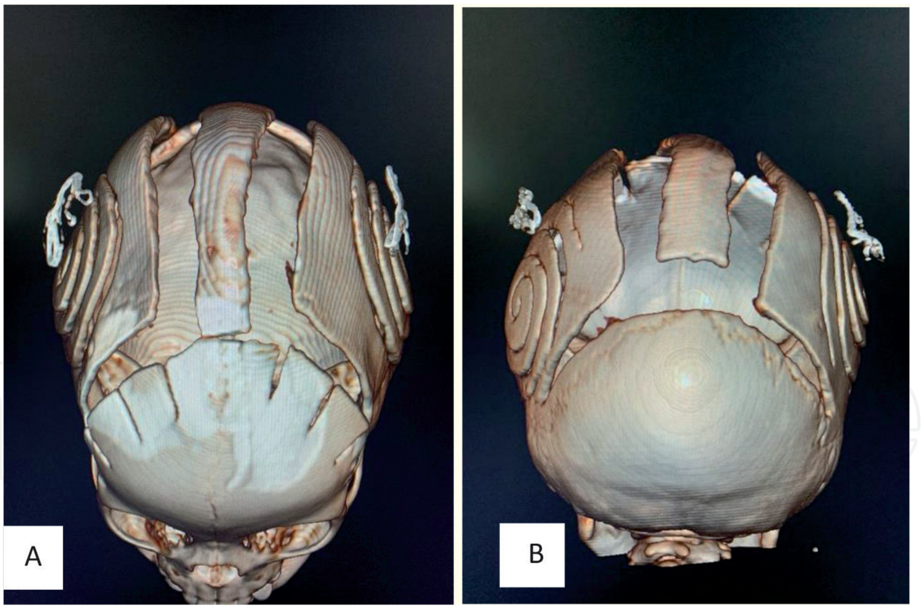


Figure 6.
3-D computerized tomography (CT) scan, it was taken on the 2nd postoperative day: (A) Superior view. (B) Posterior view.

Protection of the dura and the brain is achieved with the spiral craniotomies or dynamic revolution procedure, therefore lowering the morbidity rates. This advantage can also be observed when combining skull and facial procedures, as it's indicated in the treatment of syndromic craniosynostosis [9]. By designing bone flaps in spiral osteotomies [10, 12], the correction of the deformity has successful and stable outcomes. Also allowing adequate expansion of the brain in a more uniform, progressive way and obtaining a more anatomical shape [13, 14].

In general, it is considered that treatment should be carried out at an early age, from the third month to the first year of life [15, 16]. These osteotomies do not separate the dura from the calotte, thereby avoiding dead spaces that can allow seromas that usually complicate the craniosynostosis surgical intervention [17].

This craniotomy technique focused on keeping a stable expansion of the structures, which helps enhance the healing process. Therefore, the hypothesis was that the maintenance of expansion after the replacement and closure of the scalp flap, and despite the compression of the child's head support (e.g. at sleep), should improve esthetic and functional surgical outcomes. This study aims to contribute to the answer of two questions: how to achieve stable bone distraction and expansion. And how to perform in a simple and practical way the telescoping surgery technique by involving absorbable plates at 180 degrees from each other in the circular osteotomy (**Figure 5**).

This proposed technique has several advantages. This technique allows patients under 4-years to be treated by this surgical technique for simple craniosynostosis. It allows the brain and the skull to grow in a natural and symmetric way while having a protective frame achieved by the absorbable plates. Managing less neurological risks while obtaining a more dynamic skull growth. However, this technique is also invasive as previously described techniques. Performing the osteotomies with the expected circumvolutions requires expertise, practice of the technique is suggested before incorporating it in order to master and avoid complications. Although this technique is time consuming, no additional disadvantages or complications have been found in comparison with regular craniosynostosis procedures.

There are various techniques for cranial remodeling described in the literature for each type of craniosynostosis. Each technique has its advantages and

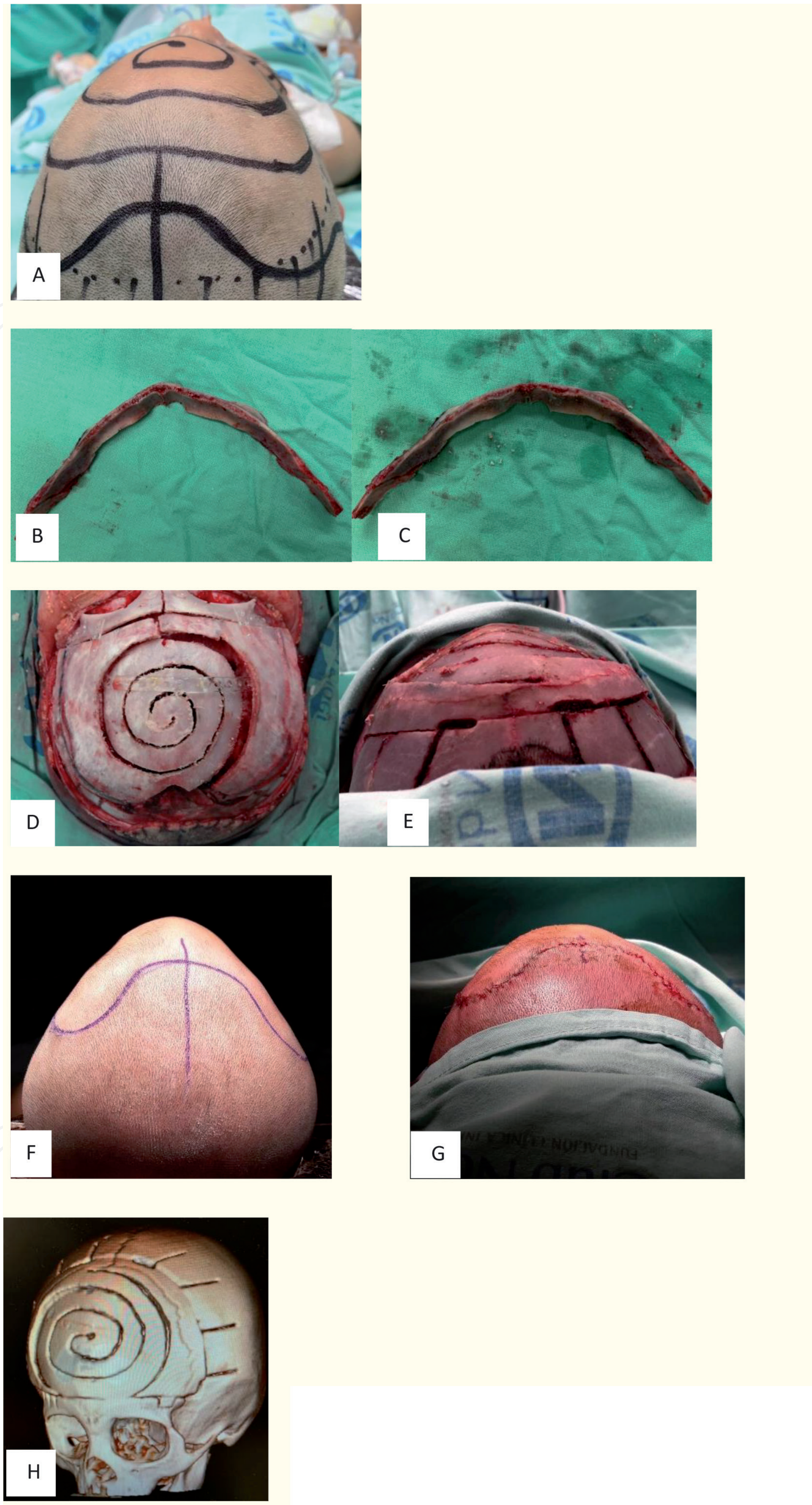


Figure 7.
Trigonocephaly correction. (A): Pre-surgical plan, (B) Fronto-orbital bar, (C) Remodeled frontoorbital bar, (D, E): Superior and frontal intraoperative views of the osteotomy showing the spiral design. (F) Preoperative, (G) Postoperative, (H) Post- surgical 3-D computerized tomography (CT).

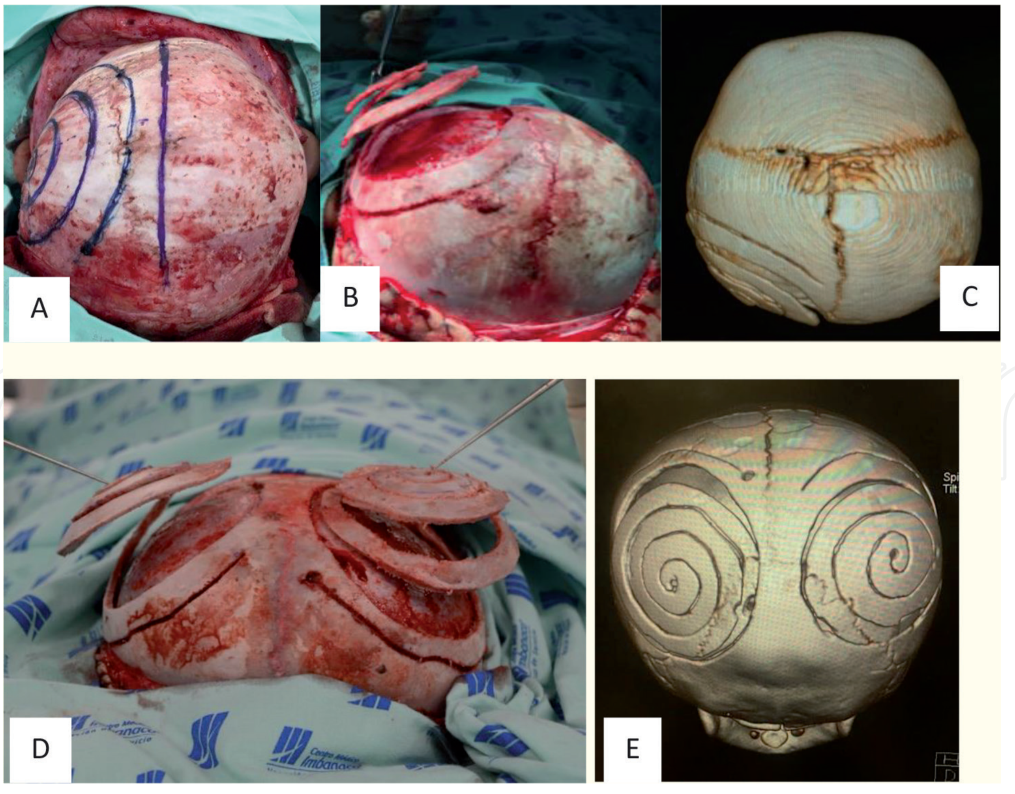


Figure 8.
Posterior plagiocephaly cases. (A) Pre-surgical plan for posterior plagiocephaly (B) Intraoperative image osteotomies showing the spiral design (C) Post- surgical 3-D computerized tomography (CT) (D) Intraoperative osteotomies for posterior plagiocephaly, showing treatment of the lambdoidea suture with the spiral bilateral shape (E) Post- surgical 3-D computerized tomography (CT).

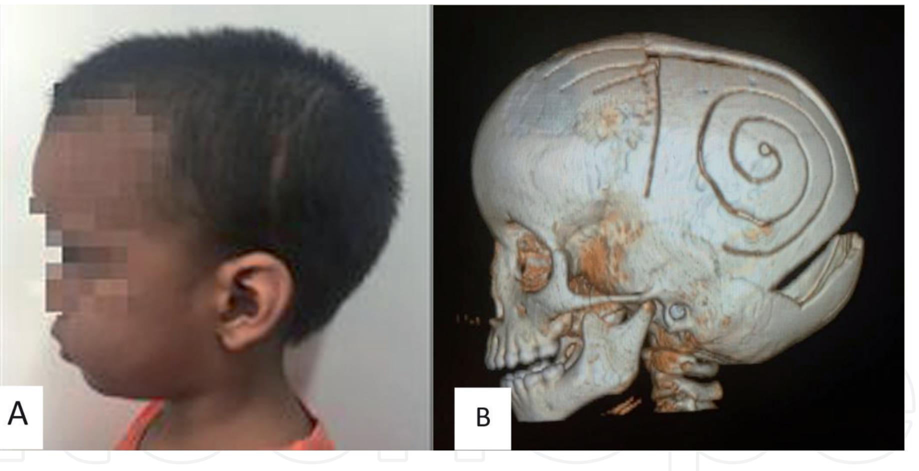


Figure 9.
(A) Scaphocephaly case, 3rd month post- surgical control, (B) 3-D computerized tomography (CT).

disadvantages. The idea of the proposed dynamic spiral craniotomies is to add other alternative to the different existing tools and to analyze its advantages.

For anterior plagiocephaly what is usually described is a unilateral fronto-orbital bar advancement that allows for the correction of asymmetries and retrusion of the orbits. For the frontal flattening and bossing of each side, what has been described is a craniectomy with cranioplasty and repositioning of each segment as bone grafts. With the spiral osteotomies what can be achieved is the correction of both the flattening and bossing, without the need of craniectomies, preserving the bone as flaps, thus conserving its vascularization and needing less dissection. These diminish the risk of comorbidities associated to greater dura detachments. For

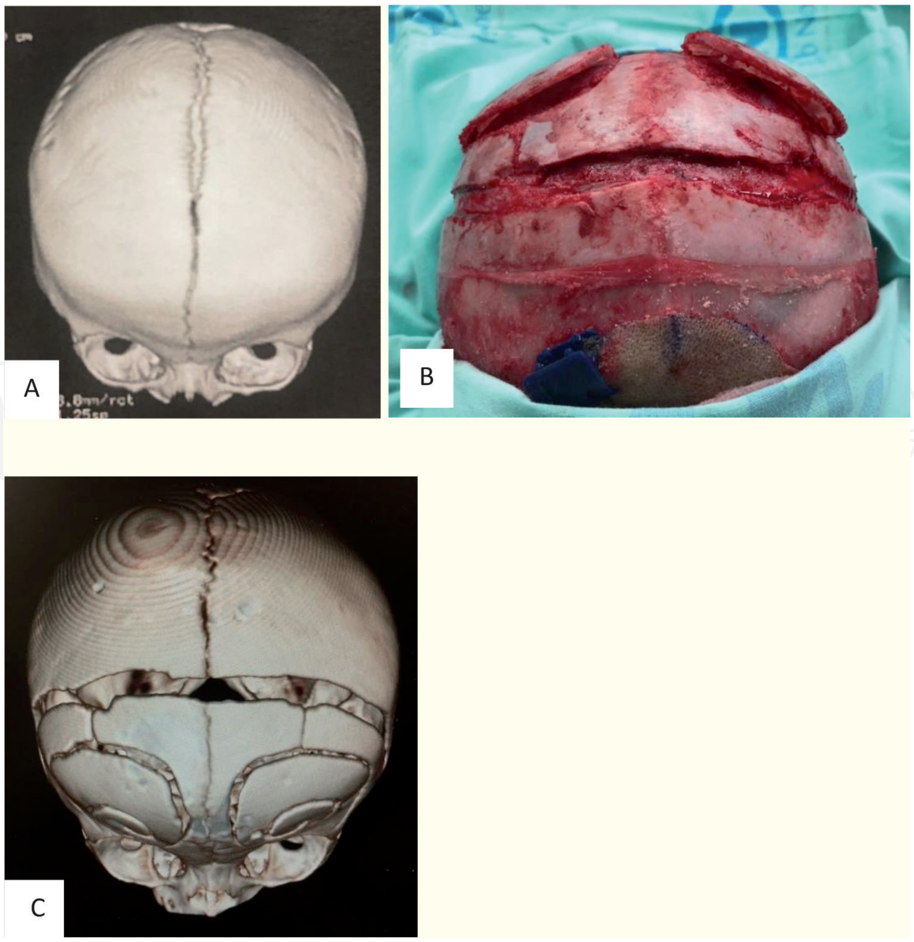


Figure 10.
Anterior brachycephaly. (A) Pre- surgical 3-D computerized tomography (CT) (B) Intraoperative view of osteotomies for coronal suturectomy and bilateral spiral osteotomies (C) Post-surgical 3-D computerized tomography (CT) superior view.

brachycephaly the technique is very similar, but the goal is to correct the flattening in both sides of the frontal bone (**Figure 10**). In posterior plagiocephaly what the literature has described for correction is the Mercedes technique, but it is associated to high complication rates for being highly traumatic and for long surgical times. With the lambdoid decompression associated to the dynamic osteotomies the functional and occipital asymmetries can be corrected with less complication rates (**Figure 8**). In trigonocephaly spiral osteotomies are also an alternative to allow for the remodeling of the frontal bone without the need of craniectomies and wide dissections (**Figure 7**).

As shown, spiral osteotomies firstly described in literature by Tullous in 2001 can be considered a useful tool for the treatment of all of the different synostosis deformities, as an alternative that conserves the vascularization of cranial bones, lowering the needs of greater dissections and craniectomies, and lowering surgical times and comorbidities. It is an option that has shown results that last over time (**Figure 11**).

7. Conclusions

The surgical correction via simple craniosynostosis with spiral osteotomies allows the achievement of cranial expansion with low morbidity rates. The results were that the skull areas where the osteotomies were performed, showed that tat they have their own vascularization, acting as bone flaps that enhanced the healing

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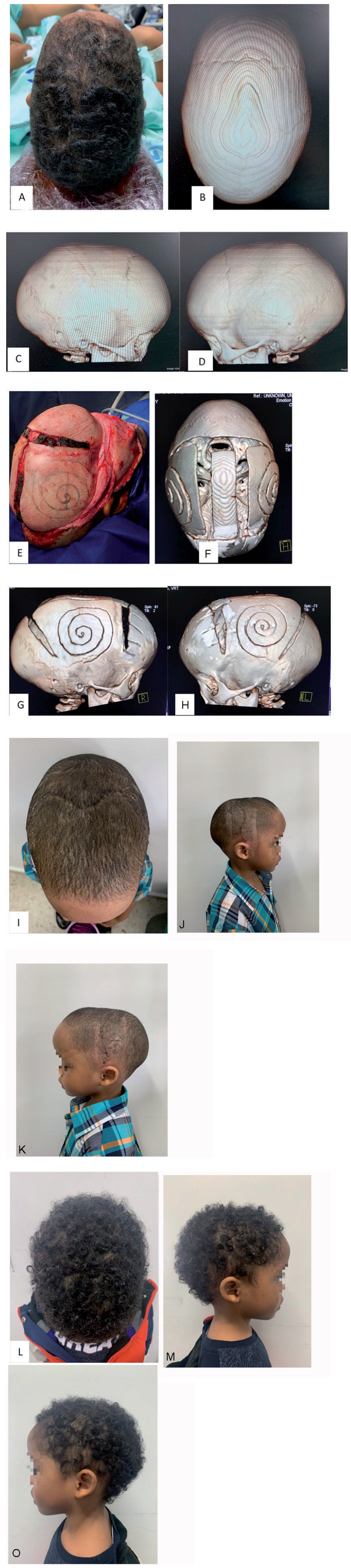

Figure 11.
(A) Scaphocephaly preoperative picture and (B-D) the 3D computerized tomography (CT), (E) Intraoperative view showing craniectomies and the marking of the spiral osteotomies in the parietal bones, (F-H) Pos surgical 3-D computerized tomography (CT), (I-K) 3 weeks pos surgical control, L,M,N: 2 and a half years post-surgical control.

process and diminished risks of seroma formation. In addition, a normal and natural development of the skull shape is achieved by the protection given by the absorbable plates in each spiral convolution of the osteotomies performed. Allowing it to maintain the surgical success over time (3 to 6 months).

Conflict of interest

The authors declare no conflict of interests regarding their current affiliations, besides the institutions where the present study was carried out.

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