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# Endoscopy-Assisted Craniosynostosis Surgery Versus Cranial Vault Remodeling for Non-Syndromic Craniosynostosis: Experience of a Single Center

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## ABSTRACT

**AIM:** To evaluate and compare open cranial vault remodeling (OCVR) and endoscopy-assisted craniosynostosis surgery (EACS) in patients with non-syndromic craniosynostosis and to develop an algorithm to determine the most appropriate surgery for each patient.

**MATERIAL and METHODS:** Eighty-five children with craniosynostosis who underwent surgery between 2010 and 2022 were retrospectively analyzed. Demographic data, comorbidities, and peri-operative findings of the patients were recorded. Pre- and post-operative comparisons were made between predetermined measurement techniques for each deformation. In addition, measurements were obtained by computed tomography (CT) or 3D stereophotogrammetric (3DSPG) methods from eligible patients and compared with one another.

**RESULTS:** In our study, 61 patients underwent EACS, whereas 24 underwent OCVR. The operating time of OCVR was approximately 54.4 minutes longer than that of EACS ($p<0.001$). The intra-operative blood loss was around 139 ml higher in OCVR ($p<0.001$). The length of hospital stay for patients who underwent EACS was shorter at 8.4 days on average ($p<0.001$). Surprisingly, 5 complications were observed in OCVR compared with 7 in EACS. While the cosmetic outcome of EACS was superior in most of the pathology-specific measurement techniques, the metopic index increased only in patients with metopic synostosis after both surgical operations. Still, this increase was lower in EACS than in OCVR.

**CONCLUSION:** This study suggests that endoscopic craniosynostosis surgery has lower estimated blood loss and operation and hospitalization times, as well as comparable cosmetic results compared with open vault surgeries on long-term follow-up. CT and 3DSPG methods can help distinguish between different types of measurement techniques for synostoses. However, no significant differences were found in the comparisons since 3DSPG can also provide reliable measurements comparable to those on CT during follow-up.

**KEYWORDS:** Suture premature closure, Craniostenosis, Molding helmet therapy, Craniometric measures

**ABBREVIATIONS: 3DSPG:** 3D stereophotogrammetric, **CI:** Cephalic index, **CT:** Computed tomography, **CVA:** Cranial vault asymmetry, **CVAI:** Cranial vault asymmetry index, **EACS:** Endoscope-assisted craniosynostosis surgery, **EuD:** Eurion, **FTD:** Frontotemporal diameter, **FPI:** Frontoparietal index, **FZA:** Frontozygomatic angle, **G:** Glabella, **GOPD:** Glabella–opisthocranion diameter, **GOPP:** Glabella–opisthocranion perimeter, **IFA:** Interfrontal angle, **MFZD:** Minimum frontozygomatic diameter, **MI:** Metopic index, **OCVR:** Open cranial vault remodeling, **PFDA:** Posterior fossa deflection angle, **TI:** Towering index, **ZF:** Zygomaticofrontal

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## INTRODUCTION

A new-born baby's skull consists of bones and sutures that ensure its passage through the birth canal and allow the brain volume to quadruple in the first 2 years. On the other hand, craniosynostosis is a congenital anomaly caused by the closure of one or more of those sutures before the natural physiological process, disrupting the expected growth of the skull. The rate of non-syndromic craniosynostosis in the new-born population is approximately 5.2/10.000 (26).

The first surgical intervention for craniosynostosis was reported at the end of the 19th century (18,19). Until the 1940s, strip craniectomy was the standard surgical method for such cases. However, because of re-ossification and unsatisfactory cosmetic results in the ensuing decades, many researchers deemed that more complex surgeries, such as total cranial reconstruction surgery, are required (20). Consequently, open cranial vault remodeling (OCVR) became more popular and advantageous for babies older than 5 months. However, in the late 1990s, Jimenez and Barone described the disadvantages of this surgery. Thus, they offered and re-described endoscope-assisted craniosynostosis surgery (EACS) followed by helmet therapy, which can reduce blood loss, operation and hospitalization times and mortality rates (14). This study evaluated and compared the results between OCVR and EACS for non-syndromic craniosynostosis and determined an algorithm for creating the most appropriate patient-oriented surgical choice.

## MATERIAL and METHODS

Children with non-syndromic synostosis who underwent either OCVR or EACS at the Neurosurgery Department of Pamukkale University between 2010 and 2022 were included in this study. Patients were grouped according to premature suture closure under scaphocephaly, trigonocephaly, anterior/posterior plagiocephaly or brachycephaly. Age at surgery, pre- and post-operative measurements, duration of operation (preparation of anesthesia and surgery), estimated blood loss, blood transfusion volume, hospitalization complications, and revision surgeries, as well as other accompanying demographic and clinical findings, were recorded. Patients with syndromic craniosynostosis or missing data were excluded from the study. EACS was proposed for all patients under 6 months old since the most appropriate group, the long-term results of which have been published previously, are infants between 2 and 6 months old (15). Alternatively, OCVR was proposed for patients older than 6 months.

### Open Cranial Vault Remodeling

After the induction of general anesthesia, positioning, and preparation, a zigzag-patterned bilateral coronal incision line was made posterior to the ears. Next, the scalp and periosteum were stripped away on both sides to reveal the frontal, temporal and parietal bones (Figure 1). After creating the burr holes, craniotomy was performed according to the synostosis type using a high-speed drill. Afterwards, bone flaps were contoured using Tessier bone benders, wedge

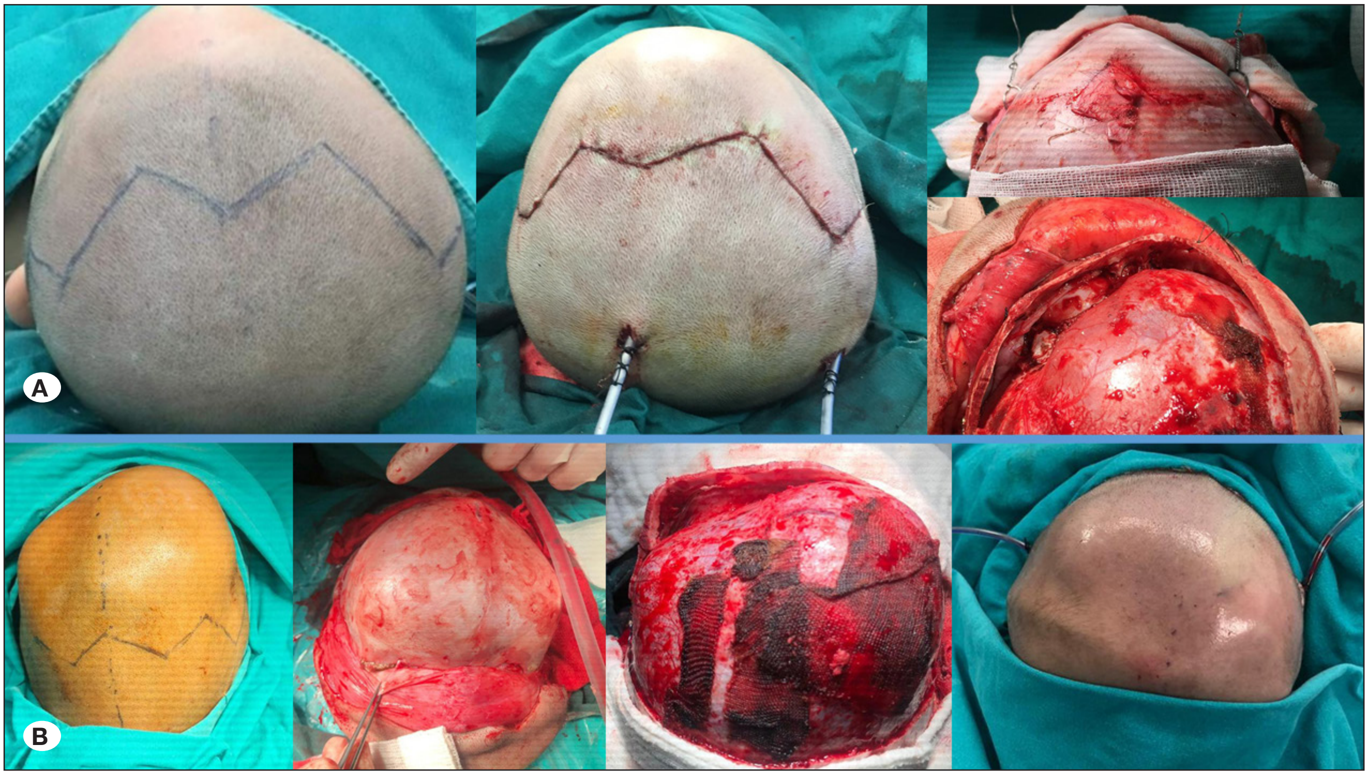


**Figure 1:** Open cranial vault remodeling procedures showing pre- and post-operative cranial shape and bone remodeling in patients with trigonocephaly **(A)**, and left anterior plagiocephaly **(B)**.

osteotomies, and barrel-stave osteotomies and then included in the procedure. After the remodeling, the bones were fixed using 2/0 silk sutures or mini plaques (Figure 2). Additionally, bilateral fronto-orbital advancement for trigonocephaly and unilateral fronto-orbital advancement with overcorrection for anterior plagiocephaly were performed.

### *Endoscopy-Assisted Craniosynostosis Surgery*

Patients with sagittal synostosis underwent surgery in a modified prone position (sphinx position) while the head was in hyperextension. Patients with metopic synostosis were positioned supine and their heads in the neutral position. Conversely, the head was rotated contralaterally to the fused suture for patients with coronal or lambdoid synostosis. The incision made for trigonocephaly was 2–3 cm long and oriented perpendicular to the metopic suture just behind the hairline. Two parallel incisions were made to the sagittal suture, one behind the anterior fontanelle and the other anterior to the lambda. Parallel incisions were made at the coronal suture at the stephanion for anterior plagiocephaly and at the lambdoid suture at the midpoint for posterior plagiocephaly.

After the incisions, a burr hole was placed 1 cm away from the affected suture to avoid sinus injury, especially in trigonocephaly and scaphocephaly, and enlarged using a Kerrison rongeur. Finally, the subgaleal and epidural spaces were dissected under endoscopy. The emissary veins were sealed by bipolar cautery, and a 2–3 cm wide craniectomy was performed on the borders of all affected sutures using bone-cutting scissors and Fulton rongeurs (Figure 3). The galea and skin were closed using absorbable sutures.

Active cranial molding helmet therapy was initiated approximately 2 weeks post-operatively, following head skin edema regression and wound healing. Helmets were used for 23 hours a day throughout the treatment. Since growth was an active process, the patients were monitored on follow-up with the cranial orthosis technician at regular intervals, such as at 1–4 weeks, depending on the baby's growth rate. Although the use of a helmet has been recommended up to 1 year of age in the literature, in our study, treatment for many patients lasted for an average of 6–9 months (24). CT imaging and laser 3D measurements obtained approximately 1 year post-operatively were used for evaluation (Figure 4).

### *Measurements*

All measurements performed for each type of craniosynostosis in this study were obtained from pre-operative cranial CT and 3D stereophotogrammetric (3DSPG) studies. Specific head CT parameters were selected for evaluation at a slice thickness of 1 mm or less and using high-resolution 3D reconstructions. The predefined anatomical landmarks and specific anthropometric cranial measurements are shown in Table I. In addition, the patients who underwent EACS were followed up with repeat 3DSPGs at periodic intervals (1–4 weeks), depending on the baby's growth rate, until the end of active molding helmet treatment, after which the annual follow-up was continued.

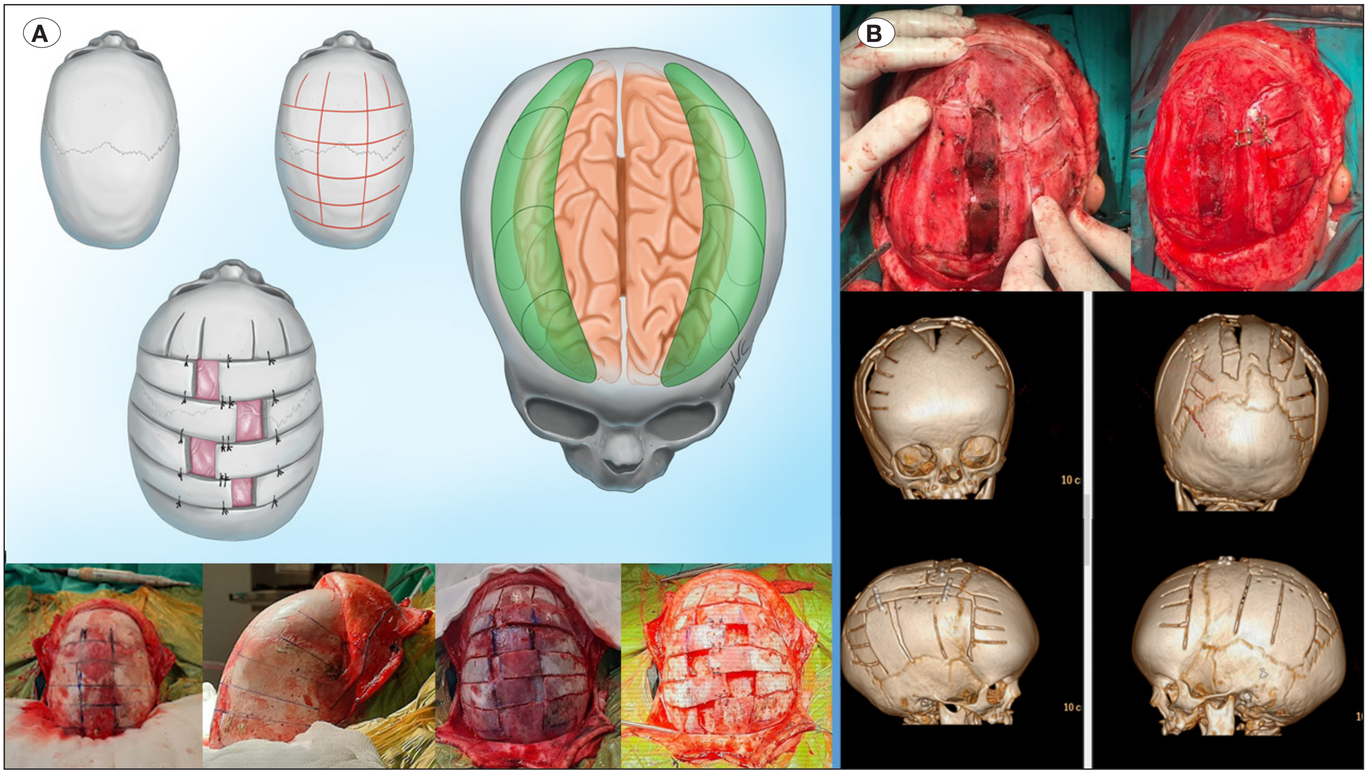


**Figure 2:** Bone remodeling in the open cranial vault remodeling procedure; shaping the parietal bones using barrel-stave osteotomies (clamshell technique) **(A)**. Fixation of reconstructed bones utilizing silk sutures or mini plate **(B)**.

Two different angles and two different indexes were evaluated to assess the severity of trigonocephaly. First, the bilateral zygomatic frontal sutures (ZFR and ZFL) and glabella (G) bone points were marked on 3D CT reconstruction. The angle between the ZFR-G-ZFL (Frontozygomatic angle measurement [FZA]) was then measured in two dimensions. Second, the inter-frontal angle (IFA), which is the angle between the lines drawn from the most anterior point to both pterion points, was measured as previously described by Kellogg et al. (16) and recorded as the IFA.

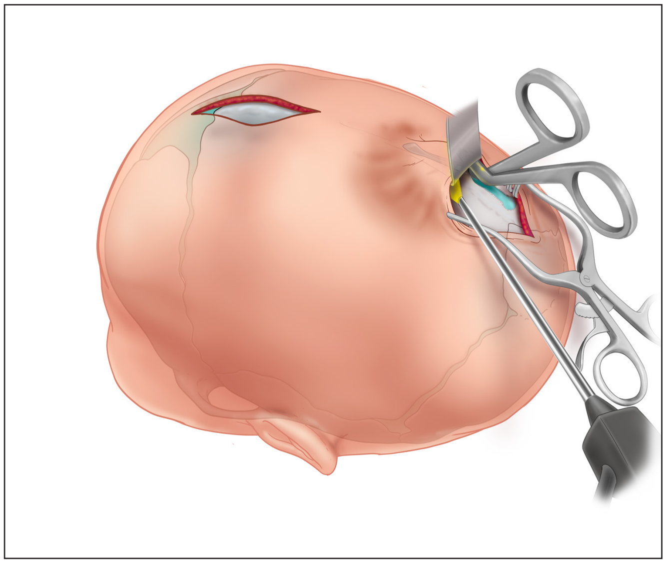

**Figure 3:** Skin incisions and placement of the burr hole. Use of surgical instruments during endoscopy-assisted craniosynostosis surgery.

The distance between the frontotemporal points of the inferolateral frontal bone was determined as the frontotemporal diameter (FTD), while the ratio of the FTD to the cranial width was recorded as the frontoparietal index (FPI). The metopic index (MI) is the ratio of the minimum frontozygomatic width (MFZD), which is the distance between the midpoints of the indentation above the brow ridge, to the cranial width between the antero-inferolateral frontal bone and the zygomatic process (22) (Figure 5).

The cephalic index, which is mainly used in sagittal and bilateral coronal synostosis, was also calculated in this study from reconstructed 3D CT images and 3DSPG. The cranial width is the diameter between the left and right eurion (EuD) landmarks, and the cranial length is the distance between the glabella and opisthocranion (GOPD). In the leveling applied in 3D laser scans, level 0 was considered as the reference cross-section plane from the sellion to both tragi and level 10 as the vertex plane. The skull was divided into nine equally spaced sections, each parallel to the reference planes. In our study, level 3, one-third of the distance from the reference plane to the apex, was used to calculate the cranial measurements in all patients (Figure 4).

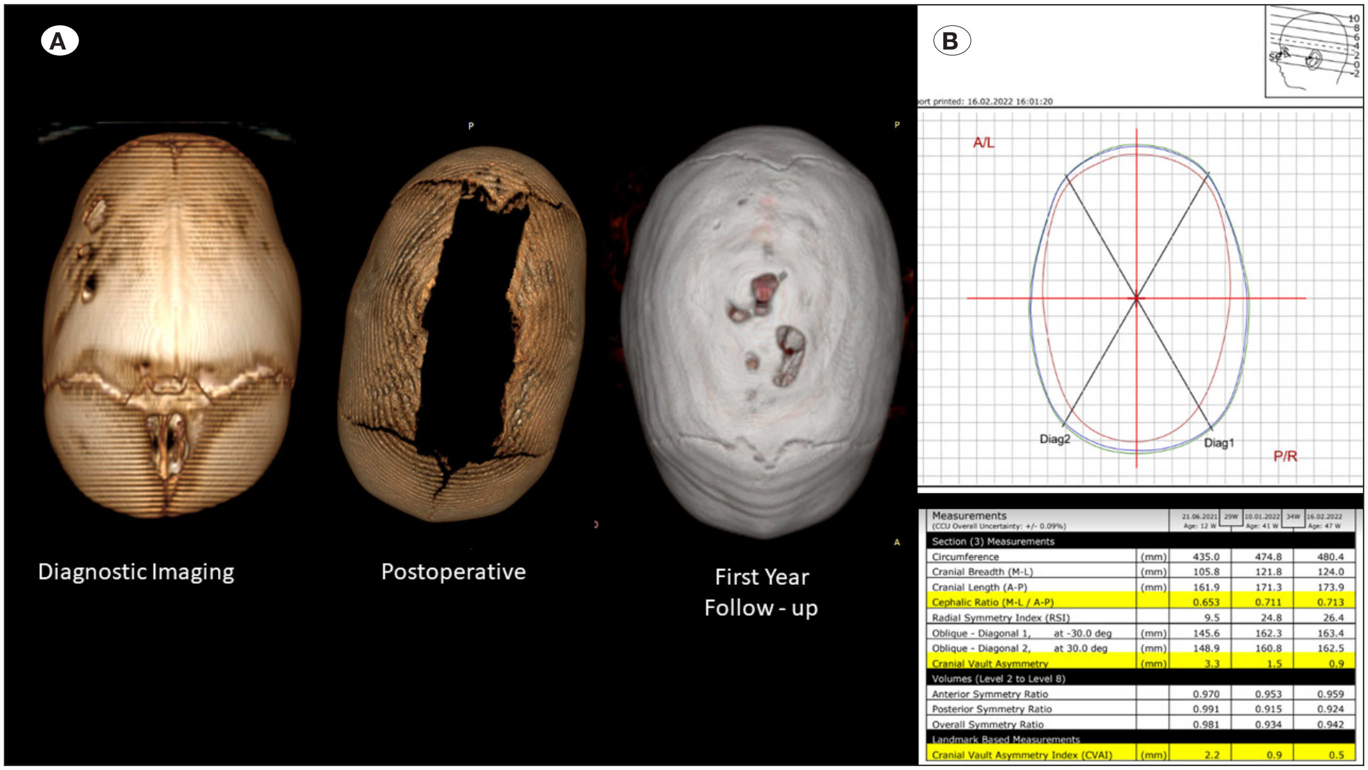


**Figure 4:** Pre- and post-operative and 1-year follow-up cranial CT images of a patient with scaphocephaly **(A)**. Pre- and post-operative and 6-month follow-up 3D stereophotogrammetric images show an increased cranial Index **(B)**.

**Table I:** Anatomical Landmarks, Anthropometric Measurements, and Cranial Indices (22)

| **Landmarks** | **Abbreviation** | **Description** |
|---|---|---|
| Glabella | G | Anterior extreme in midsagittal plane at lower margin of the frontal bone, above frontonasal suture, between superciliary arches |
| Opisthocranion | OP | The posterior extreme in the midsagittal plane on the superior squamous part of the occipital bone; may or may not coincide with the external occipital protuberance |
| Eurion | Eu | Lateral extreme on either parietal bone or upper temporal bone (avoiding any lower temporal protrusion or bulge) |
| Frontotemporal | FT | Most medial indentation of the inferolateral frontal bone, superolateral to the brow ridge, immediately posterior to the zygomatic process of the frontal bone, & anterior to the pterion |
| MFZ Recess | MFZR | Midpoint along the recess above the brow ridge between the anteroinferolateral frontal bone & zygomatic process of the frontal bone |
| **Measurements** | **Abbreviation** | **Description** |
| Glabella – Opisthocranion Diameter | GOPD | Maximum cranial AP length |
| Glabella – Opisthocranion Perimeter | GOPP | Maximum cranial AP perimeter |
| Eurion – Eurion Diameter | EuD | Maximum cranial width (breadth) |
| Frontotemporal Diameter | FTD | Minimal frontotemporal width |
| Midfrontozygomatic Diameter | MFZD | Minimal frontozygomatic width |
| **Indices** | **Calculation** | **Proposed Applicability** |
| Cephalic Index | EuD / GOPD | Sagittal synostosis |
| Frontoparietal Index | FTD / EuD | Metopic synostosis |
| Metopic Index | MFZD / EuD | Metopic synostosis |
| Towering Index | GOPD / GOPP | Bilateral coronal synostosis |

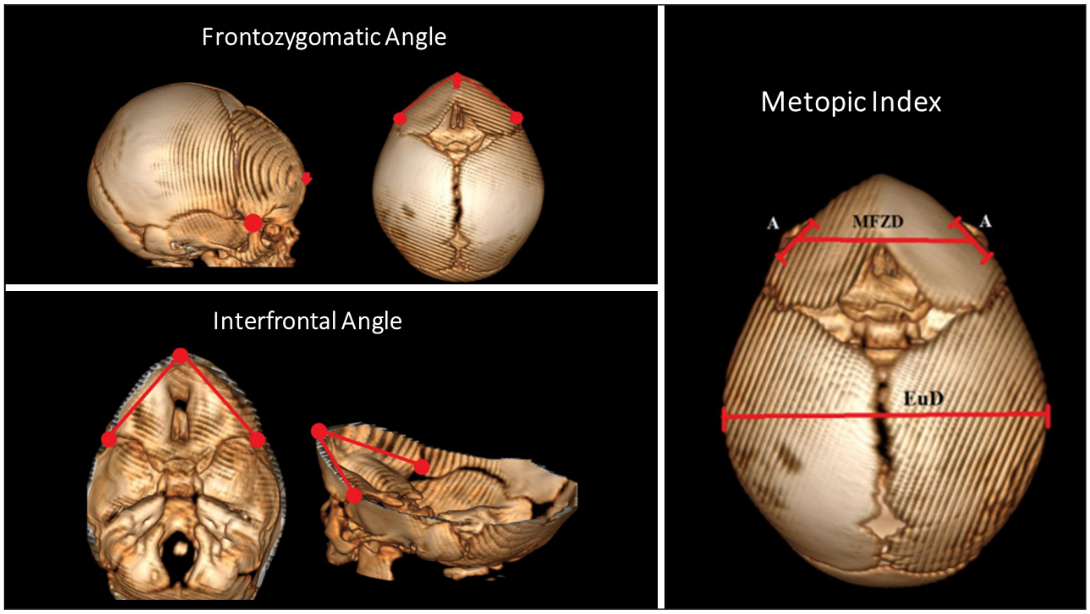


**Figure 5:** Angles used to evaluate trigonocephaly. The frontozygomatic angle between the glabella (arrow) and the midpoint of the frontozygomatic joint (point). Inter-frontal angle calculation points. Minimum frontozygomatic diameter (MFZD) and metopic index. Bilateral brow ridges (A) are used to calculate MFZD. Dividing the MFZD by the maximum cranial width (EuD) gives the metopic index.

The asymmetry values used in this study were "cranial vault asymmetry" (CVA = Diagonal A – Diagonal B) and "cranial vault asymmetry index" (CVAI = CVA/Diagonal B × 100) (14). In addition, the posterior fossa deflection angle (PFDA), representing the lateral deviation of the foramen magnum, was used for posterior plagiocephaly. The angle was defined by the intersection of the line dividing the foramen magnum between the sagittal plane and the line dissecting the cribriform plate. The positive rise indicated a deviation toward the synostotic side (28) (Figure 6).

Another measurement performed in our study was the "towering index" (TI), which is used to evaluate bilateral coronal synostosis. Therefore, the ratio of the glabella–opisthocranion circumference length (GOPP) to the GOPD could be obtained (22).

**Statistical Analysis**

SPSS 25.0 (Statistical Package for Social Sciences) program was used for data analysis. Student's t-test was used to compare groups. A normality test was performed before Student's t-test. Data that did not comply with the normality test were analyzed using the Mann–Whitney U test. The paired samples t-test was used to compare dependent samples, while the Wilcoxon signed-rank test was used for calculations involving <30 cases. A p<0.05 was considered statistically significant.

## RESULTS

A total of 85 patients with synostosis were included in the study, 35 sagittal (41.2%), 29 metopic (34.1%), 12 unilateral coronal (14.1%), six bilateral coronal (7.1%) and three lambdoid (3.5%) (Table II). Considering the age at surgery applied according to synostosis type, the earliest patient group to undergo surgery was the unilateral coronal suture synostosis group, whereas the patients with bilateral coronal suture synostosis were the last (Figure 7).

In total, 61 children underwent EACS, whereas the remaining 24 underwent OCVR. The mean duration of anesthetic preparation for OCVR was 56.8 minutes, which was significantly longer than the mean time of 28.1 minutes for EACS (p<0.001). In addition, a statistical comparison of surgical times revealed that OCVR was significantly longer than EACS at 92.9 and 38.5 minutes, respectively (p<0.001). The average surgical times were compared according to synostosis type. For example, reconstructive metopic suture synostosis surgery had the longest surgical time (approximately 74 minutes), whereas endoscopic metopic suture synostosis surgery had the shortest (about 26 minutes).

The mean intra-operative blood loss in OCVR and EACS were 194.5 ± 76.2 and 56.2 ± 33.9 ml, respectively (p<0.001). Patients with metopic synostosis who underwent OCVR had the highest average blood loss at 240 ml. In comparison, the most negligible blood loss was in EACS for lambdoid synostosis at 15 ml. Twenty-eight cases were hemodynamically stable and received no transfusion during surgery. This decision was made when the calculated blood loss was <15% of the total

**Table II:** Distribution of Patients according to Synostosis Types and Preferred Surgical Methods

| Type of synostosis | OCVR | EACS | Total |
|---|---|---|---|
| Sagittal | 8 | 27 | **35** |
| Metopic | 9 | 20 | **29** |
| Unilateral Coronal | 2 | 10 | **12** |
| Bilateral Coronal | 3 | 3 | **6** |
| Lambdoid | 2 | 1 | **3** |
| **Total** | **24** | **61** | **85** |

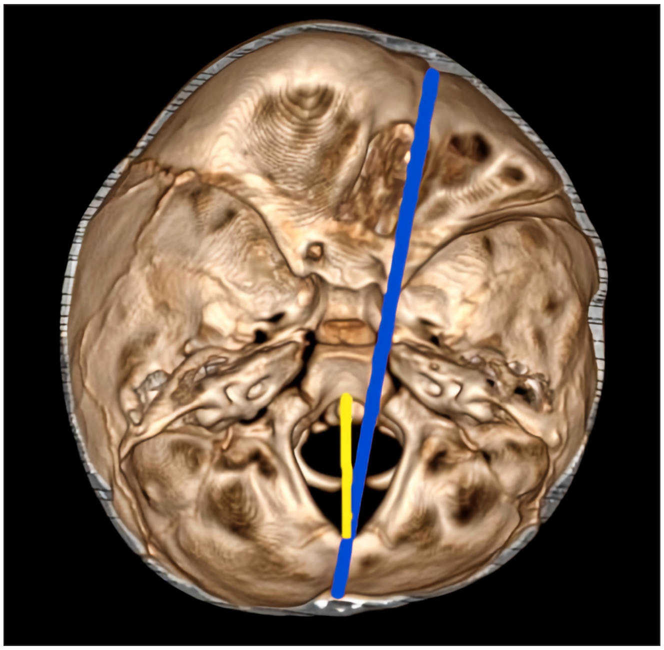

**Figure 6:** Posterior fossa deflection angle.

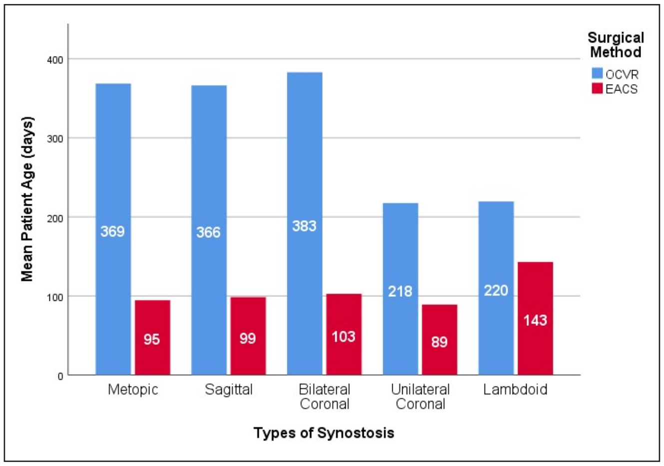


**Figure 7:** Average age at surgery according to synostosis type and surgical technique.

blood volume or when the decrease in the hematocrit level was <25%. The remaining 57 patients who underwent OCVR received 147.1 ± 69.3 ml of blood transfusion, whereas those who underwent EACS received 43.8 ± 4.0 ml (p<0.001). In addition, because of the decrease in control hemoglobin values measured at the first, fourth and 24th hour post-operatively, 53 patients received a blood transfusion within 24 hours post-operatively. Consequently, the amount of blood transfused for OCVR at 79.2 ± 3 ml was significantly higher than that for EACS with at 37.4 ± 39.3 ml (p<0.001) (Figure 8). The mean total hospitalization time was 10.1 ± 6.9 days, with 16.1 ± 8.9 days for those who underwent OCVR and 7.7 ± 3.9 days for those who underwent EACS. The longest hospitalization time was 49 days, involving a patient with metopic suture synostosis who underwent OCVR, whereas the shortest hospitalization duration was 2 days, a patient who underwent EACS (Figure 9).

Complications developed in 12 of the 85 patients (14.1%), 3 wound dehiscence (3.5%), 7 inadequate surgery (8.2%), 1 epidural hematoma (1.2%) and 1 hypothermia (1.2%). One patient died from massive bleeding. This patient had scaphocephaly and underwent EACS. Five complications were encountered in OCVR (41.6%), while the remaining 7 (58.4%) were observed in EACS.

Table III shows the pre- and post-operative cephalic indexes of patients with scaphocephaly calculated from CT and 3DSPG studies. Although the cephalic index values appeared to increase in both surgical methods, the differences among the values for EACS was more significant than those for OCVR. In addition, although the changes in cephalic index in EACS was more pronounced in both measurement techniques, the mean measurements obtained with the laser scanning technique were higher than those of measurements obtained by CT. These differences may be caused by the bone window used in CT measurements and the scalp tissue intervening in the laser scanning technique. A significant decrease in cephalic index at 10.3% was observed in patients with bilateral coronal synostosis who underwent EACS and 6.4% in those who underwent OCVR.

The CVA values obtained by 3DSPG for patients who underwent helmet therapy were examined separately for each synostosis. A slight decrease in CVA and an improvement in asymmetry were observed in these patients. However, the most significant improvement (75.6%) was observed in unilateral coronal synostosis. Similar results were noted for the CVAI values (Figure 10).

The mean pre-operative FPI of 20 patients with trigonocephaly who underwent EACS was 0.65 ± 0.054, whereas that of 9 patients who underwent OCVR was 0.55 ± 0.14053. The mean post-operative FPI values were 0.68 ± 0.062 for EACS and 0.55 ± 0.180 for OCVR. While the post-operative FPI increased significantly in all patients, this increase was more pronounced in patients who underwent EACS (p=0.011).

Another specific parameter for trigonocephaly, the MI, was measured at a pre-operative mean of 0.56 ± 0.03 for EACS at

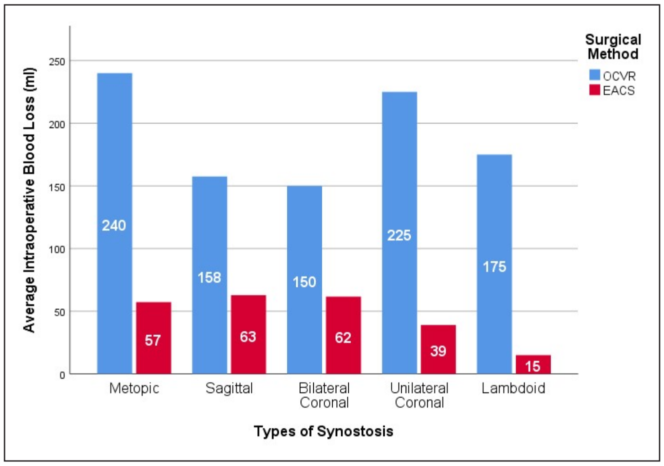


**Figure 8:** Average intra-operative blood loss according to surgical technique.

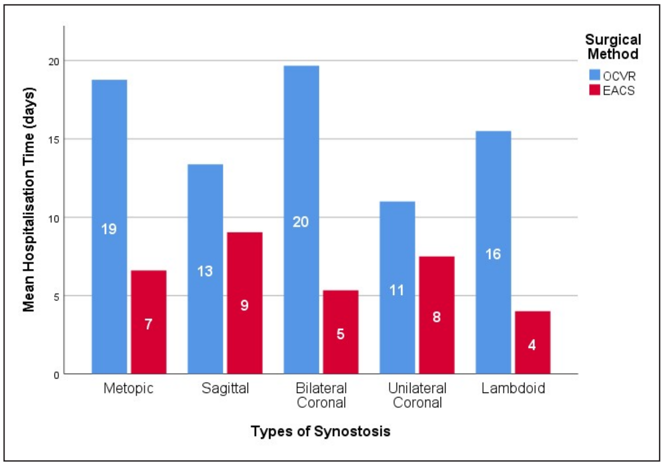


**Figure 9:** Average hospital stay for each synostosis type according to surgical technique.

**Table III:** Comparison of Cephalic Index Values in Patients with Scaphocephaly

| | 3D CT | | 3D Laser Scanner | |
|---|---|---|---|---|
| | **Preoperative** | **Postoperative** | **Preoperative** | **Postoperative** |
| OCVR | 0.7163 | 0.7625 | 0.7175 | 0.7225 |
| EACS | 0.7089 | 0.7648 | 0.7352 | 0.7793 |
| ALL | 0.7106 | 0.7643 | 0.7311 | 0.7663 |

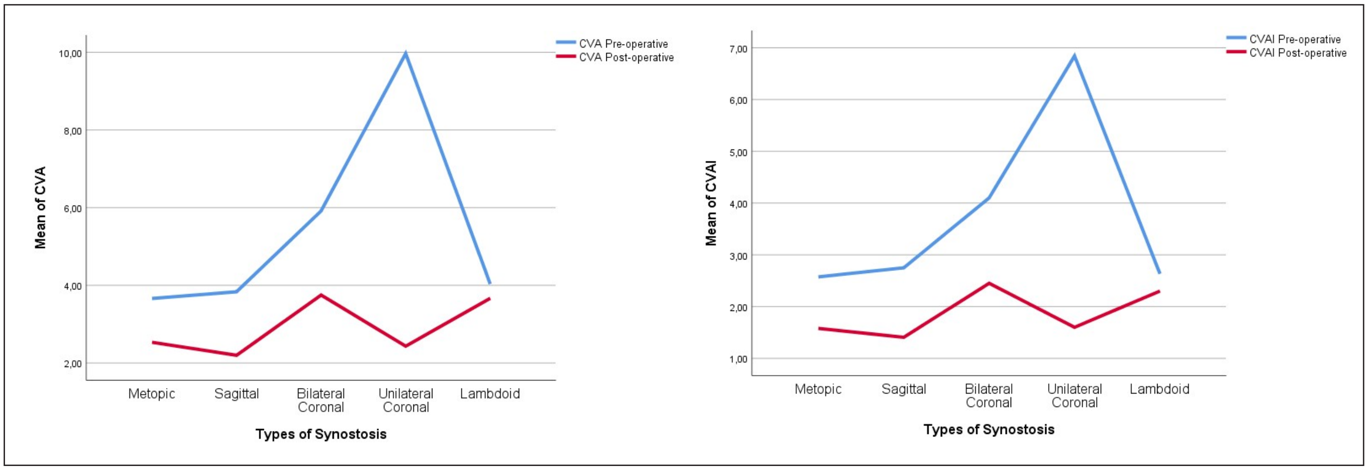


**Figure 10:** Pre- and post-operative measurements of mean cranial vault asymmetry and cranial vault asymmetry index and CVAI by synostosis type.

0.53 ± 0.05 for OCVR. Post-operative MI measurements were 0.58 ± 0.04 for EACS and 0.58 ± 0.05 for OCVR. Although the MI values increased after each surgical type, this increase was lower in EACS than in OCVR ($p<0.001$).

In addition to anthropometric indices, angular changes were also evaluated in our study. The mean value of FZA before EACS was 108.8 ± 7.2 and 109.8 ± 12.7 before OCVR in patients with trigonocephaly. The mean values after EACS and OCVR were 107.5 ± 10 and 109 ± 9.6, respectively. However, the difference was not significant ($p=0.412$).

IFA measurements before EACS and OCVR were 96.3 ± 6.6 and 89.8 ± 11.2, respectively, whereas the post-operative measurements were 104.9 ± 8.9 and 96 ± 12.5, respectively. Although both surgical methods significantly increased the IFA, the increase in OCVR was lesser ($p<0.001$).

The TI measurements defined in the literature for bilateral coronal suture synostoses were also applied to 6 bilateral coronal synostosis cases in our study. The pre-operative mean TI value of the patients who underwent EASC was 0.55 ± 0.032, whereas the post-operative value was 0.52 ± 0.015. For patients who underwent OCVR, the pre- and post-operative mean TI values were 0.64 ± 0.006 and 0.53 ± 0.09, respectively, which showed a significant decrease ($p=0.027$).

PFDA is a parameter used for lambdoid synostoses, and the preoperative value for one patient who underwent EACS was found to be 8 degrees, while postoperatively was 4 degrees. In the two patients who underwent OCVR, the preoperative PFDA value was 11 and 2 degrees, while the postoperative 6 and 1 degrees were found. All these values were statistically insignificant ($p=0.109$).

## DISCUSSION

This study comprehensively investigated all the measurement and evaluation techniques that have been used in previous studies and compared EACS and OCVR in all the data obtained. Although specific studies have investigated each type of synostosis, and studies with limited evaluation parameters for different kinds of synostoses exist in the literature, the present study encompassed several measurement techniques and a wide range of evaluation parameters for all types of synostoses.

The patient population in the present study consisted entirely of patients with non-syndromic cases. The most affected suture in non-syndromic craniosynostosis cases is the sagittal suture, followed by the coronal and metopic sutures, lambdoid suture (23,27,29). Additionally, recent studies have shown that the number of patients with metopic synostosis is gradually increasing (32). Researchers examining the incidence of sagittal synostosis in the general population have reported 56% in North America, 41% in Western Australia, and around 40% in Europe (5,6,11). In our study, patients with sagittal synostosis were the most numerous at approximately 40%, followed by metopic, unilateral coronal, bilateral coronal, and lambdoid synostoses. Furthermore, male predominance has been reported (60%–76%) in all types of synostoses (2,13,30,34). Similarly, 70.6% of the patient population in our study is male.

In a large study comparing endoscopic and open reconstructive surgery, Han et al. assessed 155 patients who underwent open reconstructive surgery and who 140 underwent EACS. They found that EACS has significant advantages over OCVR in appropriate patient populations (10). In 2018, Thompson et al. published a multicenter study in which 939 of 1382 patients underwent OCVR and 443 underwent EACS (31). These studies indicate that OCVR was performed more. However, in our study, 61 (71.8%) patients underwent EACS, whereas 24 (28.2%) patients underwent OCVR. Compared with these studies published approximately 4 and 6 prior, respectively, our study shows a proportional increase in EACS, suggesting an increasing preference for EACS by surgeons, considering its advantages and the increased ease of completing helmet treatment than ever before.

The generally accepted optimal time for EACS is the first 3 months of age, whereas the ideal time for OCVR is 6–12 months of age (1,3,4,31,33). In our study, the mean age at EACS was 96 days (approximately 3 months), whereas that for OCVR was 344 days (about 11 months). These ages at surgery also comparable to the generally accepted age range.

In the present study, the average anesthesia preparation time was 28.1 minutes for EACS and 56.8 minutes for OCVR. Conversely, the operation time was 38.5 minutes for EACS and 92.9 minutes for OCVR. Our study demonstrates that both the preparation stage and operation time utilized by the surgeon in OCVR are longer than those in EACS. Thompson et al. (31) reported that while the mean duration of anesthesia for EACS was 168 minutes, it was 248 minutes for reconstructive OCVR, 70 minutes for EACS, and 130 minutes for OCVR. Many other studies accepted these findings and shared them without separating them. For example, Han et al. reported a mean endoscopic time of 71.3 minutes and 168.5 minutes for OCVR, whereas Isaac et al. reported 45 minutes for endoscopy and 195 minutes for OCVR (10,12). Keshavarzi et al. reported similar mean operative times of 128 and 141 minutes for EACS and OCVR, respectively (17). In the study published by Garber et al. in 2017 involving approximately 200 patients, the mean time for EACS was 68 minutes and 302 minutes for OCVR (8). Similarly, in a comparison surgery performed by Vogel et al., the endoscopic time reported was 81.1 min, whereas the OCVR time was 165.8 minutes (33). Thus, in comparison, the time required for anesthesia preparation and the duration of the surgeries performed at our center are relatively shorter.

In a literature review on intra-operative blood loss and intra- and post-operative blood transfusion volumes, Keshavarzi et al. found that the mean intra-operative blood loss was 91.9 ml for EACS, whereas it was 184 ml for reconstructive OCVR. In the study by Zubovic et al., endoscopic blood loss was reported at 15 ml, whereas that for open surgery was 350 ml. Similarly, Han et al., reported a mean blood loss of 36.1 ml during endoscopic strip craniectomy and 293.2 ml for OCVR (10,17,36). Compared with these studies, the measurements obtained in our study for both blood loss and transfusion volumes were slightly lower. Furthermore, although the values for OCVR were comparable, those for EACS were somewhat higher.

Han et al. reported average hospitalization times of 1.1 and 3.8 days for EACS and OCVR, respectively. Similarly, Isaac et al., reported 1 day for EACS and 3 days for OCVR. Surprisingly, Keshavarzi et al. reported hospitalization times of 2.46 days for EACS and 2.76 days for OCVR. In the multicenter study by Thompson et al., the average hospitalization times after EACS and OCVR were 2 and 4 days, respectively, whereas in the study of Garber et al., they were 1.8 days for EACS and 4.2 days for OCVR (8,10,12,17,31).

Two meta-analyses conducted in 2018 compared EACS and OCVR and found that the blood loss volume, operation time and length of hospital stay were significantly lower for patients with all types of synostoses who underwent EACS (34,35).

Esparza and Hinojosa reported complications in 73 of 268 patients, the most common of which were dural tears and wound infections. Interestingly, in the study by Shah et al. in 2011 involving 89 patients, soft tissue infection was observed in only 1 patient. In the multicenter study conducted by Thompson et al. involving 933 patients in 2018, it complications developed in 88 of 311 patients who underwent EACS and 249 of 622 patients who underwent OCVR (7,25,31). The complication rate of 14% obtained in our study is thus consistent with the literature.

The cephalic index is the most common anthropometric measurement reported in the literature. The meta-analysis conducted by Han et al. reported cephalic index values between 0.75 and 0.77, which did not vary significantly with the surgical technique (10). Shah et al. found that post-operative cephalic index values in sagittal synostosis increased regardless of the surgical method (25). Ghenbot et al. confirmed this, further stating that the cephalic index value increased by approximately 12% equally between the open and endoscopic groups (9). Our study found a 7% increase in values for patients with sagittal synostosis who underwent OCVR and 8.5% for patients who underwent EACS. These rates, which are slightly lower than those reported in some studies, are similar when assessed based on surgical methods. Conversely, a 10% reduction in values was observed in bilateral coronal synostosis after EACS and 6% after OCVR. These indicate that, while EACS is more effective, both surgical methods meet expectations.

Nguyen et al. reported that the mean IFA of 13 patients who underwent EACS was 112.5 degrees, whereas that of 15 patients who underwent OCVR was 112.6 degrees. The same study reported FZA values of 109 degrees for EACS and 109.8 degrees for OCVR (21). These FZA values were comparable to those obtained in our study, although the IFA measurements from our population were slightly lower. Although significant increases were observed for both surgical methods in three of the four impression techniques used to evaluate metopic synostosis, namely, FZA, IFA, and FPI, the increases observed for OCVR were more limited. However, while the MI values increased after both surgical types, a lower increase was observed in EACS than in OCVR. The most likely reason is that the MFZD is calculated using two different but connected linear planes. Therefore, the midpoints of the indentation above the brow ridge cannot be distinctly evaluated in every patient.

A meta-analysis of cosmetic results revealed similar results obtained between OCVR and EACS for scaphocephaly. Furthermore, potentially better results could be obtained with EACS for other types of synostoses. In a comparison of sagittal synostosis cases, the total cost for EACS was three times lower than that for OCVR (34,35).

This study has some limitations. First, this study reports a retrospective and single-center experience, which carries the risk of certain biases. Second, the sample size of the study was relatively small. Third, since the cases were not equally distributed among all types of synostoses, statistical studies for some patient groups were not sufficiently objective.

## CONCLUSION

The detailed evaluation techniques in the present study support that EACS has relatively lower estimated blood loss, operation, and hospitalization times and complication rate. Although OCVR enables the rapid correction of skull deformation, long-term (>1 year) outcomes of the two methods offer comparable cosmetic results. To better understand cosmetic results, extensive long-term prospective multicenter studies are needed. Our study also found that post-operative molding helmet therapy offers safe and convenient restoration after an endoscopic procedure, while 3DSPG can provide comparably reliable measurements during follow-up as CT.

**AUTHORSHIP CONTRIBUTION**

Study conception and design: EE

Data collection: BA

Analysis and interpretation of results: EE, BA

Draft manuscript preparation: BA

Critical revision of the article: EE, MEC

Other (study supervision, fundings, materials, etc...): MEC

All authors (BA, MEC, EE) reviewed the results and approved the final version of the manuscript.

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