raniosynostosis refers to a number of skull deformities associated with premature fusion of one or more cranial vault sutures. The pathologic fusion often occurs in utero and frequently results in abnormal calvarial morphology, and is thought to potentiate neuronal dysgenesis. Surgical intervention is aimed at correcting the morphology and releasing growth restriction to circumvent altered brain morphology and possible neurocognitive impairment. A range of operative techniques exist for the correction of craniosynostosis, which are predominately variations of two distinct methods:

**Background:** Spring-assisted surgery is an accepted alternative to cranial vault remodeling for treatment of sagittal craniosynostosis. The long-term safety and efficacy profiles of spring-assisted surgery have not been established. 

**Methods:** This study is a retrospective examination of all patients treated with spring-assisted surgery \( (n = 175) \) or cranial vault remodeling \( (n = 50) \) for sagittal craniosynostosis at the authors’ institution from 2003 to 2017. Data collected included demographic and operative parameters, preoperative and postoperative Cephalic Indices, and complications. Whitaker grades were assigned blindly by a craniofacial surgeon not involved in patients’ care.

**Results:** The mean age at surgery was significantly lower for the spring-assisted surgery group compared with the cranial vault remodeling group (4.6 months versus 22.2 months; \( p < 0.001 \)). Even when combining spring placement with spring removal operations, total surgical time (71.1 minutes versus 173.5 minutes), blood loss (25.0 ml versus 111.2 ml), and hospital stays (41.5 hours versus 90.0 hours) were significantly lower for the spring-assisted surgery cohort versus the cranial vault remodeling group ( \( p < 0.001 \) for all). There were no differences in infection, reoperation rate, or headaches between the groups. The percentage improvement in Cephalic Index was not significantly different at 1 ( \( p = 0.13 \)), 2 ( \( p = 0.99 \)), and 6 ( \( p = 0.86 \)) years postoperatively. At 12 years postoperatively, the spring-assisted surgery group had persistently improved Cephalic Index (75.7 preoperatively versus 70.7 preoperatively). Those undergoing spring-assisted surgery had significantly better Whitaker scores, indicating less need for revision surgery, compared with the cranial vault remodeling group ( \( p = 0.006 \)).

**Conclusion:** Compared with the authors’ cranial vault remodeling technique, spring-assisted surgery requires less operating room time and is associated with less blood loss, but it has equivalent long-term Cephalic Indices and subjectively better shape outcomes. (Plast. Reconstr. Surg. 146: 833, 2020.)

**CLINICAL QUESTION/LEVEL OF EVIDENCE:** Therapeutic, III.

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strip craniectomy and cranial vault remodeling. Although both techniques have proven to be safe and efficacious, strip craniectomy is associated with shorter operative time, lower morbidity, and shorter hospital stay when compared to cranial vault remodeling. A third modality, spring-assisted surgery, combines a strip craniectomy with the dynamic, internal expansion forces of indwelling springs, to effect cranial vault expansion.

Spring-assisted surgery for craniosynostosis was first described by Persing et al. in experimental animal models. Lauritzen et al. were the first to use springs in patients for treatment of sagittal suture synostosis. Since that time, spring-assisted surgery for correction of sagittal craniosynostosis has been adopted by numerous craniofacial centers throughout the world. Because of the relative later adoption of spring-assisted surgery, there is a paucity of long-term safety and outcome data for this technique. The aims of this study are to compare our institutional experience, intraoperative complications, and long-term outcomes following spring-assisted surgery versus cranial vault remodeling for treatment of nonsyndromic sagittal craniosynostosis.

**PATIENTS AND METHODS**

A retrospective review was performed of consecutive patients undergoing either spring-assisted surgery or calvarial vault remodeling for isolated, nonsyndromic sagittal craniosynostosis performed by one of the senior authors (L.R.D. or J.T.T.) from 2001 to 2017. Medical records were reviewed following approval from the institutional review board (no. 00019941). Patients with incomplete records of spring placement and removal operations were excluded from the study.

Patients who presented with computed tomography-confirmed, isolated sagittal craniosynostosis at age 6 months or younger were offered spring-assisted surgery or cranial vault remodeling, whereas those presenting after 6 months of age were typically directed to undergo cranial vault remodeling. The decision between these options was agreed on by a mutual discussion between the patients’ parents and craniofacial surgeon. In addition to age being a deciding factor for type of procedure, other indications to not using springs include very thin bone on computed tomography or at the time of surgery, presence of a shunt in proximity of the springs, and comorbidities limiting early intervention. Patients receiving cranial vault remodeling surgery underwent surgery designed to correct the predominant phenotype deformity, and included anterior (n = 22), central (n = 21), posterior (n = 2), or total (n = 5) calvarial remodeling. The central cranial vault remodeling operation consisted of a previously described tongue-and-groove technique from the coronal to lambdoid sutures to achieve biparietal expansion. This approach was extended to the frontal bones for anterior cranial vault remodeling, to the occipital bones for posterior cranial vault remodeling, or involved both regions for cases of total vault cranial vault remodeling.

Data collected included patient demographics, operative reports, operative duration, anesthetic duration, intraoperative blood transfusions, length of intensive care unit stay, length of hospital stay, revision procedures, and complication profiles. Cephalic Indices were measured from Polhemus laser scans, 3dMD (Atlanta, Ga.) photography, or soft-tissue landmarks within computed tomographic scans using lines marked from euryon to euryon and glabella to opisthocranion. Repeated Cephalic Index measurements were obtained postoperatively within 6 months of spring removal, in addition to 1 year, 2 years, 6 years, and 12 years postoperatively. Cephalic Index calculations were performed consistently between groups.

The Whitaker classification was used to assess aesthetic outcomes between cohorts. This classification system places patients into four groups based on the need for secondary operations required to achieve aesthetic normalcy: class I, no revision procedure; class II, soft-tissue revision is required; class III, bony contouring is required; or class IV, repeated craniotomy is required.

Patient characteristics were compared with descriptive statistics; t tests and analysis of variance were used to compare continuous variables, and Fisher’s exact test was used for categorical variables. A value of p < 0.05 was considered statistically significant. All statistical analyses were performed using R Statistical Software (version 1.1.447; R Foundation for Statistical Computing, Vienna, Austria).

**RESULTS**

Two hundred twenty-five patients underwent surgery during the study period, including 175 in the spring-assisted surgery group (77.8 percent) and 50 (22.2 percent) in the cranial vault remodeling group. Representative short-term (Fig. 1) and long-term results of those undergoing spring-assisted surgery are shown. [See Figure, Supplemental Digital Content 1, which shows...
spring-assisted surgery middle-term outcomes. (Above, left) Preoperative computed tomography confirms sagittal craniosynostosis. (Above, second from left, and above, second from right) Spring expansion at 1 weeks and 4 months after the initial surgery. (Above, right) Overlay of laser head lateral scans from preoperatively (pink) to 1-year (green), 3-year (blue), and 6-year (tan) follow-up. This overlay allows for a temporal comparison of brow protrusion and vertex height. (Center) Preoperative photographs and laser head scan 1 week before surgery. (Below) Six-year photographs and
laser head scan. The patient’s assigned Whitaker class was I. (Figure used with permission from *A Collection of Images and Illustrations*, Department of Plastic Surgery, Wake Forest School of Medicine, edited by E. Stanley Gordon), http://links.lww.com/PRS/E188. See Figure, Supplemental Digital Content 2, which shows spring-assisted surgery long-term outcome. Frontal (above), lateral (second row), and vertex (third row and below) views of a patient treated with spring-assisted surgery for sagittal craniosynostosis, preoperatively at 5 months (left) and postoperatively at 4 years (second from left), 7 years (second from right) and 16 years (right) of age. The patient’s Whitaker class was I. (Figure used with permission from *A Collection of Images and Illustrations*, Department of Plastic Surgery, Wake Forest School of Medicine, edited by E. Stanley Gordon), http://links.lww.com/PRS/E189.) As expected, the mean age at the time of initial surgery was significantly lower in those undergoing spring-assisted surgery (4.6 months; \( p < 0.001 \)) compared with the cranial vault remodeling group (22.2 months).

### Operative Outcomes

Anesthetic and operative times were significantly lower in the spring-assisted surgery group, even when durations of both spring placement and removal operations were combined (Table 1). In the cranial vault remodeling cohort, the estimated intraoperative blood loss was greater at 111.2 ml compared to the 15.7 ml at the time of strip craniectomy and spring placement and 9.3 ml at the time of spring removal in the spring-assisted surgery cohort (\( p < 0.001 \)). No patients undergoing spring-assisted surgery required a blood transfusion, either at the time of spring placement or at the time of removal. In contrast, 40.5 percent of patients undergoing cranial vault remodeling received a blood transfusion (\( p < 0.001 \)). In the spring-assisted surgery cohort, the mean time between spring placement and removal was 5.0 months. The mean spring forces were 6.7 N in the anterior position and 7.1 N in the posterior position. Spring force selection is dependent on age at the time of surgery, severity, and type of deformity.19 After the initial surgery, none of the patients in the spring-assisted surgery cohort were admitted to the intensive care unit, whereas those in the cranial vault remodeling cohort had a mean intensive care unit length of stay of 18 hours (\( p < 0.001 \)). The total hospital stay was also significantly shorter in the spring-assisted surgery group (33.7 hours at spring placement, and 7.8 hours at spring removal), compared with the cranial vault remodeling cohort (90.9 hours; \( p < 0.001 \)).

Total perioperative complications were not significantly different between the spring-assisted surgery (7.4 percent) and cranial vault remodeling groups (8.0 percent; \( p = 0.89 \)) (Table 2). Minor perioperative complications (spring-assisted surgery, \( n = 1 \); cranial vault remodeling, \( n = 3 \)) were infections treated with antibiotics alone or emergency department visits. Major complications were defined as those requiring a return to the operating room. These were not significantly different between spring placement and removal was 5.0 months. The mean spring forces were 6.7 N in the anterior position and 7.1 N in the posterior position. Spring force selection is dependent on age at the time of surgery, severity, and type of deformity.19 After the initial surgery, none of the patients in the spring-assisted surgery cohort were admitted to the intensive care unit, whereas those in the cranial vault remodeling group had a mean intensive care unit length of stay of 18 hours (\( p < 0.001 \)). The total hospital stay was also significantly shorter in the spring-assisted surgery group (33.7 hours at spring placement, and 7.8 hours at spring removal), compared with the cranial vault remodeling cohort (90.9 hours; \( p < 0.001 \)).

### Table 1. Perioperative Data for Spring-Assisted and Cranial Vault Remodeling Operations*

<table>
<thead>
<tr>
<th></th>
<th>Spring Insertion</th>
<th>Spring Removal</th>
<th>CVR</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>175</td>
<td>175</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Age at surgery, mo</td>
<td>4.6 ± 1.4</td>
<td>9.6 ± 1.6</td>
<td>22.2 ± 15.3</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Current age, mo</td>
<td>131.5 ± 52.7</td>
<td>131.5 ± 52.7</td>
<td>132.3 ± 61.1</td>
<td>0.933†</td>
</tr>
<tr>
<td>Estimated blood loss, ml</td>
<td>15.7 ± 12.1</td>
<td>9.2 ± 4.6</td>
<td>113.3 ± 100.3</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Mean transfusion, ml</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
<td>97.2 ± 127.2</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Anesthetic time, min</td>
<td>112.0 ± 27.8</td>
<td>73.4 ± 26.5</td>
<td>272.2 ± 46.5</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Surgical time, min</td>
<td>51.5 ± 18.6</td>
<td>26.7 ± 17.2</td>
<td>174.9 ± 44.0</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Mean hospital stay, hr</td>
<td>34.7 ± 14.6</td>
<td>7.8 ± 9.4</td>
<td>91.8 ± 17.6</td>
<td>&lt;0.001†</td>
</tr>
</tbody>
</table>

CVR, cranial vault remodeling. *Values presented as means ± SD.†Analysis of variance.‡t test.

### Table 2. Perioperative and Long-Term Complications/Complaints

<table>
<thead>
<tr>
<th>Complication/complaint</th>
<th>SAS (%)</th>
<th>CVR (%)</th>
<th>( p ^{∗} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>175</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Complication/complaint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perioperative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13 (7.4)</td>
<td>4 (8.0)</td>
<td>1.00</td>
</tr>
<tr>
<td>Minor</td>
<td>1 (0.6)</td>
<td>3 (6.0)</td>
<td>0.035</td>
</tr>
<tr>
<td>Major</td>
<td>12 (6.9)</td>
<td>1 (2.0)</td>
<td>0.307</td>
</tr>
<tr>
<td>Speech delay</td>
<td>17 (9.7)</td>
<td>12 (24.0)</td>
<td>0.015</td>
</tr>
<tr>
<td>Headache</td>
<td>17 (9.7)</td>
<td>14 (28.0)</td>
<td>0.002</td>
</tr>
<tr>
<td>Widened scars</td>
<td>14 (8.0)</td>
<td>12 (24.0)</td>
<td>0.004</td>
</tr>
<tr>
<td>Ossification difficulties</td>
<td>15 (8.6)</td>
<td>5 (10.0)</td>
<td>0.779</td>
</tr>
<tr>
<td>Revision surgery</td>
<td>2 (1.1)</td>
<td>0 (0.0)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

SAS, spring-assisted surgery; CVR, cranial vault remodeling. ∗Fisher’s exact test.
between groups but were more frequent in the spring-assisted surgery group, with 11 undergoing reoperations to address spring malposition \((n = 6)\), exposure or threatened exposure \((n = 3)\), or superficial infection \((n = 2)\). An additional two spring patients required subsequent cranial vault remodeling: one had early spring malposition that resulted in asymmetric expansion, and the other developed unicoronal craniosynostosis 4 months after spring removal prompting subsequent cranial vault remodeling. One patient in the cranial vault remodeling group was returned to the operating room for scalp incision dehiscence.

Clinic notes were examined for reports of speech delays prompting therapy referrals, headaches prompting referrals to ophthalmology and/or neurology, widened scars, and delays in calvarial ossification. Patients undergoing cranial vault remodeling had significantly higher long-term rates of speech delays \((p = 0.01)\), headaches \((p < 0.01)\), and widened scars \((p < 0.01)\). No patients in either group developed papilledema or increased intracranial pressure. None of the patients undergoing cranial vault remodeling underwent revision surgery.

Cranial vault remodeling surgery varied in approach depending on the predominant phenotype (Fig. 2), but was most often anterior two-thirds vault remodeling \([n = 22 (44.0 \%)\]) or a central expansion \([n = 21 (42 \%)\]). There were no differences in Whitaker scores, headaches, speech delays, scars, or ossification delays between the different cranial vault remodeling subtypes. (See Table, Supplemental Digital Content 3, which shows long-term complications by cranial vault remodeling subtype, http://links.lww.com/PRS/E190.)

**Outcome Measures**

Mean Cephalic Indices (Table 3) were significantly lower preoperatively in the spring-assisted surgery group versus the cranial vault remodeling group \((70.7 \text{ versus } 72.7; p = 0.012)\). In the immediate postoperative period, the Cephalic Index of the spring-assisted surgery cohort increased by 5.53 percent compared to the 3.83 percent observed in the cranial vault remodeling cohort \((p = 0.13)\). There were no significant differences in Cephalic Index at 2 and 6 years postoperatively. The Cephalic Index at 12 years postoperatively was increased by 7.58 percent compared with preoperative values for the spring-assisted surgery group, but inadequate numbers were available at this time point for a comparison with the cranial vault remodeling group.

Whitaker scores were assigned in blinded fashion by a craniofacial surgeon (C.M.R.) not involved in the patients’ care using patient photographs and head laser or 3dMD scans (Fig. 3). There were more patients in the spring-assisted surgery cohort with no necessary revisions (Whitaker class I) \((81.3 \% \text{ versus } 62.2 \%\) for cranial vault remodeling group; \(p = 0.006)\). Patients identified as benefiting from further surgery were assigned one of three Whitaker classes: II (minor soft-tissue or bony contour irregularities), III (residual deformities requiring bony contouring) or IV (requiring repeated cranioplasty in excess of original surgery). A significantly higher percentage of those in the cranial vault remodeling group were classified as II to IV \((38 \% \text{ versus } 19 \%\); \(p = 0.006)\).

**DISCUSSION**

Since the initial clinical report by Lauritzen et al. of spring-assisted surgery in 1998,\(^\text{12}\) multiple major craniofacial centers have adopted the technique as their treatment of choice for treatment of infants with sagittal craniosynostosis.\(^\text{13,20,21}\) Our findings reinforce those of these groups and our earlier reports,\(^\text{9}\) which demonstrate clear advantages of spring-assisted surgery over cranial vault remodeling with regard to operative time, bleeding, hospital length of stay, and total costs. Surgeons may consider the potential negative neurologic impact of multiple operations required in the spring-assisted surgery approach. Technically, all patients undergoing spring-assisted surgery undergo a second operation for spring removal. However, the concern for two shorter operations must be weighed against the concern that surgery in those younger than 3 years lasting longer than 3 hours may also be associated with risks for negative neurologic effects.\(^\text{22}\) The combined anesthetic time for spring placement and removal operations approaches this 3-hour cutoff, whereas anesthetic time for cranial vault remodeling in our series exceeded 4 hours. There is no evidence regarding the relative risks of combined shorter operations versus one longer operation, and this topic awaits further research.

The perioperative complications in our spring-assisted surgery group were predominately spring malposition or superficial infection leading to exposure. Accordingly, we modified our technique to place a Vicryl suture (Ethicon, Inc., Somerville, N.J.) to anchor the overlapping springs to the edge of the parietal bone on each side, eliminating this complication over the
past 5 years. We did not experience any sagittal sinus tears, durotomies, or postoperative subdural hematomas as reported by others performing spring-assisted surgery.\textsuperscript{13,20,21} Two patients required subsequent cranial vault remodeling for cranial asymmetry that developed early following spring-assisted surgery, one of whom had spring dislodgment that contributed to the asymmetry. The second developed uncoronal craniosynostosis identified by orbital asymmetry 4 months after spring removal. Secondary coronal suture fusion has been reported to occur from 9.5 percent of those undergoing sagittal suturectomy with barrel staving\textsuperscript{23} to 40 percent of those undergoing total cranial vault remodeling.\textsuperscript{24} Van Veelen et al. reported that of those undergoing spring-assisted
surgery for sagittal synostosis, 70 to 80 percent of the coronal sutures examined radiographically were confirmed to be open and the remaining 20 to 30 percent of sutures were not visible or were undetermined. We did not obtain radiographs for our patients after spring removal, and other than our single case, we cannot confirm the associated incidence with spring-assisted surgery. The cause of secondary coronal fusion in our patient is also uncertain, but may be attributable to elimination of the normal outward forces following rapid expansion of the vault, or to physical disruption of the signaling between the coronal suture mesenchyme and the underlying dura.

We have had good continuity with our spring-assisted surgery cohort, with over 55 percent of patients with over 5 years of annual visits. Of these, none have been diagnosed with increased intracranial pressure or papilledema. Frequent headaches occur in up to 33 percent of those treated for craniosynostosis, and have been shown to have a low but significant positive predictive value of 6.7 percent for increased intracranial pressure among patients with nonsyndromic craniosynostosis. Within our spring-assisted surgery cohort, only 8 percent experienced frequent headaches prompting a referral to neurology, and all have been successfully managed medically. The effects of sagittal craniosynostosis on neurologic development, including differences between treatment types, are areas of particular controversy and interest. Neurologic studies on those undergoing spring-assisted surgery as compared to cranial vault remodeling have not been reported and are certainly warranted.

The Cephalic Index is the ratio of the maximum cranial width (euryon to euryon) to its maximum length (glabella to opisthocranion) and has long been used as the primary tool to measure correction of scaphocephaly. We used Cephalic Index as a primary objective measure of long-term correction of scaphocephaly between our groups. Those undergoing spring-assisted surgery had a significantly lower Cephalic Index preoperatively. This likely reflects a correlation between severity and likelihood of early surgical

<table>
<thead>
<tr>
<th></th>
<th>SAS*</th>
<th>SAS Postoperatively</th>
<th>CVR*</th>
<th>CVR Postoperatively</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperatively</td>
<td>70.7 ± 4.0</td>
<td>73.1 ± 6.0</td>
<td>0.044‡</td>
<td></td>
</tr>
<tr>
<td>Postoperatively</td>
<td>74.6 ± 4.2</td>
<td>76.1 ± 5.7</td>
<td>4.5</td>
<td>0.062§</td>
</tr>
<tr>
<td>1 yr postoperatively</td>
<td>73.8 ± 4.0</td>
<td>76.1 ± 4.2</td>
<td>5.0</td>
<td>0.519§</td>
</tr>
<tr>
<td>2 yr postoperatively</td>
<td>72.6 ± 8.7</td>
<td>75.0 ± 5.2</td>
<td>4.9</td>
<td>0.289§</td>
</tr>
<tr>
<td>6 yr postoperatively</td>
<td>74.7 ± 4.4</td>
<td>73.0 ± 3.8</td>
<td>7.3</td>
<td>0.710§</td>
</tr>
<tr>
<td>12 yr postoperatively</td>
<td>75.6 ± 3.8</td>
<td>7.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Values presented as means ± SD. †Only patients with both preoperative and postoperative imaging at the given time points included in statistical analysis. ‡t-test for absolute difference in Cephalic Index (statistically significant). §t-test for difference in percentage change from preoperative Cephalic Index.

Fig. 3. Whitaker classes of patients undergoing cranial vault remodeling (CVR) or spring-assisted surgery (SAS) for sagittal craniosynostosis.
referral. Given this difference, we compared the percentage increase in Cephalic Index over time between our spring-assisted surgery and cranial vault remodeling groups. There were no differences in the improvement in Cephalic Index between the two techniques at any time point. The percentage improvement in Cephalic Index for the spring-assisted surgery group persisted at 12 years, indicating a stable long-term outcome. We recognize that Cephalic Index is an imperfect tool for assessing shape outcomes. Others have nicely demonstrated the superiority of a “normative Cephalic Index,” which corrects for the abnormally positioned euryon in patients with sagittal synostosis. The traditional Cephalic Index also does not adequately evaluate shape abnormalities at a more cephalad position, often failing to identify an anterior displaced vertex and lack of posterior height. Because of these weaknesses, Cephalic Index may not be predictive of subjective assessments of severity. We anticipate that the increasing use of noninvasive three-dimensional stereophotogrammetry will allow craniofacial surgeons to draw more definitive conclusions about calvarial shape outcomes. 

A final means to assess outcomes is whether patients did or should undergo revision surgery to correct persistent shape deformity. Among those with sagittal craniosynostosis, reported ranges for secondary cranial vault remodeling are 0 to 8 percent following primary cranial vault remodeling, and 0 to 2.4 percent for spring-assisted surgery. Our results were similar, with 0 percent in our cranial vault remodeling cohort and 1.1 percent in our spring-assisted surgery cohort undergoing secondary cranial vault remodeling. Accepting that not all patients who may benefit from a revision undergo revision surgery, we assigned Whitaker classes to patients in each group. This was performed by a craniofacial surgeon not involved in the patients’ care, in blinded fashion. We found significantly lower Whitaker classes in those undergoing spring-assisted surgery compared to cranial vault remodeling. These differences were primarily (Whitaker class II) attributable to minor residual temporal and frontal deformities found more often in those undergoing cranial vault remodeling, which could be treated with soft-tissue augmentation.

A significant limitation of comparing our spring-assisted surgery to cranial vault remodeling groups is selection bias, as there was a significantly increased delay in presentation and age at the time of cranial vault remodeling surgery compared with the spring-assisted surgery cohort. Surgical intervention for sagittal craniosynostosis may be considered to be more complex at an older age, as the calvaria loses plasticity with growth. Spring-assisted surgery quickly corrects biparietal and vertex narrowing with dynamic forces, but it has less direct effects on frontal bossing and occipital prominence. Performed at a young age, spring-assisted surgery benefits from gradual, secondary improvements in frontal and occipital prominence. Cranial vault remodeling techniques, particularly when performed at an older age, not only must correct restriction in the region of the fused suture but must directly address these compensatory changes. An ideal comparison of spring-assisted surgery to cranial vault remodeling would match patients for age to eliminate this selection bias. Furthermore, given that many surgeons use disparate cranial vault remodeling techniques and intervene at an earlier age (<12 months) than our cranial vault remodeling group, it is inappropriate for us to conclude that spring-assisted surgery would yield better shape outcomes than cranial vault remodeling in the hands of others.

CONCLUSIONS

Spring-assisted surgery for early treatment of sagittal craniosynostosis is associated with decreased operative morbidity compared with open calvarial vault remodeling. Correction of Cephalic Index is maintained over a 12-year period in those treated with spring-assisted surgery, suggesting a permanent improvement. Those undergoing spring-assisted surgery had subjectively better shape outcomes than those in our cranial vault remodeling group. Together, these data suggest that spring-assisted surgery should strongly be considered as an alternative to cranial vault remodeling for treatment of infants (younger than 6 months) with sagittal craniosynostosis.

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REFERENCES


