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Microscopic Versus Open Approach to Craniosynostosis: A Long-Term Outcomes Comparison

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Abstract

The purpose of this retrospective study was to evaluate the long-term outcomes of using the microscopic minimally invasive approach for the treatment of nonsyndromic craniosynostosis. During the last 10 years, 180 consecutive patients with nonsyndromic craniosynostosis were treated: 67 patients were treated with microscopic minimally invasive approach, and 113 were treated with the open approach. In the microscopic group, there was 1 intraoperative complication (1.5%). There were 10 postoperative complications (14.9%), of which 9 required major reoperations and 1 required a minor procedure. The major complications occurred in 7 unicoronal patients (58.3%) and 2 metopic patients (25.0%). In the open-approach group, there were 8 complications (7.1%), 2 patients required major reoperations and 6 required minor procedures. Chi-squared test showed that there was no statistically significant difference in the overall complication rate between the microscopic and open approaches. However, in the unicoronal patients, the complication rate was significantly higher in the microscopic group ($P < 0.001$). In conclusion, the microscopic approach is our treatment of choice in nonsyndromic patients with sagittal and lambdoidal craniosynostosis. We no longer use the microscopic approach in patients with unicoronal or metopic craniosynostosis because of the high complication rate.

Keywords

Nonsyndromic; craniosynostosis; microscopic approach; minimally invasive; traditional open approach

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The current treatment of craniosynostosis patients has evolved from craniectomy to total cranial vault reconstruction. Recently, the minimally invasive approach of Barone and Jimenez^{1,2} has renewed interest in craniectomy. The minimally invasive approach and craniectomy have also been used with spring-mediated cranioplasty^{3–5} and distraction osteogenesis.^{6,7} Whereas there have been numerous reports on the minimally invasive approach for craniosynostosis, there has been only 1 report on long-term outcomes.⁸ The goal of this study is to compare the long-term outcomes using the microscopic minimally invasive approach versus the traditional open approach in the treatment of nonsyndromic craniosynostosis.

MATERIALS AND METHODS

From May 2001 to April 2011, 180 patients with nonsyndromic craniosynostosis were treated at the University of Texas Health Science Center at Houston or Children's Memorial Hermann Hospital. Sixty-seven patients were treated with the microscopic minimally invasive approach.^{9,10} The mean age of the patients was 3.5 months (SD, 1.6 mo), with a mean follow-up of 7.4 years (SD, 2.5 y). There were 47 boys and 20 girls (Table 1). The affected sutures are seen in Table 2. During the same period, 113 patients were treated with the traditional open approach. The mean age of the patients was 14.8 months (SD, 14.6 mo), with a mean follow-up of 7.2 years (SD, 3.3 y). There were 66 boys and 47 girls (Table 1). The affected sutures are seen in Table 2. All the patients were treated by a single group of surgeons (J.E.B. and J.F.T.). The inclusion criterion in this retrospective study was that the patients completed surgery for nonsyndromic single-suture craniosynostosis. The study was approved by the institutional review board.

The patients were assigned to the open or minimally invasive group based on the age of presentation and on the parent's preference. As reported earlier, the authors used the microscopic minimally invasive approach in all nonsyndromic craniosynostosis patients younger than 3.5 months. The authors discussed the possible need for the secondary surgery with all of the families who elected microscopic surgery. In patients with sagittal craniosynostosis, the incisions are over the anterior fontanel and midway between the inion and the lambda. Additional incisions are placed midway between these 2 incisions. The craniectomy (4 cm × 16–18 cm) extends from the anterior fontanel to the occiput with bilateral temporoparietal craniotomies. In patients with unicoronal or bicoronal craniosynostosis, there is an incision over the anterior fontanel with unilateral or bilateral incisions over the superior temporal line. The unilateral or bilateral craniectomies (1 cm × 8–10 cm) extend from the anterior fontanel to the squamosal suture. In patients with metopic craniosynostosis, there is an incision over the anterior fontanel and bilateral incisions over the superior temporal lines. A metopic craniectomy (1 cm × 6–8 cm) is carried down to the nasofrontal suture line. Additional bilateral coronal craniectomies (1 cm × 8–10 cm) are also completed. Finally, in patients with lambdoidal craniosynostosis, an incision is made over the affected suture with a lambdoidal craniectomy (1 cm × 6–8 cm). Following our clinical routine, all the patients in both groups had postoperative molding helmets for 3 months.⁹ The duration of the molding was increased to 4 to 5 months in patients with persistent postoperative asymmetry and concurrent posterior plagiocephaly.

The open approach is through a coronal incision. In patients with metopic, unicoronal, and bicoronal craniosynostosis, a bifrontal cranioplasty and frontal bar reconstruction are used. In patients with sagittal craniosynostosis, an extended strip craniectomy with coronal and lambdoidal craniotomies is used. In older sagittal patients and/or those with significant frontal bossing, a frontal cranioplasty is also used for total cranial vault remodeling. In patients with lambdoidal craniosynostosis, a suturectomy with posterior cranial vault remodeling is used. Finally, in patients with multiple suture craniosynostosis, total cranial vault remodeling is used, focused on the deformity. As per our clinical routine, all of the open-group patients also had a postoperative molding therapy for 3 months.⁹

Outcomes were evaluated for complications and reoperations. Minor reoperations involved soft-tissue refinement or simple bony contouring. Major reoperations involved calvarial osteotomies and cranial remodeling. Chi-squared test was used to detect whether there was a statistically significant difference in complication rate between the microscopic and traditional open approaches

RESULTS

In the patients treated with the microscopic approach, there were no deaths. One patient (1.5%, 1/67) had an intraoperative superior sagittal sinus tear. Ten patients (14.9%, 10/67) required additional surgery (Table 2). The mean age at the reoperation was 16.3 months (SD, 13.8 mo). In this group, 9 patients required major reoperations (13.4%, 9/67); and 1, a minor procedure (1.49%, 1/67). The causes of the procedures included inadequate surgical correction (4 patients), suture resynostosis resulting in a phenotypic relapse (4 patients), and a postoperative central spinal fluid (CSF) leak. The 1 minor procedure was for a persistent cranial bone defect.

Using the traditional open approach, there were no deaths or intraoperative complications. Eight patients (7.1%) required additional surgery (Table 2). The mean age at the time of reoperation was 27.1 months (SD, 24.7 mo). In this group, 2 patients required major reoperations, whereas 6 patients required minor reoperations. The causes for the major procedures included incomplete or inadequate correction (1 patient) and CSF leak (1 patient). The causes for the minor procedures included postoperative superficial wound infection (1 patient), persistent cranial bone defect (2 patients), an exposed absorbable palate (2 patients), and scare alopecia (1 patient).

The complication rate in both groups of sagittal synostosis patients was similar. The microscopic group (41) had 1 minor procedure (2.4%, 2/41), whereas the open group (48) had 1 major (2.1%, 2/48) and 2 minor (4.2%, 2/48) procedures. The complication rate differed significantly ($P < 0.001$) in the 2 groups of patients treated for unicoronal synostosis. The microscopic group (12) had 7 major procedures (58.3%, 7/12), whereas the open group (28) had no major reoperations. The complication rate for the 2 groups of metopic synostosis patients was similar. The microscopic group (8) had 2 major procedures (25%, 2/8), whereas the open group (26) had 1 major procedure (3.8%, 1/26) and 1 minor procedure (3.8%, 1/26). The bicoronal groups were also similar. The microscopic group (5) had no reoperations, and the open group had 2 minor procedures (33.3%, 2/6). Finally, the

lambdoidal groups were similar with 1 minor procedure (20%, 1/5) in the open group and none in the microscopic group.

DISCUSSION

Since Barone and Jimenez^{1,2} introduced the minimally invasive approach to the treatment of craniosynostosis, there have been numerous studies that showed that the minimally invasive approach to nonsyndromic craniosynostosis has the same morphologic results as the open approach.^{9–14} However, there have been few reports on the approach's long-term complications. Most of these studies have been limited to patients with sagittal craniosynostosis.¹⁵ Ridgeway in a recent article on endoscopic suturectomy in sagittal craniosynostosis reported a complication rate of 5.3% (3/56).¹⁶ Taylor and Maugans¹⁷ reported a complication rate of 14.3% (1/7) in their minimally invasive study on sagittal craniosynostosis. Wong et al⁸ reported a complication rate of 7.89% in all types of nonsyndromic craniosynostosis patients.

Whereas there have been a limited number of reports on the complication rate of the minimally invasive approach to craniosynostosis, there have been a number of studies on the complication rate with the open approach.¹⁸ An early report by Whitaker et al¹⁹ noted 2.2% of mortality rate and 25.7% of complication rate for intracranial operations. A subsequent report by Whitaker et al²⁰ had 0% of mortality rate and 19.0% of complication rate. McCarthy et al²¹ had 13.5% and 36.8% of reoperation rates, respectively, for simple and syndromic craniosynostosis patients. Seruya et al's²² article on the open approach had 3.3% of complication rate with no deaths. He also reported 10.8% of reoperation rate. Foster et al,²³ in another open approach study, reported 4.2% of complication rate with 16.8% of reoperation rate. They noted that the reoperation rate was higher in the patients with multiple suture craniosynostosis than in those with single suture involvement (15.4% versus 5.7%). The rate of resynostosis in these reports varied from 5.7% to 70.9%. Wall et al²⁴ had a higher reoperation rate in children operated on before 6 months old. Foster et al²³ noted no increase in the rate of reoperation or resynostosis as a function of age.

The long-term outcomes for the microscopic and open groups are comparable with other reports as indicated previously. In our minimally invasive craniosynostosis patients, there were no deaths and only 1 major intraoperative complication. The reoperation rate was 14.9% (10/67). In this group, 9 patients had major reoperations, whereas 1 patient had a minor procedure (1.49%, 1/67). There was a significant increase in the reoperation rate for the unicoronal craniosynostosis patients (58.3%, 7/12). All were major procedures: 3 patients required an additional open bifrontal cranioplasty with frontal bar reconstruction, and 4 patients had burring of a bony bridge for phenotypic relapse. One patient had a minor procedure involving an onlay cranioplasty for persistent bony defect.

The microscopic metopic patients had a major complication rate of 25% (2/8). Both patients required an additional open bifrontal cranioplasty with frontal bar reconstruction. Because of the small number of microscopic metopic patients, the reoperation rate of 25% was not statistically significantly different than the patients who were treated with the traditional open approach. In the microscopic sagittal patients, 1 patient had a minor onlay cranioplasty

for a persistent cranial defect. This is notable because the sagittal microscopic group had the most extensive surgery. No complications were seen in the bicoronal or lambdoidal craniosynostosis patients, although the number of patients in these groups was limited.

The predominant reason for reoperation in the microscopic group was the failure of the suturectomy to correct the underlying cranial deformity. Among the 9 major reoperation patients, 4 had a repeat suturectomy, and 5 had a complete cranial vault and forehead reconstruction. In the microscopic unicoronal group, this was due to a refusion of the coronal suture, which always occurred during the helmet therapy. The problem with refusion of the affected coronal suture persisted despite the authors widening the coronal craniectomy trough from 1.0 to 2.0 cm. The site of refusion was always at the superior temporal line and was independent of the severity of the cranial vault deformity. There remains the question of whether the vector of the postoperative helmet therapy increased bony deposition at the affected coronal suture. In the microscopic metopic group, the reason for reoperation (2) was not suture refusion, but inadequate correction of the patient's deformity.

In our previous reports on the microscopic approach, we described reducing the duration of helmet therapy from 6 to 3 months. Given that all the patients had the refusion during the helmet therapy, it is unlikely that extending the course of molding therapy would have affected these outcomes.

In the craniosynostosis patients treated with the open approach, there were no deaths or intraoperative complications. The reoperation rate was 7.1% (8/113). Three patients (3/48) treated for sagittal craniosynostosis required reoperation: one for a CSF leak, one for a persistent cranial bone defect, and one for an exposed absorbable plate. In the metopic patients treated with the open approach, 2 (of the 26) patients required additional surgery: one for an inadequate correction and one for scar alopecia. In the open-approach patients with bicoronal craniosynostosis, there were 2 patients who required additional surgery: one for an exposed absorbable plate and one for a superficial wound infection. Finally, in the open-approach patients with lambdoidal craniosynostosis, there was 1 patient who required additional surgery for inadequate correction. In the open approach, perioperative complications (6/8) were the predominant reason for reoperation. In only 2 patients was a secondary operation necessary for inadequate correction (2/8).

The authors also noted a higher incidence of reoperation in girls than in boys, although there were more boys in the study. The question of whether to reoperate was certainly not affected by the sex of the patient. It was solely based on the complication. The authors are at a loss to explain this discrepancy.

In conclusion, the current study demonstrates that the complication rate with the minimally invasive approach is comparable with other minimally invasive reports as well with other open-approach reports. There was no statistical difference in complication rates between the minimally invasive and the open groups (14.9% versus 7.1%). However, the microscopic group tended to have a higher major reoperation rate, although this was not statistically significantly different. The microscopic unicoronal patients had a statistically significant higher reoperation rate (58.3%). The microscopic metopic patients also had a higher

reoperation rate, although this was not statistically significant. The authors no longer use the microscopic approach in unicoronal or metopic patients. It is still our operative approach in nonsyndromic patients with sagittal and lambdoidal craniosynostosis.

Finally, because of the relative small sample size for both groups, it is worth to note that the lack of statistically significant difference may be due to the lack of statistical power.

Therefore, a large sample-size study is warranted to definitively confirm whether there is a difference between the minimally invasive group and the traditional open group.

REFERENCES

1. Barone CM, Jimenez DF. Endoscopic craniectomy for early correction of craniosynostosis. *Plast Reconstr Surg.* 1999; 104:1965–1973. discussion 1974–1965. [PubMed: 11149758]
2. Barone CM, Jimenez DF. Endoscopic approach to coronal craniosynostosis. *Clin Plast Surg.* 2004; 31:415–422. [PubMed: 15219748]
3. Lauritzen CG, Davis C, Ivarsson A, et al. The evolving role of springs in craniofacial surgery: the first 100 clinical cases. *Plast Reconstr Surg.* 2008; 121:545–554. [PubMed: 18300975]
4. Windh P, Davis C, Sanger C, et al. Spring-assisted cranioplasty vs pi-plasty for sagittal synostosis—a long term follow-up study. *J Craniofac Surg.* 2008; 19:59–64. [PubMed: 18216666]
5. David LR, Plikaitis CM, Couture D, et al. Outcome analysis of our first 75 spring-assisted surgeries for scaphocephaly. *J Craniofac Surg.* 2010; 21:3–9. [PubMed: 20061981]
6. Cho BC, Hwang SK, Uhm KI. Distraction osteogenesis of the cranial vault for the treatment of craniofacial synostosis. *J Craniofac Surg.* 2004; 15:135–144. [PubMed: 14704580]
7. Park DH, Chung J, Yoon SH. Rotating distraction osteogenesis in 23 cases of craniosynostosis: comparison with the classical method of craniotomy and remodeling. *Pediatr Neurosurg.* 2010; 46:89–100. [PubMed: 20664235]
8. Wong RK, Emelin JK, Meltzer HS, et al. Nonsyndromic craniosynostosis: the Rady Children's Hospital approach. *J Craniofac Surg.* 2012; 23:2061–2065. [PubMed: 23154350]
9. Baumgartner JE, Teichgraeber JF, Waller AL, et al. Microscopic approach to craniosynostosis. *J Craniofac Surg.* 2005; 16:997–1005. [PubMed: 16327547]
10. Teichgraeber JF, Baumgartner JE, Waller AL, et al. Microscopic minimally invasive approach to nonsyndromic craniosynostosis. *J Craniofac Surg.* 2009; 20:1492–1500. [PubMed: 19816284]
11. Cohen SR, Holmes RE, Meltzer HS, et al. Immediate cranial vault reconstruction with bioresorbable plates following endoscopically assisted sagittal synostectomy. *J Craniofac Surg.* 2002; 13:578–582. discussion 583–574. [PubMed: 12140427]
12. Jimenez DF, Barone CM, McGee ME, et al. Endoscopy-assisted wide-vertex craniectomy, barrel stave osteotomies, and postoperative helmet molding therapy in the management of sagittal suture craniosynostosis. *J Neurosurg Spine.* 2004; 100:407–417.
13. Jimenez DF, Barone CM. Endoscopic craniectomy for early surgical correction of sagittal craniosynostosis. *J Neurosurg.* 1998; 88:77–81. [PubMed: 9420076]
14. Jimenez DF, Barone CM. Early treatment of coronal synostosis with endoscopy-assisted craniectomy and postoperative cranial orthosis therapy: 16-year experience. *J Neurosurg Pediatr.* 2013; 12:207–219. [PubMed: 23808724]
15. Gociman B, Marengo J, Ying J, et al. Minimally invasive strip craniectomy for sagittal synostosis. *J Craniofac Surg.* 2012; 23:825–828. [PubMed: 22565892]
16. Ridgway EB, Berry-Candelario J, Grondin RT, et al. The management of sagittal synostosis using endoscopic suturectomy and postoperative helmet therapy. *J Neurosurg Pediatr.* 2011; 7:620–626. [PubMed: 21631199]
17. Taylor JA, Maugans TA. Comparison of spring-mediated cranioplasty to minimally invasive strip craniectomy and barrel staving for early treatment of sagittal craniosynostosis. *J Craniofac Surg.* 2011; 22:1225–1229. [PubMed: 21772211]

18. Lee HQ, Hutson JM, Wray AC, et al. Analysis of morbidity and mortality in surgical management of craniosynostosis. *J Craniofac Surg.* 2012; 23:1256–1261. [PubMed: 22948658]
19. Whitaker LA, Munro IR, Salyer KE, et al. Combined report of problems and complications in 793 craniofacial operations. *Plast Reconstr Surg.* 1979; 64:198–203. [PubMed: 377338]
20. Whitaker LA, Bartlett SP, Schut L, et al. Craniosynostosis: an analysis of the timing, treatment, and complications in 164 consecutive patients. *Plast Reconstr Surg.* 1987; 80:195–212. [PubMed: 3602170]
21. McCarthy JG, Glasberg SB, Cutting CB, et al. Twenty-year experience with early surgery for craniosynostosis: I. Isolated craniofacial synostosis—results and unsolved problems. *Plast Reconstr Surg.* 1995; 96:272–283. [PubMed: 7624400]
22. Seruya M, Oh AK, Boyajian MJ, et al. Long-term outcomes of primary craniofacial reconstruction for craniosynostosis: a 12-year experience. *Plast Reconstr Surg.* 2011; 127:2397–2406. [PubMed: 21311385]
23. Foster KA, Frim DM, McKinnon M. Recurrence of synostosis following surgical repair of craniosynostosis. *Plast Reconstr Surg.* 2008; 121:70e–76e.
24. Wall SA, Goldin JH, Hockley AD, et al. Fronto-orbital re-operation in craniosynostosis. *Br J Plast Surg.* 1994; 47:180–184. [PubMed: 8193856]

TABLE 1

Demographics

	Micro Primary	Reoperation	Reoperation Rate, %	Open Primary	Reoperation	Reoperation Rate, %
Boys	47	4	8.5	66	4	6.0
Girls	20	6	30.0	47	4	8.5
Total	67	10	14.9	113	8	7.1

TABLE 2

Reoperation Rate (Microscopic Versus Open Minor and Major Complications)

	Microscopic Reoperation Rate		Open Reoperation Rate	
	Micro Minor	Micro Major	Open Minor	Open Major
Bicoronal	—	—	33.3% 2/6	—
Unicoronal	—	58.3% 7/12	—	—
Lambdoid	—	—	20.0% 1/5	—
Metopic	—	25.0% 2/8	3.8% 1/26	3.8% 1/26
Sagittal	2.4% 1/41	—	4.2% 2/48	2.1% 1/48
Total	1.49% 1/67	13.4% 9/67	5.3% 6/113	1.8% 2/113