OBJECTIVE: We sought to determine whether functional endoscopic sinus (FES) surgery performed in children with chronic rhinosinusitis alters facial growth.

STUDY DESIGN AND SETTING: This was a retrospective age-matched cohort outcome study performed at a tertiary care hospital.

RESULTS: Sixty-seven children participated. There were 46 boys and 21 girls, and the mean age was 3.1 years at presentation and 13.2 years at follow-up. There were 46 children who underwent FES surgery and 21 children who did not undergo FES surgery. Quantitative anthropomorphic analysis was performed using 12 standard facial measurements. A facial plastic expert performed qualitative facial analysis. Both quantitative and qualitative analyses showed no statistical significance in facial growth between children who underwent FES surgery and those who did not undergo FES surgery.

CONCLUSIONS: In this study, there was no evidence that FES surgery affected facial growth.

SIGNIFICANCE: These results will aid physicians when discussing with parents the risks of FES surgery.

Pediatric rhinosinusitis is estimated to complicate approximately 5% to 10% of upper respiratory infections in early childhood. Chronic rhinosinusitis is generally defined as ≥12 weeks of symptoms despite medical therapy and is a serious problem for many young children. A variety of authors suggest different treatments, including functional endoscopic sinus (FES) surgery. The variation in treatment recommendations is likely a reflection of different spectra of patients and treatment philosophies.

The potential problem of altered facial growth development as a result of chronic rhinosinusitis and surgical treatment is recognized. With the recent advances in FES surgery, greater understanding of sinus development has been gained. Maxillary sinus development occurs in successive stages. In a study by Bingham et al, prolongations from the space lateral to the uncinate process form the maxillary and ethmoid sinuses. The uncinate process, hiatus semilunaris, and ethmoidal bulla are well developed in the newborn and make consistent landmarks for FES surgery. Wolf et al discuss the rapid development of the maxillary and ethmoid sinuses. The uncinate process, hiatus semilunaris, and ethmoidal bulla are well developed in the newborn and make consistent landmarks for FES surgery.

Ethmoid sinus development occurs from the lateral wall of the primitive olfactory pit. The full complement of these cells is present in the newborn in the form of small infundibular pouches. They subsequently expand progressively, giving rise to the ethmoidal labyrinth. Sinus development...
is intimately linked to facial development. Sinuses tend to not only passively occupy the space created by the bony development but also possess a development potential of their own. In so doing, they fulfill the role of a morphogenetic motor for facial bone development.15

The objective of this study was to determine whether FES surgery performed in children with chronic rhinosinusitis alters facial growth. Facial growth was assessed using quantitative anthropometric techniques and qualitative photographic analysis.

**METHODS**

**Study Design**

This was a retrospective age-matched cohort study. The research was conducted at the Division of Pediatric Otolaryngology, Department of Otolaryngology-Head and Neck Surgery, Washington University School of Medicine. All surgical procedures were performed at the St Louis Children’s Hospital, where pediatric FES surgery has been performed since 1988. The Washington University Institutional Review Board approved this study.

**Study Population**

The study population consisted of white children between the ages of 2 and 4 presenting between 1989 and 1990 with signs and symptoms consistent with the diagnosis of chronic rhinosinusitis. This population was identified through a search of the clinical billing records of the Division of Pediatric Otolaryngology using the following ICD-9 diagnosis codes (381, 382, 461, 471, 473, 474, 477, 478, 493) and CPT surgical codes (31237, 31254, 31255, 31256, 31267, and 31287). Children with significant congenital syndromes such as Down syndrome and cystic fibrosis, a history of significant maxillofacial trauma, nasal fractures, or previous nasoseptal surgery were excluded because these conditions could cause a disturbance in facial growth. Parents of eligible children were contacted by mail and invited to participate in this study. White children were selected because normative facial bone anthropometric measurements are available for only this population.16 From this population, a cohort of patients who underwent FES surgery and a second age-matched cohort was identified who did not undergo FES surgery. The age-matched children were selected to control for the impact that chronic rhinosinusitis may have on facial growth. Of the 131 eligible children, 67 agreed to participate and form the study population for this research.

**Definition of Variables**

**Patient-based clinical factors.** From a retrospective review of the medical record, detailed information was obtained on duration of sinus symptoms; severity of sinus symptoms; presence and size of tonsils and adenoids; history of tonsillectomy, adenoidectomy, or pressure equalization tubes; presence of nasal airway obstruction, asthma, allergy, or gastroesophageal reflux; immune deficiency; or primary ciliary dyskinesia. Parents or caregivers described the severity of 6 key sinus symptoms (runny nose, nasal obstruction, irritability, daytime cough, nighttime cough, and headache) at the initial presentation. The severity of the child’s sinus disease was graded using a 0-to-6 ordinal scale, where 0 indicates the absence of symptom and 6 indicates the presence of all 6 symptoms. The overall initial severity of sinus symptoms was the sum of the 6 symptoms. The attending physician (R.P.L.) documented this information at the time of initial visit using a standard data collection form.

**Sinus computed tomography (CT).** The severity of sinus disease according to CT scans was recorded using the Pediatric Rhinosinusitis CT Scoring System. With this system, the amount of disease is graded on a 0-to-3 ordinal scale, where 0 indicates no disease, 1 indicates <50% of the sinus is diseased, 2 indicates >50% of the sinus is diseased, and 3 indicates complete opacification. Congenitally absent sinuses or sinuses not yet developed were not scored. The overall severity of sinus disease was determined as the average of the severity of the individual sinuses.

**Quantitative Anthropometric Evaluation**

Quantitative assessment of facial growth consisted of quantitative anthropometric evaluation by one of the authors (M.R.B.). Anthropometry is a widely recognized, accurate, and noninvasive technique for the assessment of facial proportions.16-20 The relatively thin soft tissue cover of the skull, with few contour inequalities, allows for accurate surface measurements of bony cranial structures.16 Age and gender-specific normal values for whites are available.16 Facial structures that measure within 1 standard deviation (SD) of the age and gender-specific normal values are regarded as optimal. Borderline-small is defined as measurements between 1 and 2 SD smaller than normal. Borderline-large is defined as measure-
ments between 1 and 2 SD larger than normal. Subnormal and supranormal refers to measurements 2 SD smaller or larger than normal. The study population was compared to these normal values.

Before measurement, M.R.B. received personal instruction from Dr Leslie Farkas and viewed the videotape entitled, “Craniofacial Examination In Medicine Anthropometric Measurement.” To ensure adequate coverage of all bony facial structures that could be affected by FES surgery, 12 locations on the face were selected for measurements. These structures were nasion-gnathion, nasion-subnasale, nasion-stomion, zygion-zygion, endocanthion-endocanthion, tragus-nasion—right and left projection, tragus-subnasale—right and projection, tragus-gnathion—right and left projection.

The measurements were repeated 3 times at each location and the average value was used. All measurements were then transformed into Z scores to allow for direct comparison of individuals of different sex and age. Z scores were calculated by subtracting the observed measure from the age and gender-specific normative measurements and dividing this result by the standard deviation of the normative measurement. A Z score of zero indicates no difference from normal. A Z score value of 1.96 indicates a value so different from the normative value to occur only 1 time out of 20 (ie, \( p = 0.05 \)). All measurements were made without knowledge of whether the subject had undergone FES surgery or not.

**Qualitative Assessment of Facial Growth**

Qualitative assessment of facial symmetry and growth was performed by one of the co-authors (B.D.R.) with the use of standard frontal, left, and right lateral color photographs. The appearance of the face was assessed in 12 ways with the Qualitative Facial Growth Evaluation Form. First, an overall qualitative assessment of the child’s facial proportions was made. Specifically, the “Rules of Thirds” was used to evaluate vertical height of the face by dividing the face into thirds, with the upper third extending from trichion to glabella, the middle third from glabella to subnasale, and the lower third from subnasale to menton. The “Rule of Fifths” was used to evaluate facial proportion by dividing the face into fifths vertically, with each fifth approximating one eye width. Intercanthal distance was assessed with the *Rule of Fifths*. Nasal projection/nasal length (Goode’s law) was used to assess nasal projection. Values less than .55 were classified as abnormal. Nasomaxillary dysostosis (Binder’s syndrome), which is an under- or mal-development of the anterior maxilla and nasal spine and leads to inadequate tip projection, was assessed. Anterior projection of the chin, a measurement of the horizontal ramus of the mandible, was evaluated by the Gonzalez-Ulloa line. This line is determined with a vertical line that is dropped 90 degrees to the Frankfort horizontal to the nasion and extended past the chin. The chin should fall in or just short of this line. If chin is posterior to this line *Retrognathia* is present and if anterior to this line *Prosognathia* is present. Occlusion was documented in standard fashion as Class 1, Class 2, or Class 3 with Classes 2 and 3 representing abnormal values.

Overall Symmetry of the face was judged subjectively by comparing key facial features between the right and left side of face. An Overall Composite Qualitative Score was calculated as the sum of the presence of abnormal characteristic for each of the individual facial measurements. The presence of abnormal features was scored as 1 and the absence as 0. The range of scores was 0-9 with higher scores representing more abnormal facial structures. The angles of Peck (nasal, maxillary and mandibular) were identified. There are no known pediatric normative values for these measurements. Finally, BDR as a blinded observer, recorded whether he thought the child had FES surgery or not.

**Functional Endoscopic Sinus Surgery**

Surgical values were recorded: type of FES surgery (middle meatus antrostomy, ethmoidectomy either anterior or anterior/posterior, or combination of procedures), documentation of unilateral or bilateral surgery, findings at time of surgery, and any complications related to surgery.

**Statistical Analysis**

Data extracted from the medical record, the qualitative assessment and the quantitative mea-
measurements were entered into an Access 97 database (Microsoft Corporation, Seattle, Washington) using specially created data-entry screens. The Access database was transformed to a SAS Version 6.12 for Windows 95 (SAS Institute, Inc., Cary, NC) dataset for statistical analysis.

Description of the population and other variables was performed with standard descriptive statistics, including mean and standard deviation. Standard statistical tests, including $t$-test and $\chi^2$, were used to assess the significance of the differences between groups; 95% confidence intervals were used to indicate the precision of the differences. Multivariable linear regression was performed to assess the impact of FES surgery on facial growth after controlling for other demographic and clinical factors. A significance level of $P < 0.05$ was selected for all analyses. The Kappa Index was calculated to determine the facial plastic surgeon’s accuracy in identifying those patients who underwent FES surgery. Power calculations were computed prior to the conduct of the study and a sample size was selected to ensure 80% power to detect a clinically significant difference in anthropomorphic craniofacial measurements at the $P < 0.05$ level.

**RESULTS**

**Description of the Population**

The average age at presentation was 2.6 years for children in the FES-surgery group and 4.1 years for children in the no-FES-surgery group (difference of 1.5 years, 95% confidence interval [CI] 0.72-2.16, $P < 0.001$). The age at follow-up was 13.4 years for children in the FES-surgery group and 12.7 for children in the no-FES-surgery group (difference of 0.7 year, 95% CI 0.09-1.29, $P < 0.018$). The sinus symptom score was not significantly different between groups. CT scan severity was significantly worse at baseline for the FES-surgery group (mean score 1.04) versus the no-FES-surgery group (mean score 0.33) ($P < 0.003$).

Of the 46 operations performed in the FES-surgery group, 46 of the patients underwent enlargement of the antrostomy. Forty-three of the patients underwent bilateral anterior ethmoidectomies, and 2 underwent only unilateral anterior ethmoidectomies. Twenty-five underwent bilateral total ethmoidectomies, and 6 underwent only unilateral total ethmoidectomy.

**Quantitative Evaluation**

The quantitative evaluation showed no statistically significant difference in mean Z scores for any of the 12 anthropometric measurements for each group relative to the age-gender norms (Table 1). Further, no measurement was significantly different between the 2 groups.

**Qualitative Evaluation**

The qualitative evaluation also showed no statistical significance in any of the 9 variables between the 2 groups (Table 2). Interestingly, the
mean overall score for the no-FES-surgery group (2.15) was significantly worse than the score for the FES-surgery group (2.04). The angles of peck (nasal, maxillary, and mandibular) showed no statistical difference between the FES-surgery group and the no-FES-surgery group. When asked to estimate whether a child had had FES surgery, the facial plastic expert achieved a sensitivity of 0.50 (95% CI 0.35-0.63), specificity of 0.71 (CI 0.48-0.85), and $\kappa$ value of 0.17. A $\kappa$ value of $<0.20$ is interpreted as negligible agreement or only slightly above chance agreement.24

**Revision Surgery**

Due to the concern that revision FES surgery would have a greater effect on facial growth, the FES-surgery group was divided into revision and primary FES-surgery groups. The senior author performed all surgeries. The number of revisions varied between patients from 1 (most common) to 5 (rare). Further analysis showed no statistical significance on facial growth with both quantitative and qualitative analyses between the revision FES-surgery children and the primary FES-surgery group.

**DISCUSSION**

In this study we investigated the impact of rhinosinusitis and FES surgery on long-term facial growth in children. Facial growth was measured with both quantitative and qualitative measures approximately 10 years after young children presented with signs and symptoms consistent with chronic rhinosinusitis. Quantitative measures were compared with age- and gender-specific norms. Based on both quantitative and qualitative measures, there was no significant difference in facial growth between children undergoing FES surgery and those not undergoing FES surgery. Of interest, the overall qualitative score was statistically different between the 2 groups, with the FES-surgery group having the better (ie, more normal appearance) facial analysis score.

Many studies document that surgical intervention, such as cleft lip and palate and mandible fracture repairs, may impede facial growth.18,20,25,27 It is well known those individuals with repaired clefts of the lip and palate have adverse maxillary growth.27,28 Significant differences in maxillary growth and soft tissue profile were noted after repair of cleft lip and palate in a 2-center study based in Oslo, Norway, and Bristol, United Kingdom. The precise etiology of the deficient growth is not known, although it seems probable that a substantial proportion of this is due to the scarring produced by the primary surgical repair.26

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**Table 2. Facial plastic expert scoring of color photographs**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rating</th>
<th>FES surgery (n = 46)</th>
<th>No FES surgery (n = 21)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule of thirds</td>
<td>Abnormal (1)</td>
<td>19 (41%)</td>
<td>6 (28%)</td>
<td>0.31</td>
</tr>
<tr>
<td>Rule of fifths</td>
<td>Abnormal (1)</td>
<td>6 (13%)</td>
<td>2 (10%)</td>
<td>0.89</td>
</tr>
<tr>
<td>Intercanthal distance</td>
<td>Abnormal (1)</td>
<td>7 (15%)</td>
<td>3 (14%)</td>
<td>0.92</td>
</tr>
<tr>
<td>Nasal projection/nasal length &gt;0.55</td>
<td>Abnormal (1)</td>
<td>0 (0%)</td>
<td>1 (5%)</td>
<td>0.14</td>
</tr>
<tr>
<td>Class 1 occlusion</td>
<td>Abnormal (1)</td>
<td>14 (30%)</td>
<td>7 (33%)</td>
<td>0.67</td>
</tr>
<tr>
<td>Binder’s phenomenon</td>
<td>Yes (1)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Retrognathia</td>
<td>Yes (1)</td>
<td>25 (54%)</td>
<td>14 (67%)</td>
<td>0.34</td>
</tr>
<tr>
<td>Prognathic</td>
<td>Yes (1)</td>
<td>0 (0%)</td>
<td>2 (10%)</td>
<td>0.33</td>
</tr>
<tr>
<td>Overall facial symmetry</td>
<td>Abnormal (1)</td>
<td>22 (48%)</td>
<td>10 (48%)</td>
<td>0.67</td>
</tr>
<tr>
<td>Overall mean score* (0-9)</td>
<td></td>
<td>2.04</td>
<td>2.15</td>
<td>0.02</td>
</tr>
<tr>
<td>Nasal angle of peck</td>
<td></td>
<td>17.7</td>
<td>17.9</td>
<td>0.69</td>
</tr>
<tr>
<td>Maxillary angle of peck</td>
<td></td>
<td>14.1</td>
<td>14.5</td>
<td>0.86</td>
</tr>
<tr>
<td>Mandibular angle of peck</td>
<td></td>
<td>18.9</td>
<td>19.5</td>
<td>0.07</td>
</tr>
<tr>
<td>Did patient have FES surgery?†</td>
<td>Yes</td>
<td>23</td>
<td>6</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>23</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

*Abnormal ratings received a value of 1, and the overall score was calculated as the sum of the values for the 9 variables.

†Represents opinion of facial plastic expert regarding whether child had FES surgery.

FES, Functional endoscopic sinus.
Wolf et al\textsuperscript{10} reviewed 124 post–FES surgery children and concluded that no clinically significant disturbances in facial bone development were obvious. However, the mean age of these children at surgery was 12 years, and only 3 (4\%) children in the study were \(<5\) years old. Because the most rapid growth of the sinuses is between the ages of 1 and 4 years, the lack of facial growth disturbance that Wolf et al report might have been reflective of the older age of the study population.

Altered facial growth may occur as a result of disruption of the facial growth plates. Mair et al\textsuperscript{29} studied the impact of FES surgery on facial growth in newly weaned piglets. FES surgery was performed unilaterally and CT scanning was used to compare the surgical with the nonsurgical sides. The maxillary and ethmoid sinuses of the operated side reached only 57\% and 65\%, respectively, of the size of the same sinus on the nonoperated side.

Carpenter et al\textsuperscript{11} also noted alterations in the snout, midsnout, and maxilla after uncinectomy, middle meatus antrostomy and ethmoidectomy groups in a piglet model. These conclusions are not translated to children in this clinical outcome study.

There are several weaknesses and limitations of this study. Because the use of FES surgery was not random, it is possible that the 2 populations differed in one or more significant ways that affect facial growth. It is true that the children who underwent FES surgery tended to be younger and to have more severe CT scan results at presentation than did children who did not undergo FES surgery. Multivariable analytical techniques were used to control for these demographic and clinical differences (not shown). With these analytical adjustments, there still was no difference in facial growth between the 2 groups.

Radiographic cephalometric analysis was considered as an adjunct to anthropometric measurements. Given the accuracy and ease of attainment of direct soft tissue measurements and the risk of radiation exposure associated with cephalography and CT, we decided not to use these techniques.

It is possible that the facial plastic expert missed facial growth changes and that these changes may have been picked up by a second concurrent reviewer. We believe that this possibility is quite unlikely; we defined “significant facial growth disturbance” as disturbance so severe as to be noticeable to a nonprofessional observer. Disturbances of this degree would most certainly be obvious to a professional.

Results from children aged 1 through 4 years may not be properly extrapolated to other age populations. However, this age group was specifically selected because we believe that this group is most susceptible to any potential long-term growth deformity resulting from surgery.

Given the failure to find a difference between the 2 groups and the relatively small size of the no-FES-surgery population, it is possible that the study did not have sufficient power to detect a difference between the 2 groups. However, in the planning of the study, a power of 80\% was selected in sample size calculations; therefore, we believe that this study has adequate power to detect a difference. Furthermore, the narrow CIs around the observed differences suggest that the estimates are fairly stable and certain. It should also be noted that the observed differences did not even approach a consistent trend or clinically significant difference.

In conclusion, there is no evidence that facial growth alteration will be clinically significant 10 years after FES surgery. These results will aid physicians when discussing with parents the risks of FES surgery. With confirmation of these findings by other investigators, it will be appropriate to advise parents of young children with chronic rhinosinusitis that there is little risk of long-term facial growth deformity after FES surgery.

We wish to acknowledge Edward L. Spitznagel, Jr, PhD, professor of mathematics and biostatistics, Washington University, St Louis, MO, for his help in preparing and reviewing the manuscript. We also wish to thank Nancy Kollmar for assistance in statistical analysis, Amy Johnston for assistance with grant writing, Don Davis for photographic instruction, and Judy Stockstead for clinical coordination.

REFERENCES