Objective: To analyze the long-term effects of the Le Fort I osteotomy approach for the resection of juvenile nasopharyngeal angiofibroma (JNA) on maxillary growth and dental sensation.

Design: Prospective collection of structured data.

Setting: Tertiary care academic teaching hospital.

Patients: Between 1993 and 1998, 5 adolescents (aged 10-14 years) constituted the evaluable cohort among 14 patients who underwent Le Fort I osteotomy for JNA resection. Mean follow-up was 47.2 months.

Interventions: The Le Fort I osteotomy approach was used to resect JNA. Cephalometric x-ray films were taken at various postoperative intervals to assess maxillary growth. The results were matched against age-correlated predictions from Dentofacial Planner software.

Main Outcome Measures: Horizontal and vertical maxillary growth were each measured anteriorly and posteriorly by comparing interval postoperative cephalometric x-ray films. Dental sensation was longitudinally evaluated by performing interval pulp testing postoperatively.

Results: (1) Average vertical growth of the maxilla achieved 30% of predicted growth anteriorly ($P=.02$). (2) Average horizontal growth matched predicted growth in all patients. (3) All patients demonstrated long-term maxillary dental denervation.

Conclusions: Le Fort I osteotomy provides excellent surgical exposure for resection of JNA in the growing facial skeleton. Although it significantly affects vertical but not horizontal growth, its cosmetic effect is negligible. It also causes long-term dental denervation, which in most cases is undetected by patients.

PATIENTS AND METHODS

This study involved 5 boys aged 10 to 14 years constituting the evaluable cohort identified among 14 patients undergoing a Le Fort I osteotomy for the resection of juvenile nasopharyngeal angiofibroma (JNA) between 1993 and 1998 at Yale–New Haven Hospital, New Haven, Conn (Figure 1). Because the age period of greatest maxillary growth is from 8 to 16 years,6 we limited our study to patients in this age group, thus excluding 9 of 14 patients older than 16 years. The mean follow-up was 47.2 months. Preoperative embolization of the tumor feeding vessels was carried out in all patients. All operations were performed by 2 of us (C.T.S. and R.A.L.). The surgical technique involved sacrifice of the greater palatine arteries, application of rigid titanium fixation in all cases, and removal of impacted third molars. Maxillomandibular fixation was not applied postoperatively. All the patients had class I occlusion. One patient had preoperative and postoperative orthodontic therapy and another had postoperative orthodontic therapy.

CEPHALOMETRY

Each patient had a reference lateral cephalometric x-ray film taken in a Weimer head frame at 90 kilovolt peak (kVp)/0.1125 milliampere second (mAs) within 1 week after surgery. The film was then repeated at a future interval varying from 8 to 108 months postoperatively. Each cephalogram was digitized by one of us (M.K.). Each image contained 66 points of data that were entered into Dentofacial Planner software (Dentofacial Software Inc, Toronto, Ontario). This software constructs a growth estimate curve for the location of the maxilla based on the age of the patient at the time of surgery, immediate postoperative skeletal landmarks, and the interval period.

The cephalometric growth data were analyzed in the following fashion. An axis was created parallel to the Frankfort horizontal and perpendicular to the Frankfort horizontal (Figure 2). The Frankfort horizontal is the distance from the superior aspect of the external auditory meatus (porion) to the inferior aspect of the orbital rim (the orbitale). Horizontal growth of the maxilla in an anterior fashion was defined as a positive right change along the x-axis. Vertical growth was defined as positive down change along the y-axis. The points to define maxillary position were the anterior nasal spine (ANS) and the posterior nasal spine (PNS). The ANS was defined as the point at which the anterior process reached a thickness of 3 mm, while the PNS was defined as the posterior end point of the hard palate (Figure 2).

Thus, spatial movement as a function of time of ANS defined anterior growth, and spatial movement as a function of time of PNS defined posterior growth. We then compared the actual growth of the maxilla as a percentage of growth predicted by the Dentofacial Planner software. The average of the actual growth was compared with the average predicted growth and the results were analyzed for statistical significance using a paired \( t \) test.

PULP TESTING TECHNIQUE

In the first week after surgery, the entire maxillary and mandibular dentition were tested electrically for pulp sensation using a monopolar Digitest Pulp Vitality Tester (model D626D; Parkell Electronics Division, Farmingdale, NY). The measurement technique used a constant current of 130 \( \mu \)A, as described previously by Matthews and Searle.7 Because surrounding soft tissue moisture contamination can introduce inaccuracies in pulp test data, each tooth tested was isolated from the saliva with soft tissue retraction, cotton rolls, and air drying. Current was applied incrementally until the patient was able to identify a stimulus. This test was then longitudinally repeated at a postoperative interval varying from 8 to 108 months postoperatively.

The vertical growth of the anterior maxilla (along the y-axis) is presented in the ANS-Y column. For patient 2, ANS moved 0 mm (S-F measurement). The predicted movement of the ANS point (S-P measurement) was 2 mm. Thus, there was 0% of predicted anterior maxillary vertical growth at 16 months postoperatively. Similar results were obtained by analyzing the movement of the PNS point in the PNS-X and PNS-Y columns.

Table 1 also summarizes the average growth data for all patients. It appears that all patients grew 100% of the predicted growth along the horizontal axis, ie, ANS (X) and PNS (X) are shown as 100% of predicted. However, growth of the maxilla along the vertical axis was not as complete. The average vertical growth of our patients along the anterior maxilla (as described in the ANS-Y column) was 30% of the predicted growth. This result was found to be statistically significant compared with the average expected growth using a paired \( t \) test (\( P = .02 \)). For the posterior maxillary segment (PNS-Y), the average vertical growth was 27% of the predicted growth. This result was not found to be statistically significant (\( P = .06 \)). Interestingly, the reduction in vertical maxillary growth was largely subjectively unnoticed in our patient cohort.

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PULP TESTING

In all patients, there was no evidence of sensation as recorded by electrical stimulation to all the maxillary teeth at the postoperative interval period. However, pinprick sensation was intact in the adjacent palatal mucosa, and dental numbness went largely unnoticed. These results are summarized in Table 2.

COMMENT

Although there are numerous studies of the effects of plating in long bone growth, few specifically address the growth effect across maxillary suture lines. There are 2 studies on the effect of Le Fort I osteotomies on maxillary growth. However, both of these studies were made on patients undergoing surgical repositioning of the maxilla for correction of dentofacial deformities. A 1997 study showed normal maxillary growth in patients undergoing a Le Fort I osteotomy for excessive vertical maxillary growth. In addition, these patients underwent concomitant orthodontic therapy. The method of evaluation involved measurement of the presurgical and postsurgical spatial change in ANS and PNS in a lateral cephalogram. The surgical group was compared with unoperated-on matched controls from a data bank similar to that of the Dentofacial Planner software. The mean age of the patients was 14.5 years and the mean postsurgical follow-up was 25 months. In our study only 2 of the 5 patients underwent postsurgical orthodontics, and our mean follow-up was 47.2 months.

An earlier study that had examined the maxillary growth of subjects (aged 13-17 years) who had undergone surgical repositioning of the maxilla with interosseous wiring and intermaxillary fixation found that there was an increase of the vertical dimension of the maxilla after surgery. However, no comparison with a control group was made. Patients in our series differed from patients in previous studies in that rigid fixation plates across the horizontal osteotomy were used to stabilize the maxilla. Because JNA is located posterior to the maxilla, it is unlikely that the growth of the tumor played a role in disturbing maxillary growth centers. We believe the effect on vertical maxillary growth is therefore surgically related.

All of our patients exhibited denervation of the maxillary teeth in the long-term postoperative period. However, a study by Al-Din et al that looked at the sensory nerve disturbances that occur after Le Fort I osteotomy showed contrasting results. They reported that of patients who had a positive response to an electric pulp tester preoperatively, 78% regained sensitivity to pulp testing after 6 months. Other studies of sensation in teeth following Le Fort I osteotomy also indicate that there are no long-term sensory sequelae in the teeth after this procedure. A study by De Jongh and...
coworkers in 1986 compared electric pulp testing of 10 patients after Le Fort I osteotomy with 10 matched controls who did not have any surgery. He found that 14 months after surgery, 71% of the teeth tested were responsive to electric pulp stimulation. The figure in the control group was 93%. Other studies by Kahnberg and Engstrom and Tajima also demonstrated that most patients who underwent Le Fort I osteotomy recovered teeth sensation to pulp testing 6 to 18 months after surgery. In contrast, all the patients in our study showed long-term dental denervation following the Le Fort I osteotomy—explained in part by our necessity to section both anterior and posterior superior alveolar nerves.

In examining palatal sensation, Al-Din et al. found that the return of fine touch and pinprick sensation of the palate was affected by whether the greater palatine nerve was divided during surgery. That all of the patients in our study were able to regain pinprick sensation in the postoperative period confirms this explanation since palatine nerves were stretched by the down fracture but anatomically preserved.

**CONCLUSIONS**

Despite the important advantages of surgical exposure, the clear visibility of resection margins, and the avoidance of visible facial scars, the Le Fort I osteotomy approach comes with certain postoperative consequences. This study demonstrates that patients who undergo Le Fort I osteotomy for JNA resection have long-term dental denervation, although, for the most part, this was unnoticed by our patients. These results contrast to those of previous studies in patients undergoing Le Fort I osteotomy for skeletal repositioning (orthognathics).

We also confirm that Le Fort I osteotomy performed with metal rigid fixation is unlikely to have an impact on horizontal maxillary growth. However, we demonstrate that there is a statistically significant decrease of anterior vertical maxillary growth. As all of our patients developed a functional occlusion, this effect was not clinically significant, nor was the effect on vertical maxillary growth noticeable to the patients or their parents.

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### Table 1. Cephalometric Data

<table>
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<th>Patient No.</th>
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<td>S-F</td>
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<td>S-F</td>
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* ANS X indicates distance that the anterior nasal spine (ANS) grew in the horizontal direction; PNS X, distance that the posterior nasal spine (PNS) grew in the horizontal direction; ANS Y, distance that the ANS grew in the vertical direction; PNS Y, distance that the PNS grew in the vertical direction; S-F, distance (in millimeters) from the starting point (S) to the final growth point (F); S-P, distance (in millimeters) from the starting point (S) to the predicted growth point (P); and % PG, actual maxillary growth as a percentage of predicted growth.

### Table 2. Pulp Testing Data

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<th>Patient No.</th>
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