Cephalometric pharyngeal changes after Le Fort I osteotomy in patients with unilateral cleft lip and palate

Arja Heliövaara, Reijo Ranta, Jyri Hukki and Marja-Leena Haapanen

Cleft Center, Department of Plastic Surgery, Helsinki University Central Hospital, Helsinki, Finland

Heliövaara A, Ranta R, Hukki J, Haapanen ML. Cephalometric pharyngeal changes after Le Fort I osteotomy in patients with unilateral cleft lip and palate. Acta Odontol Scand 2002;60:141–145. Oslo. ISSN 0001-6357.

Pharyngeal changes after Le Fort I osteotomy were evaluated cephalometrically in 37 patients (27 M, 10 F; mean age 23.8 years) with unilateral cleft lip and palate (UCLP). Seven patients had previously undergone velopharyngeal (VPP) flap surgery to improve speech. One year postoperatively the patients without previous VPP showed a significant change (55%–85% of the surgical change) in the upper and lower sagittal depth of the nasopharyngeal airway, but not in the depth of oropharyngeal airway, length of soft palate, or position of hyoid bone. No significant changes were observed between 6 months and 1 year postoperatively. Mean surgical horizontal advancement was 4.7 mm and the mean vertical lengthening 4.7 mm anteriorly and 1 mm posteriorly. There was a correlation between the amount of horizontal advancement and the amount of change in the nasopharyngeal airway. The patients with previous VPP showed significant postoperative change (85% of the surgical change) only in the lower nasopharyngeal airway, although their surgical advancement was similar to that without previous VPP. Patients with previous VPP showed significantly smaller depths of upper nasopharyngeal airway postoperatively than the patients without previous VPP. Five patients (13%) needed VPP after the osteotomy. There was no difference in the nasopharyngeal airway in the patients with VPP after the osteotomy when compared to those without, but they seemed to have shortest maxillary lengths and largest mean surgical changes vertically both anteriorly (5.5 mm) and posteriorly (2.3 mm). Moderate maxillary advancement in UCLP patients results in significant changes in the nasopharyngeal airway. □ *Cephalometry; cleft lip and palate; osteotomy; pharynx*

Arja Heliövaara, Cleft Center, Department of Plastic Surgery, Helsinki University Central Hospital, P.O. Box 266, FI-00029 Hus, Finland. Tel: +358 9 471 87247, fax: +358 9 471 87654, e-mail: arja.heliovaara@mbnet.fi

Le Fort I osteotomy is commonly used in correction of maxillary deformities in cleft and non-cleft patients. Ross (1) has estimated that roughly 1/4 men with UCLP require orthognathic surgery to permit adequate functional occlusion. In addition to the improved occlusion, the treatment objectives include improved dentofacial aesthetics and self-esteem. The effects of maxillary advancement on speech and pharyngeal dimensions are contradictory, especially in cleft patients. Maxillary advancement may improve the quality of articulation in the labiodental area (2) as the occlusion is normalized, but VPP competence may be compromised. Maxillary advancement generally increases the anteroposterior dimensions of the nasopharynx, resulting in an increased distance for soft palate to move during VPP closure (3). Most patients have sufficient compensatory reserve to ensure normal VPP closure. The compensatory ability of a patient with cleft following maxillary advancement may be impaired as a result of scarring, a shortened hard and soft palate, relatively increased nasopharynx depth, improperly positioned musculature, muscular atrophy, and perhaps an already extended compensatory mechanism (4). However, it has been shown that the patients who had previously undergone VPP flap surgery showed improved VPP function postoperatively (5).

The purpose of this study was to evaluate, cephalometrically, pharyngeal changes after maxillary osteotomy in patients with unilateral cleft lip and palate without and with previous VPP flaps. An additional purpose was to evaluate pharyngeal dimensions of the patients who needed velopharyngeoplasty after the osteotomy.

Materials and methods

Patients, surgical technique and orthodontics

The series consisted of 37 (27 M, 10 F) Caucasian UCLP patients who had undergone a Le Fort I osteotomy at the Cleft Center, Department of Plastic Surgery, Helsinki University Central Hospital between 1987 and 1995. Mean age at the time of operation was 23.8 years (range 16.3–40.4). The initial consecutive series consisted of 60 cleft patients, but 23 patients were excluded because of bi-maxillary surgery, syndromes or combined clefts, or missing or poor quality X-rays.

The method of primary lip closure at the age of 3–6 months varied from modifications of Veau, Le Mesurier, and Skoog to Millard I and II. The method of palatal closure at the age of 1.5 to 2 years was either Veau-Wardill-Kilner or Cronin push-back. Secondary operations before Le Fort I osteotomy were done in the case of 36 patients. Bone-grafting of the alveolar cleft had been done in 33 patients at the age of 10–17 years. Other secondary procedures included rhinoplasty ($n = 32$), closure of fistula ($n = 28$; frequently in connection with bonegrafting), lip correction ($n = 24$), and velopharyngeoplasty ($n = 7$). The VPP was either Rosselli ($n = 5$) or modified Honig ($n = 2$).

The operations of this study were performed by 4 surgeons and 1 senior orthodontist. The osteotomies were grafted using bone from the iliac crest and fixed with titanium plates. Prefabricated interocclusal splints were used during the operation to determine the occlusion. Afterwards the splint was removed immediately. No postoperative intermaxillary fixation was applied. Patients were given orthodontic treatment before or after the osteotomy, or both. During postoperative orthodontics intermaxillary elastics were used individually for minor corrections of intercuspidation.

Cephalometric measurements

Standardized lateral cephalometric radiographs, taken with the head positioned according to the Frankfort horizontal plane with molar teeth occluded and lips in repose, were used. The radiographs were taken shortly before operation, immediately after operation, and at 6 months (mean 6.1 months, range 4.8–7.9), and 1 year (mean 1.1 year, range 0.9–1.4) postoperatively. When analysing the pharyngeal changes the preoperative and 6 months and 1 year postoperative X-rays were used to avoid the period of postoperative oedema and to ensure that soft tissue stability was established.

The cephalograms were traced twice by the same orthodontist during the same day using a computer-connected digitiser. The computer was programmed to calculate the mean of the two digitalizations, which were to be at an accuracy of 1 mm. The subsequent cephalometric tracings were superimposed on the structures of the anterior cranial base. The change in maxillary position was established by superimposing a template of the preoperative outline of the maxilla onto subsequent radiographs using anatomical best fit. To differentiate horizontal and vertical changes an x–y co-ordinate system was used. The x-axis was determined as a line through Nasion rotated 7° upwards from the Sella-Nasion line. The y-axis was determined as a vertical line perpendicular to the horizontal line through Sella. The reference points and landmarks are shown in Fig. 1. All measurements were corrected for cephalometric enlargement. Cephalometric points A and PM were used to calculate the mean anterior and posterior surgical change.

Student's *t* test and Pearson correlation analysis were used in the statistical analysis.

Speech analysis

VPP function during speech was assessed perceptually both pre- and postoperatively. The need of postosteotomy VPP flap was confirmed instrumentally by the Nasometer and in addition by aerodynamic measurements, nasoendoscopy, or videofluoroscopy, when felt necessary.

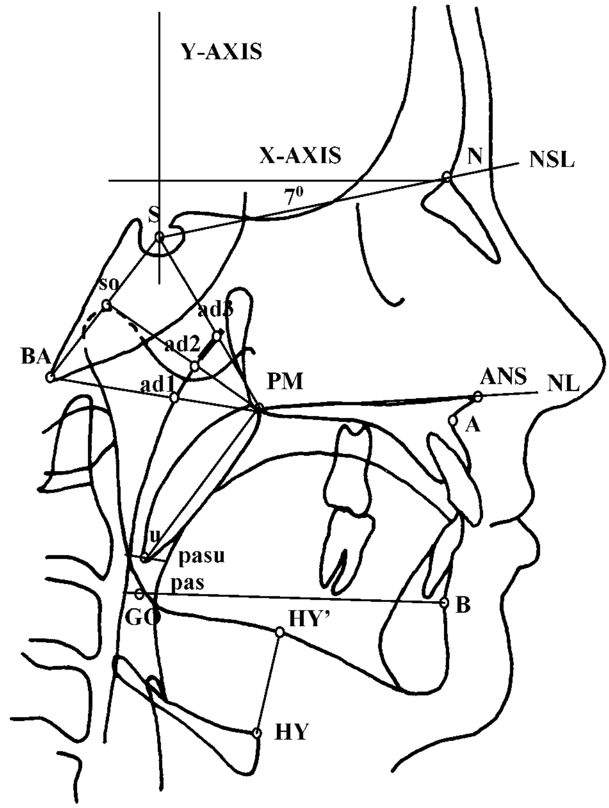

Fig. 1. Cephalometric landmarks. Abbreviated and full names and definitions. **A** (Point A): deepest point on the anterior contour of the maxillary alveolar arch. **ad1**: intersection of the line PM-BA and the posterior nasopharyngeal wall. **ad2**: intersection of the line PM-so and the posterior nasopharyngeal wall. **ad3**: intersection of the line PM-S and the posterior nasopharyngeal wall. **ANS** (anterior nasal spine): tip of anterior nasal spine. **B** (Point B): deepest point on the anterior contour of the mandibular alveolar arch. **BA** (Basion): most inferior point of the clivus of the occipital bone. **GO** (Gonion): intersection between the external contour of the mandible and the bisector of the angle between the ramus line and mandibular line. **HY** (Hyoid): most anterior and superior point of hyoid bone. **HY'** (projection point of Hy): perpendicular distance of point Hy on the mandibular line. **N** (Nasion): most anterior point on the nasofrontal suture. **NL** (Nasal line): line through points ANS and PM. **NSL** (Nasion-Sella line): line through points N and S. **pas** (posterior airway space at gonion level): sagittal depth of pharynx on the line through points B and Go. **pasu** (posterior airway space at uvula level): sagittal depth of pharynx on the line through points B and u. **PM** (Pterygomaxillare): intersection between nasal floor and the posterior contour of maxilla. **S** (Sella): centre of sella turcica. **so:** midpoint of the distance from points S to Ba. **u:** most inferior tip of soft palate. **X-axis**: horizontal line through N rotated 7° upwards from the Nasion-Sella line. **Y-axis**: vertical line perpendicular to the horizontal line through Sella.

Results

Patients without ($n = 30$) and with ($n = 7$) previous VPP

Table 1. Comparability of the groups without previous velopharyngeal flap (VPP−) and with previous velopharyngeal flap (VPP+). Mean horizontal and vertical surgical change (calculated from point A anteriorly and point PM posteriorly)

				Surgical change					
UCLP ($n = 37$)	No. of patients	Male	Female	Horizontal	Range (mm)	Vertical anterior	Range (mm)	Vertical posterior	Range (mm)
VPP−	30	22	8	4.7	0–8.9	4.7	−0.6–10.5	1	0.1–6.3
VPP+	7	5	2	4.6	2.6–7.8	3.8	1.4–5.7	0.7	−0.6–2.2

flaps were analysed separately. The comparability of the groups and the mean surgical changes (anterior and posterior) are given in Table 1. The mean surgical relapse 1 year postoperatively was 12.6% horizontally and 22% vertically; there were no significant differences between the patients with or without VPP. The posterior vertical lengthening of the maxilla was less than the anterior movement as the maxillas were rotated downwards. The effect of sex was significant for measurements ad1-BA and ad2-so, males having larger dimensions both pre- and postoperatively.

One year postoperatively the patients without previous VPP showed significant change (55%–85% of the surgical change) in the lower and upper sagittal depth of the nasopharyngeal airway (ad3-PM 55%, ad2-PM 83%, ad1-PM 85%). A correlation existed between the amount of horizontal advancement and the amount of change of the nasopharyngeal airway, ad1-PM ($P < 0.01$) and ad2-PM ($P < 0.05$). There were no significant changes in the depth of oropharyngeal airway (at the level of uvula or gonion), length of soft palate or position of hyoid bone (Table 2). No significant changes were observed between 6 months and 1 year postoperatively.

The patients (5 M, 2 F) with previous VPP before Le Fort I osteotomy showed significant postoperative change (85% of the surgical change) only in the lower nasopharyngeal airway (ad1-PM), although their surgical advancement was similar when compared to those without previous VPP (Tables 1 and 2). Postoperatively, the patients with previous VPP showed significantly smaller depths of upper nasopharyngeal airway (ad2-PM, ad3-PM) than the patients without previous VPP. No significant diffences existed in these dimensions preoperatively, although the patients with previous VPP had smaller values.

Five patients (13%, all male) needed VPP flap 1–2 years after the osteotomy. Before the osteotomy in 4 of these patients, a slight VPP insufficiency was found but in 1 patient the preoperative VPP function was competent. One of these patients had previosly undergone Roselli VPP flap surgery. Patients who needed VPP postoperatively had the smallest mean surgical advancements horizontally (3.3 mm) but largest mean surgical changes vertically both anteriorly (5.5 mm) and posteriorly (2.3 mm). There was no difference in the nasopharyngeal airway in the patients with VPP after the osteotomy compared to those without, but they seemed to have shortest maxillary lengths (47.4 mm vs 50.2 mm) although the difference was not statistically significant ($P = 0.136$, ns).

Discussion

The effects of maxillary osteotomy on facial attractiveness, occlusion and speech are of major importance for both the cleft patient and the cleft team. Le Fort I osteotomy caused a significant increase (55%–85% of the surgical change) in the nasopharyngeal airway in patients with unilateral cleft lip and palate. The patients without previous VPP showed significant change in the lower and upper sagittal depth of the nasopharyngeal airway, whereas the patients with previous VPP showed significant postoperative change only in the lower nasopharyngeal airway. A pre-existing VPP flap seems to restrict the forward movement of the soft tissue in the upper posterior nasopharyngeal wall. The similarity of the pre- and postoperative maxillo-mandibular relationship and the equal amount of surgical advancement and relapse adds validity to the comparison. The similarity of the preoperative dimensions is in agreement with previous studies (6, 7) that failed to substantiate a significant long-term effect of pharyngeal flaps on facial growth.

It has been reported that a pre-existing pharyngeal flap may cause decreased ability to mobilize and stabilize the advanced maxilla (4). Flaps that are tight and poorly vascularized may prevent achievement of the desired amount of advancement (3). Superiorly based pharyngeal flaps should interfere less with maxillary advancement than inferiorly based flaps, because the inferior flap hangs in a more vertical direction and tends to restrict palatal movement (3). The presence of a VPP flap at the time of maxillary osteotomy has also been shown to increase postoperative relapse (8, 9) but not in all studies (10).

It is of interest that in the present study no significant changes were observed in the depth of oropharyngeal airway (at the level of uvula or gonion), length of soft palate, or position of hyoid bone. Schendel et al. (11) have found that in patients with clefts the soft palate lengthened by 0.4 mm per mm of the maxillary advancement. In patients without clefts the soft palate lengthening was 0.5 mm per mm of the maxillary advancment. They also

Table 2. Cephalometric surgical change and significance in patients without previous velopharyngeal flap (VPP−) and with previous velopharyngeal flap (VPP+). T1 = immediate preoperative, T4 = 1 year postoperative

UCLP	VPP− (n = 30)					VPP+ (n = 7)					VPP−/VPP+	
(n = 37)	T1 mean	SD	T4 Mean	SD	T1/T4 *P*-value	T1 Mean	SD	T4 Mean	SD	T1/T4 *P*-value	T1/T1 *P*-value	T4/T4 *P*-value
S-N-A	74.9	3.7	78.4	3.5	0.000***	74.2	4.6	78.1	4.6	0.153	0.725	0.864
S-N-B	79.3	4.5	77.7	4	0.16	78.2	4.8	77.3	4	0.724	0.566	0.809
SN/NL	7.4	4.8	11.1	5.8	0.811	8.8	5.5	12.2	6	0.296	0.472	0.454
PM-BA	40.8	4.8	44	3.7	0.002**	38.5	2.5	42	2.4	0.019*	0.234	0.121
ad1-PM	20.1	4.4	24.1	4.1	0.000***	19.1	2.2	23.1	3.1	0.017*	0.576	0.566
ad1-BA	20.7	2.8	20.3	3.2	0.601	19.4	3.2	19	3.7	0.822	0.28	0.338
ad2-PM	19.2	4.4	23.1	3.8	0.000***	16.5	3.8	19.8	4.2	0.156	0.149	0.047*
ad2-so	17.2	3.4	16.6	3.3	0.554	16.7	3.9	16.4	2.3	0.841	0.784	0.859
ad3-PM	17.6	3.6	20.1	2.8	0.01**	15.3	4.7	15.1	5.4	0.952	0.11	0.001***
PM-u	32.5	4	33.4	5.3	0.357	32.1	6.5	34.4	5.6	0.518	0.92	0.681
pasu	14.2	4.3	14.3	3.7	0.88	14.4	3.9	15	5.3	0.839	0.893	0.717
pas	11.9	5.4	11.6	3.8	0.774	11.9	2.6	11.4	4.4	0.777	0.99	0.634
HY-HY′	18.7	5.4	17.4	6	0.323	21	4.2	21.3	6.1	0.917	0.333	0.128

noticed that the angle of the soft palate and hard palate increased 2 degrees per millimeter of advancement in cleft patients and 1 degree in non-cleft patients. After maxillary distraction in cleft patients an increase in nasopharyngeal depth by 1:1 ratio with bony movement has been reported; the length of soft palate remained unchanged but the velar angle increased (12). Cephalometrics is widely used in diagnosis, treatment planning, and treatment evaluation in orthodontics and orthognathic surgery. However, lateral cephalograms give a static two-dimensional representation of the structural pharyngeal changes after maxillary osteotomy. The difficulties in comparing serial radiographs, and method error should also be considered, especially when the sample size is small.

It is of clinical importance that no significant changes in the pharyngeal dimensions were observed between 6 months and 1 year postoperatively. If hypernasality occurs after midface advancement, a posterior pharyngeal flap should be delayed at least 6 months, and preferably 1 year (13). The VPP mechanism is capable of adaptation, and at least 6 months should be allowed for this process to occur (13). Kummer et al. (14) found evidence for compensatory changes in the VPP function after maxillary advancement. On the postoperative videofluoroscopic speech studies, velar stretching and lengthening and increased lateral pharyngeal wall movement was noticed.

The reported incidence of VPP incompetence in cleft patients after maxillary osteotomy varies from 0% to 84% (2, 5, 11, 14–21). Comparison of the studies is difficult because of the differences in subjects and methods. However, the incidence of VP incompetence following Le Fort I osteotomy seems to correlate with preoperative VP function and with the amount of advancement (22). The consensus is that if the patient has preoperative VP competency, the sphincter will be competent postoperatively; if there is VP dysfunction preoperatively, it will persist postoperatively (22). The patients of concern are those with marginal preoperative VP function (22). According to Epker & Wolford (16), patients with borderline VP closure may demonstrate VP insufficiency following maxillary advancement particularly if the advancement exceeds 10 mm. There is an increased risk of a deterioration in VP effectiveness with more than 10 mm of advancement (15). In the present series, the amount of advancement was moderate, and the changes in the nasopharyngeal airway correlated with the amount of surgical horizontal advancement. None of the patients had horizontal advancements greater than 9 mm. Vertically, two patients had more than 10 mm lengthening anteriorly. Posteriorly, the vertical changes were smaller as the maxillas were rotated downwards. Furthermore, the advancement of maxilla is often multidimensional. In addition to horizontal advancement and vertical lengthening there is often transverse and vertical rotation, which are difficult to measure.

In the present study, 5 patients (13%) needed VPP flap after the osteotomy. A mild preoperative VPP insufficiency became worse in 4 patients and a VPP was required.

However, 1 patient developed VPP insufficiency despite preoperative VPP competence. There was no difference in the nasopharyngeal airway after the osteotomy in the patients with VPP after the osteotomy compared to those without, but they seemed to have shortest maxillary lengths and largest surgical changes vertically, although the difference was not statistically significant. Because of the small number of patients, caution is needed when interpreting the results and more studies are needed. Wu et al. (23) have observed that the cleft patients with borderline VPP competency differed from cleft patients with VPP incompetency in smaller pharyngeal depth and greater length of the hard palate.

In this study, maxillary Le Fort I osteotomy in UCLP patients caused significant cephalometric changes in the nasopharyngeal skeletal and soft tissue architecture. No adverse effect of a pre-existing VPP flap was observed. The pharyngeal cephalometric changes were not clearly related to the need of postoperative VPP when the advancement was moderate.

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Received for publication 7 Sepember 2001
Accepted 7 January 2002