Stability of maxillary advancement using rigid fixation and porous-block hydroxyapatite grafting: Cleft palate versus non-cleft patients

This study was undertaken to evaluate the stability of maxillary advancement using bone plates for skeletal stabilization and porous block hydroxyapatite (PBHA) as a bone graft substitute for interpositional grafting in cleft and non-cleft patients. The records of 74 patients (41 females, 33 males) who underwent Le Fort I maxillary advancement using rigid fixation and PBHA interpositional grafting were evaluated retrospectively. All patients also underwent simultaneous sagittal split mandibular ramus osteotomies. Patients were divided into 2 groups for study purposes: group 1 consisted of 17 cleft palate patients and group 2 consisted of 57 non-cleft patients. Each group was further subdivided into 2 subgroups based on the concurrent vertical positioning of the maxillary incisors: groups 1a and 2a, where the maxilla underwent 3 mm or more of inferior repositioning, and groups 1b and 2b, where the maxilla underwent minimal vertical change (≤1 mm). Presurgery, immediate postsurgery, and longest follow-up lateral cephalometric tracings were superimposed and analyzed to calculate surgical change and long-term stability of results by assessing horizontal and vertical changes at point A, incisor superius, and the mesial cusp tip of maxillary first molar. The average follow-up time in group 1 was 37.9 months (range 12 to 136) and in group 2 was 28.77 months (range 17 to 88). Average maxillary advancement at point A was: group 1a, 5.4 mm; group 1b, 5.25 mm; group 2a, 5.48 mm; group 2b, 5.46 mm. Average relapse at point A was: group 1a, –0.75 mm; group 1b, –1 mm; group 2a, –0.47 mm; group 2b, –0.48 mm. Average horizontal and/or vertical relapse at the central incisors and first molars was 1 mm or less in group 1 and less than 0.5 mm in group 2. Although there was a slightly greater relapse in group 1, no statistically significant difference was observed between the groups. Maxillary advancement with Le Fort 1 osteotomies using rigid fixation and interpositional PBHA grafting during bimaxillary surgery is a stable procedure with good predictability in cleft and non-cleft patients, regardless of the direction of vertical maxillary movement. (Int J Adult Orthod Orthognath Surg 2001;16:193–199)
Although historically, various fixation techniques have been used for maxillary stabilization (transosseous and suspension wires,8 threaded Steinmann pins,12 and intraoral skeletal fixation appliances13), the most popular contemporary method of fixation utilizes bone plates and screws for stabilizing the osteotomized segments.14–16 Different grafting materials have been used to fill continuity defects, including autogenous rib, cranial bone, and iliac crest bone grafts17; freeze-dried bone18; proplast blocks19; solid-block hydroxyapatite grafts20; and porous-block hydroxyapatite grafts (PBHA).3

Questions remain regarding the most predictable method for fixation, as most studies have been plagued by variable factors such as type and amount of maxillary movement, multiple surgeons involved, small sample size, length of time for follow-up, and different methods of fixation employed within the study sample. The aim of this retrospective study was to assess our experience with the stability of the Le Fort I maxillary advancement using rigid fixation for skeletal stabilization and porous-block hydroxyapatite (Interpore 200, Interpore International) as a bone graft substitute (Fig 1a) in cleft palate and non-cleft patients undergoing bimaxillary surgery.

Patients and methods

A retrospective analysis was performed on the records of 74 patients (41 females and 33 males) with a presurgical diagnosis of anteroposterior (A-P) maxillary hypoplasia. Average age of the patient sample was 28.4 years (range 15 to 62 years). All patients were operated by one surgeon and underwent multiple-segment Le Fort I osteotomies using the maxillary step osteotomy modification in combination with bilateral mandibular ramus sagittal split osteotomies.

Criteria for inclusion in the study included: (1) bimaxillary surgery with multiple segmental Le Fort I osteotomy for maxillary advancement, (2) minimum of 12 months postsurgery follow-up, (3) rigid internal fixation using 4 bone plates (2.0-mm-diameter screws), and (4) use of PBHA interpositional grafts (Fig 1b) along the lateral maxillary walls and at the maxillary step areas between the advanced maxilla and stable bones (Figs 2 and 3). The PBHA grafts were first shaped from larger blocks (15×50×6 mm) using a #701 tapered fissure bur (Fig 1b) and a #15 scalpel blade and were then wedged into position without direct fixation with screws or wires.

For study purposes, the 74 patients were divided into 2 groups: group 1 (17 cleft palate patients) and group 2 (57 non-cleft patients). Each group was further subdivided into 2 subgroups based on the concurrent vertical positioning of the maxillary incisors: groups 1a (10 patients) and 2a (27 patients), where the maxilla was advanced horizontally and repositioned inferiorly (3 mm or greater inferior...
repositioning), and groups 1b (7 patients) and 2b (30 patients), where the maxilla was advanced horizontally with minimal change in vertical position (1 mm or less change in vertical position). Standardized lateral cephalometric radiographs taken before surgery (T1), immediately post-surgery (T2), and at the longest follow-up (T3) were traced by an independent examiner who was not involved in any of the surgeries. The tracings were superimposed and assessed under magnification (6×) to calculate surgical change (T2 – T1) and long-term stability of results (T3 – T2) at the following landmarks: point A (A), incisor superius (Is), and mesial cusp tip of the maxillary first molar (molar superius [Ms]). Postsurgical relapse was measured in a horizontal (A-P) and vertical direction using the same dental landmarks and in an A-P direction for the skeletal landmark (A). The 6× magnification was used to improve the accuracy of assessment, since many of the measurements were small in magnitude; the numeric values determined at magnification were then divided by a factor of 6 to determine the actual changes. The Student t test was used to determine the statistical significance of the data obtained, and a P value of less than .05 was considered to be statistically significant.

**Results**

The average follow-up time in group 1 was 37.9 months (range 12 to 136 months) and in group 2 was 28.7 months (range 17 to 88 months).

**Anteroposterior skeletal stability (Table 1)**

The average A-P maxillary advancements measured at A for the 4 subgroups were: group 1a, 5.4 mm (range 5 to 9 mm); group 1b, 5.25 mm (range 5 to 8 mm); group 2a, 5.48 mm (range 5 to 9 mm); group 2b, 5.46 mm (range 5 to 10 mm). The average A-P relapse as measured at A was 1 mm or less in group 1 and less than 0.5

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**Table 1**

<table>
<thead>
<tr>
<th>Group</th>
<th>Surgical advancement</th>
<th>Relapse</th>
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<tbody>
<tr>
<td>1a (n = 10)</td>
<td>5.40 (5 to 9)</td>
<td>–0.75 (0 to –2)</td>
</tr>
<tr>
<td>1b (n = 7)</td>
<td>5.25 (5 to 8)</td>
<td>–1.00 (0 to –2)</td>
</tr>
<tr>
<td>2a (n = 27)</td>
<td>5.48 (5 to 9)</td>
<td>–0.47 (0 to –2)</td>
</tr>
<tr>
<td>2b (n = 30)</td>
<td>5.46 (5 to 10)</td>
<td>–0.48 (0 to –2)</td>
</tr>
</tbody>
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**Fig 2** (left) Maxillary advancement using the maxillary step osteotomy technique with rigid fixation with bone plates. The osteotomy areas (a, b, c) are filled with PBHA interpositional grafts.

**Fig 3** (below) Intraoperative photograph showing placement of PBHA interpositional grafts in the left maxillary osteotomy areas after advancement.
mm in group 2. Although the cleft group had slightly greater relapse, the difference in stability between the 2 groups was not statistically significant ($P > .05$).

**Anteroposterior dental stability (Table 2)**

The average A-P advancements measured at the dental landmarks for the 4 subgroups were: group 1a, 4.7 mm (range 3.5 to 5 mm) at the incisors and 4.9 mm (range 3.5 to 5 mm) at the molars; group 1b, 5.1 mm (range 3.5 to 5.5 mm) at the incisors and 5.5 mm (range 3.5 to 6 mm) at the molars; group 2a, 6.57 mm (range 5 to 10 mm) at the incisors and 6.9 mm (range 5 to 11 mm) at the molars; and group 2b, 6.73 mm (range 5 to 11 mm) at the incisors and 6.7 mm (range 5 to 12 mm) at the molars. The average A-P relapse at the incisors or molars was 1 mm or less in group 1 and less than 0.5 mm in group 2. There were no statistically significant differences between the groups ($P > .05$).

**Vertical dental stability (Table 3)**

The average vertical surgical change for the 4 subgroups (positive numbers indicate inferior repositioning and negative numbers indicate superior repositioning) were as follows: group 1a, 3.76 mm (range 3 to 5 mm) at the incisors and 3.1 mm (range 3 to 3.5 mm) at the molars; group 1b, 0.75 mm (range 0 to 1 mm) at the incisors and 0.75 mm (range 0 to 1 mm) at the molars; group 2a, 4.06 mm (range 3 to 7 mm) at the incisors and 3.92 mm (range 3 to 10.5 mm) at the molars; group 2b, –0.18 mm (range –1 to 1 mm) at the incisors and 0.6 mm (range 0 to 1 mm) at the molars. The average postsurgical vertical relapse was 0.8 mm or less in group 1 and 0.35 mm or less in group 2. There were no statistically significant long-term differences between the groups ($P > .05$).
Discussion

The Le Fort I osteotomy of the maxilla is the most commonly performed surgical procedure for correction of maxillary and midfacial deformities. Stability of the Le Fort I osteotomy is considered essential for a stable and predictable postsurgical result. The etiology of relapse after Le Fort I maxillary advancement is considered to be multifactorial, and conditions such as soft tissue mobilization, approximation of osteotomized bony walls, bone quality, dental occlusion/orthodontics, masticatory and respiratory function, use of interpositional grafts, presence of clefts, previous surgical procedures, and type of fixation are considered to be important.1–8 It is generally agreed that superior repositioning of the maxilla with the Le Fort I osteotomy is stable, provided bone contact and stabilization are adequate.21 However, contrasting results have been reported with inferior repositioning, superior repositioning when bone contact is poor or thin, and with advancement of the maxilla.21 Stability of the maxilla after bimaxillary surgery has been reported to be equivalent to that seen following single-jaw (maxilla-only) surgery.1,22

Although both non-rigid fixation (wire fixation) and rigid internal fixation (bone plates and screws) can be used for stabilization of the Le Fort I osteotomy, the latter technique is currently more popular. Use of rigid internal fixation eliminates the need for maxillomandibular fixation, thereby leading to increased patient comfort, improved oral hygiene, improved dietary considerations, faster healing, and increased stability of postsurgical results. Satrom et al23 and Mogavoro et al24 demonstrated significantly better stability using bone plate stabilization as compared to wire fixation in bimaxillary surgery. All patients in our study had rigid internal fixation with 4 bone plates (one plate each at the lateral pyriform rim and zygomatic buttress bilaterally) stabilized with screws 2.0 mm in diameter and 5.0 mm in length. For each bone plate, 2 screws were placed above and at least 2 screws were placed below the osteotomy level.

The need for interpositional grafting in maxillary osteotomies has also been a subject of debate, with studies reporting contrasting results.20,25 Interpositional grafting may be indicated in maxillary orthognathic surgery where bony continuity defects exist for several reasons:26; to provide bony continuity, to improve bone healing, to decrease postsurgical relapse, and to provide surgical stability in traditionally unfavorable orthognathic movements. Various materials have been utilized for interpositional grafting, including autogenous bone, freeze-dried bone, silastic, proplast, solid-block HA, and PBHA.3,17–20,26,27 Although autogenous bone grafts are the most popular material used for interpositional grafting in maxillary surgery, they have significant disadvantages, including the requirement for a second surgical site with associated harvest morbidity, difficulty in shaping the grafts, and the physiologic process of remodeling and resorption that occurs during healing, which could result in unpredictable relapse. Freeze-dried bone undergoes even greater resorption and remodeling, takes longer to heal, and has the problems associated with being a homograft. Solid-block HA does not allow bone ingrowth, is very difficult to shape, and does not get intimately incorporated into the host bony matrix.

Coralline PBHA (Fig 1) is approved by the United States Food and Drug Administration specifically for use in orthognathic surgery and is a very attractive alternative for use as an interpositional grafting material in cases where grafting is indicated. It is porous and osteoconductive, allowing for intimate bony ingrowth through it. The pore size is similar to normal osteon size in bone (190 µm). Advantages of the use of PBHA as an alloplastic implant material include: (1) no donor site morbidity, (2) no resorption, (3) no known hypersensitivity or immune response, (4) ease of manipulation, (5) no constraints on working time, (6) shorter overall surgical time compared with bone grafting, (7) shorter recovery time, and (8) unlimited volume availability. Wolford et al27 introduced the use of PBHA as a bone graft substitute in orthognathic surgery in 1987 and reported a high success rate in 92 consecutive patients. In a subsequent study, Wardrop and Wolford reported 1 mm or less of horizontal relapse in 14 patients after...
maxillary advancement using rigid fixation and PBHA grafting, and recommended that grafting be used in cases where the advancement is 5 mm or greater in magnitude. The successful use of PBHA grafting for maxillary downgrafting and advancement has been demonstrated. Cottrell and Wolford presented 5- to 10-year follow-up data on 110 patients with 403 PBHA implants placed in the maxilla and found that lateral maxillary wall grafting had a 95.7% long-term success rate. Holmes et al conducted a histologic analysis of 17 human biopsy specimens of PBHA implants used in orthognathic surgery and showed an average composition of 48.5% hydroxyapatite matrix, 18% bone, and 33.5% soft tissue/vascular space in healed PBHA grafts. They also showed that bone growth through the PBHA graft was essentially complete at 4 months postsurgery, and subsequent changes involved maturation of the ingrown bone. Ayers et al demonstrated that the human body establishes a near balance between the PBHA graft and surrounding maxillary bone relative to long-term bone ingrowth and microhardness of grafts placed during maxillary orthognathic surgery.

Rigid fixation of the maxilla is critical for success when using PBHA, as it provides for stress-shielding of the graft material and minimizes micromovement during the initial healing phase. An important factor is that PBHA is brittle to handle, and like any new technique, there is a learning curve for the clinician when first using it. Once the practitioner is experienced, it should take him or her only 10 to 15 minutes to appropriately contour and place the HA grafts in position.

Although our study has the disadvantage of being retrospective in nature and lacking a control group (non-grafted group), it shows that rigid fixation with PBHA grafting is a very effective way to minimize postsurgical relapse following maxillary advancements in bimaxillary surgery for cleft palate and non-cleft patients. Interpositional grafting was used on all patients included in this study because of 1 or more of the following factors that predispose to greater relapse: presence of clefts (group 1), more than 5 mm of advancement (groups 1 and 2), and inferior repositioning of the maxilla (groups 1a and 2a). Cleft palate patients are known to relapse more (up to 68%) than non-cleft patients after surgical correction of maxillary hypoplasia, and some authors advocate significant overcorrection to compensate for this relapse tendency. In our study also, as expected, a greater skeletal relapse tendency was seen in the cleft group (approximately 25% of the A-P advancement) as compared to the non-cleft group (approximately 10% of the A-P advancement). The molars were generally seen to advance a greater amount than the incisors because of surgical maxillary expansion, which moves the molars forward relative to the incisors. It is possible that some of the dental changes reported may be a result of postsurgical dental/orthodontic changes. All patients had segmental maxillary surgery, and the maxillary and mandibular teeth were placed into the best occlusion possible at the time of surgery, thereby avoiding final occlusal coverage splints (some patients had palatal splints but without any occlusal coverage). No maxillomandibular fixation was used postsurgery, but light-force interarch elastics were usually applied to help control the occlusal relationships.

This is the first reported study that has compared cleft and non-cleft patients for long-term stability of Le Fort I maxillary advancement (with the use of rigid fixation and PBHA grafting) during bimaxillary surgery. The use of rigid internal fixation and interpositional PBHA grafting provides for stable and predictable postsurgical outcomes after maxillary advancement in both cleft and non-cleft patients.

References


