Rehabilitation of the severely atrophied maxilla by horseshoe Le Fort I osteotomy (HLFO)

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Objective. The purpose of this study was to determine the long-term outcome of the horseshoe Le Fort I osteotomy (HLFO) as a preprosthetic operation technique for implant insertion in the extremely atrophied maxilla.

Study design. 36 patients (8 male, 28 female, average age 57.6 years) underwent HLFO combined with iliac crest bone grafting. They were divided into 2 groups: group A with 12 patients who simultaneously received 100 implants; group B with 24 patients where 176 implants were inserted in 18 patients in a second-stage procedure. Clinical and radiographic outcome with regard to implant osseointegration, alveolar bone height in the canine and molar regions, peri-implant bone loss and satisfaction of patients (esthetics, masticatory function, overall treatment) were investigated in all cases.

Results. The overall 2-year failure-free fraction of implants was 95.5%; the 5-year failure-free fraction was 89.3%. In the 1-step group the 2-year and 5-year failure-free fractions were 95.9% and 86.9%, respectively, in the 2-step group 95.0% and 91.3% (log rank test \( P = .57 \)). A total of 27 implants were lost during the entire follow-up: 14 in 6 patients of the 1-stage and 13 in 9 patients of the 2-stage group. The mean loss of alveolar bone after augmentation in the canine and molar regions was almost equal in both groups (overall means for the 2 regions 3.67 \( \pm \) 2.77 and 4.42 \( \pm \) 2.72 mm, respectively). The relationship between the jaws and thereby the esthetic profile could be improved in all cases. All patients were satisfied with the dental rehabilitation and the achieved new esthetic appearance.

Conclusions. HLFO combined with iliac bone grafting is a feasible preprosthetic technique prior to implant insertion in cases of severe atrophy of the maxillary alveolar ridge, leading to satisfying implant survival and rehabilitation of function.

moved down and anterior after osteotomy. The hard palate remains pedicled on the nasal septum and vomer (Fig 1).

In 1984 Obwegeser and Farmand\textsuperscript{22} and in 1986 Farmand\textsuperscript{23} reported on the first results of a modified horseshoe osteotomy, a combination with a submucous vestibuloplasty. In 1989 Neukam et al\textsuperscript{24} and Sailer\textsuperscript{12} stabilized and fixed the interpositional bone graft in a 1-stage procedure with screw-type implants. Ewers et al\textsuperscript{25} and Watzinger et al\textsuperscript{26} were first to present the horseshoe Le Fort I osteotomy in combination with endosseous implants. Gössweiner et al\textsuperscript{27} reported on the same patient group in 1999.

This study investigates the long-term outcome of the horseshoe Le Fort I osteotomy, implant survival in 1- and 2-step surgery, alveolar bone height in the canine and
molar region, peri-implant bone loss, and satisfaction of patients.

PATIENTS AND METHODS

Patients

From 1990 to 2001, the horseshoe Le Fort I osteotomy with iliac crest bone grafting was performed in 36 patients (28 female, 8 male) with severe atrophy of the maxillary alveolar process (Cawood and Howell Class VI²⁰), a flat palate, and a reversed intermaxillary relationship (Figs 2-5). The average age was 57.6 ± 10 years (range 43 to 78 years). A total of 276 implants were placed in 30 patients. One hundred implants were placed simultaneously with the HLFO in 12 patients (group A). One hundred seventy-six implants were placed 6-12 months after HLFO in 18 patients (group B). Six patients of group B underwent HLFO but were not rehabilitated with implants until the end of this study.

Planning of treatment

After physical examination, analysis of the oral status, remaining dentition, relationship between the jaws, and the facial esthetics were assessed for presurgical treatment planning. Using radiographic imaging, dental study casts, and a model surgery, the essential anterior and downward movement of the maxilla was determined according to the facial esthetic improvement, the estimated position of the implants, the intermaxillar relationship, and the expected occlusal plane.

Operation technique

Corticocancellous bone graft harvested from the iliac crest was used for sandwich interposition. The graft was taken simultaneously with the horseshoe osteotomy. The bone was harvested by use of a medial approach to the anterior iliac crest.

Circumvestibular and median palatal incisions provided the surgical access to the maxilla. The palatal roof was exposed by raising bilateral mucoperiosteal flaps up to the palatine arteries. Then the palatal roof was osteotomized medial of the palatine arteries. Conventional Le Fort I osteotomy was carried out but modified with a prior sinus floor elevation to keep the sinus membrane intact. The horseshoe-shaped alveolar process could then be carefully downfractured. The hard palate remained pedicled to the nasal septum, vomer, and nasal...
mucosa. The desired inferior and anterior position of the alveolar crest was determined by analyzing the cephalometric radiographs and models. The harvested iliac crest bone, shaped and placed into the recess of the maxillary sinuses after sinus floor elevation, bridged the maxilla and the mobilized alveolar crest. The remaining space was filled with a mixture of cancellous bone and Algipore®, a hydroxyapatite bone substitute. Then the alveolar ridge was fixed with micro- and miniplates.

In 30 patients, 6 to 10 implants (IMZ®-TCS, IMZ®-TwinPlus, Frialit®-2 (Friadent GmbH, Mannheim, Germany); Camlog® (Altatec, Wurmberg, Germany)) were either placed simultaneously or after a healing period in the augmented maxilla. All patients were rehabilitated with implant-borne bars and removable overdentures.

Clinical and radiographic assessment

Postoperative follow-up intervals were every 3 months during the first year and then annually for clinical and radiological investigations. Postoperative recall data relating to wound dehiscence, bone sequestration, inflammation, pain, sinusitis, fracture, loosening, and loss of implants were recorded. The nasal respiration was also examined and Waters radiographs were taken if patients complained about rhinorrhea, nasal obstruction, or pain. Once a year the implant-borne bar was removed to evaluate the peri-implant tissue condition and the stability of the implants. Dental rehabilitation was evaluated for implant osseointegration, retention of overdenture, occlusion, and speech function. Masticatory and esthetic results together with the overall treatment satisfaction were evaluated by means of a visual analog scale (VAS) graded 1-5 (1 = excellent; 2 = good; 3 = moderate; 4 = poor; 5 = very poor).

Dental computer tomography scans and radiographic examinations, including orthopantomograms and periapical films taken with a standard film holder and a paralleling technique were performed to assess the height and resorptive changes of the maxillary alveolar bone. The height of the maxillary alveolar bone at the site of the canine and first molar on both sides of the maxilla
was measured on the images preoperatively, immediately after HLFO, and at the last recall. The results were statistically analyzed. Peri-implant bone loss was measured from these radiographs taking into account the geometric distortion and the known length of the implants. The measured marginal bone level mesial and distal to the implants was assessed according to a 4-point scale (0-3) as described by Raghoebar et al: 0 = no bone loss detectable; 1 = reduction of bone level not exceeding one-third of implant length; 2 = reduction of bone level exceeding one-third but not one-half of implant length; and 3 = reduction of bone level exceeding one-half of implant length.

Statistical methods

All continuous variables were reported as means (standard deviation). We first computed the means per patient over all implants and then the mean over the patients to avoid bias through a few patients with many implants. For statistical evaluation SAS/STAT, Version 8, 1999 (SAS Institute Inc, Cary, NC) was used.

To assess the differences between the groups with simultaneous versus nonsimultaneous horseshoe Le Fort I osteotomy, we performed a survival analysis (SAS procedure lifetest) and a log rank test. As failure times of multiple implants per patient appeared heavily correlated, we chose as endpoints besides the failure time of each implant (per implant analysis) also the time until the first failure for each patient (per patient analysis). For both endpoints, product-limit estimates with standard deviations for 2-year and 5-year failure-free fractions were computed (SAS procedure lifetest). The overall time to the first failure of an implant was assessed with a Kaplan-Meier estimate. The 2-year and 5-year failure-free fractions with respective standard errors were computed with the SAS procedure lifetest.

RESULTS

Clinical results

No serious complications occurred during the operations or the whole follow-up period. Wound dehiscences and inflammation could be handled easily by adequate local or systemic therapy. In 8 patients secondary surgery was performed for removal of hyperplastic tissue around several implants. In 3 patients, local soft tissue breakdown resulted in partial loss of bone graft particles. This could be treated by closure of the wound by secondary sutures or transposition of a buccal fat pad. In cases of local inflammation or dehiscence of peri-implant tissue, treatment of choice was photosensitization with a diode soft laser and toluidine blue solution in combination with antibiotic therapy. Further healing of mucosa was uneventful afterwards.

Symptoms of transient sinusitis were observed in 2 patients after implant insertion, which resolved after antibiotic therapy. In 1 female patient, symptoms of chronic maxillary sinusitis occurred and could be diagnosed clinically and in Waters radiographs 6 years after Le Fort I osteotomy with simultaneous implant insertion. The sinusitis healed uneventfully after nasal antro-rhinostomy. In all patients, harvesting of the corticocancellous bone from the iliac crest was without any postoperative complications. Pain and hip-related discomfort were observed in almost all patients but were modest and transient within 3 to 6 weeks postoperatively. No dehiscences or inflammation were observed.

In 30 patients a total of 276 implants were placed. One hundred implants were installed simultaneously with the horseshoe Le Fort I osteotomy in 12 patients (group A), and 176 implants were placed 6-12 months after HLFO in a second procedure after osteotomy in 18 patients (group B) (Table I). Six patients of group B had no implant insertion at the time of the last recall. Implant exposure was carried out 6 to 9 months after implant
Table I. Implant statistics

<table>
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<th>Step</th>
<th>1</th>
<th>2</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Patients</td>
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<td>18</td>
<td>30</td>
</tr>
<tr>
<td>Number of implants</td>
<td>100</td>
<td>176</td>
<td>276</td>
</tr>
<tr>
<td>Failure</td>
<td>14</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>Number of patients</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 implant lost</td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>2 implants lost</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3 implants lost</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5 implants lost</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Input-output survival rate</td>
<td>86.0</td>
<td>92.6</td>
<td>90.2</td>
</tr>
<tr>
<td>2-year failure-free fraction</td>
<td>95.9</td>
<td>95.0</td>
<td>95.5</td>
</tr>
<tr>
<td>5-year failure-free fraction</td>
<td>86.9</td>
<td>91.3</td>
<td>89.3</td>
</tr>
</tbody>
</table>

placement in group A, and after 6 months in group B. 30 patients were rehabilitated with removable implant-supported overdentures. The mean follow-up period after surgery was 94.1 \( \pm \) 24.9 (range 46.3-126.2) months for group A, 45.3 \( \pm \) 40.6 (range 0.3-121.7) months for group B, and 61.5 \( \pm \) 42.7 (range 0.3-126.1) months for both of the groups.

The overall implant loss was 27/276. Fourteen implants in 6 patients of group A and 13 implants in 9 patients of group B were lost up to the time of the last recall. Seven of these 27 implants were lost at the uncovering operation due to osseointegration failure. The remaining 20 implants were lost between 1 and 9 years after implantation. Ten patients (4 group A, 6 group B) lost 1 implant each, 2 patients (both group B) lost 2 implants, 1 patient (group B) lost 3, and 2 patients (both group A) lost 5 implants each. One of the patients with removal of 5 implants lost 2 implants due to osseointegration failure; the other 3 implants were lost 2 years after loading. The other patient with 5 implants being removed had developed an oronasal fistula after osteotomy and simultaneous implant insertion. Although frequent controls were suggested after successful surgical and antibiotic treatment, the patient was not compliant and used the unadapted old prostheses. Five implants were exposed and had to be removed. Half of all patients had no implant failure. Seven of all lost implants were replaced in 4 patients.

A total of 22 patients were followed up for 2 years and 19 patients for 5 years. The overall 2-year failure-free fraction was 95.5%; the 5-year failure-free fraction was 89.3%. The 2-year failure-free fraction for group A was 95.9% and for group B 95.0%. The 5-year failure-free fraction for group A was 86.9% and for group B 91.3%. The difference between the failure time curves is not significant \( P = .57 \). Implant statistics and life-table analysis of the failure times according to Kaplan and Meier28 are shown in Table I and Fig 6.

When looking per patient at the time until the first failure of an implant the overall 2-year fraction of patients free of any failure was 70.7%, and the 5-year fraction was 54.7%. There was no significant difference in the time until the first failure between groups A and B \( P = .91 \).

In all patients implant-supported dentures allowed Class I occlusion. All patients showed an improvement of their esthetic appearance by the recreation of the harmony of facial proportions (Figs 2-4). The retention and speech function of the denture was restored, and masticatory and esthetic results were evaluated by 26 patients (10 group A, 16 group B) by VAS at the last recall. In the VAS the masticatory function was evaluated as 1 (excellent) by 69% (60% in group A, 75% in group B) and as 2 (good) by the remaining patients. The esthetic appearance of the new facial harmony and the denture situation was evaluated as 1 by 76.9% (90% in group A, 69% in group B) and as 2 by the remaining patients. The VAS for the overall treatment satisfaction showed a score of 1 in 54% (60% in group A, 50% in group B) and a score of 2 in the remaining patients.

Radiographic results

Table II presents the mean alveolar bone height in the region of the canine and the first molar before the horseshoe Le Fort I osteotomy, immediately after the operation, and at the last recall measured in the radiographs and CT scans. In the canine region the overall mean reduction of the augmented alveolar bone level was from 20.00 \( \pm \) 2.93 mm \( (N = 36) \) postoperatively to 16.33 \( \pm \) 4.05 mm \( (N = 32) \) at the last recall \( (-3.67 \pm 2.77 \text{ mm}) \). At the first molar region the overall value for alveolar bone height was reduced from 21.76 \( \pm \) 3.32 mm \( (N = 36) \) postoperatively to 17.34 \( \pm \) 4.21 mm \( (N = 32) \) at the last recall \( (-4.42 \pm 2.72 \text{ mm}) \). In group A, the alveolar bone height at the canine region was 20.63 \( \pm \) 2.71 mm \( (N = 12) \) postoperatively and 16.83 \( \pm \) 4.16 mm \( (N = 12) \) at last recall \( (-3.79 \pm 2.03 \text{ mm}) \); the values in the first molar region were 22.50 \( \pm \) 3.18 mm \( (N = 12) \) postoperatively and 18.00 \( \pm \) 5.07 mm \( (N = 12) \) at last visit \( (-4.5 \pm 3.67 \text{ mm}) \). In group B, the alveolar bone height at the canine region was 19.69 \( \pm \) 3.04 mm \( (N = 24) \) postoperatively and 16.03 \( \pm \) 4.05 mm \( (N = 20) \) at last recall \( (3.66 \pm 2.66 \text{ mm}) \); the bone reduction at the first molar region was from 21.40 \( \pm \) 3.39 mm \( (N = 24) \) postoperatively to 16.95 \( \pm \) 3.69 mm \( (N = 20) \) at last recall \( (-4.45 \pm 2.03 \text{ mm}) \). Marginal bone levels mesial and distal to implants measured from the radiographs and assessed according to a 4-point scale, as described above, resulted in a score of 2 (reduction of bone level exceeding one-third but not one-half of implant length) in 9 implants (3.5%); a score of 1 (reduction of bone level not exceeding one-third of implant length) in 116 implants (45.3%), and a score of 0 (no bone loss detectable) in 131 implants (51.2%).
DISCUSSION

The classic Le Fort I osteotomy of the edentulous maxilla as first described by Bell et al\(^{11}\) has proved to be a reliable operation technique when the maxillary alveolar process is extremely atrophied, the sagittal relation of the jaws is reversed, and the palatal vault is adequately shaped. The horseshoe technique, in contrast, is indicated in cases with a flat palatal vault: The hard

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**Table II.** Alveolar bone height in the region of the canine and the first molar before horseshoe Le Fort I osteotomy, immediately after the operation, and at the last recall

<table>
<thead>
<tr>
<th>Step</th>
<th>Region</th>
<th>Alveolar bone height</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Median</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>preoperative</td>
<td>2.81</td>
<td>2.07</td>
<td>0.50</td>
<td>2.25</td>
<td>6.50</td>
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<td></td>
<td></td>
<td>postoperative</td>
<td>20.63</td>
<td>2.71</td>
<td>16.50</td>
<td>20.25</td>
<td>25.50</td>
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<td></td>
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<td>last recall</td>
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<td>4.16</td>
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<td>17.75</td>
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<td>0.50</td>
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</table>

Fig 6. Life-table analysis of implant survival in 1-step and 2-step procedures.
palate remains in situ and only the alveolar crest is moved in a favorable place, resulting in a well shaped palatal vault. Additional oral space avoids speech impairment and tongue displacement.

In this study only minor changes, due to postoperative bone remodelling and bone resorption, occurred over the follow-up period and did not endanger implant stability. There was no evidence of necrosis of soft tissue or the osteotomized alveolar ridge owing to nonvascularization. Small dehiscences could be managed as reported above. The grafted maxilla provided sufficient stability for simultaneous and consecutive implant insertion. In our study, no statistically significant difference between the failure times of the 1- and 2-step procedures was found, although the 2-step implant surgery indicates to be the slightly safer procedure. In 1997, Nyström et al16 reported that in 10 patients after Le Fort I osteotomy and interpositioning of bone graft 60 implants were placed in a second step. Three implants were lost during the follow-up period of 39 months. In the year 2002, the same author presented a study17 in which the 5-year survival rate was 74.6% after reconstruction of the resorbed maxilla with onlay bone grafts and implant placement in a 1-stage procedure. Kahnberg et al18 performed 2-stage implantation after Le Fort I osteotomy with interpositional bone grafting in 25 patients and showed a 5-year survival rate of 85.6%. Stoelinga et al19 followed up 15 patients up to 8 years after 2-stage operation with Le Fort I osteotomy and implant placement: Implant survival was 94.6%. The 5-year survival rates of our study (in the 1-step group 86.9%, in the 2-step group 91.3%) compare favorably with these reports and show outstanding long-term performance over the follow-up period of more than 10 years. Problems like fracturing of the atrophic edentulous maxilla during the operation as described by Li and Stephens30 and by Sailer31 and discussed by Stoelinga et al19 did not occur in this patient population. Concerns of Stoelinga et al19 about less secure vascular supply by the horseshoe technique compared to the classical Le Fort I osteotomy were needless; the operation outcome was never endangered.

Fig 6 shows the life-table analysis of the 1- and 2-step procedure according to Kaplan and Meier.28 Probably, the higher survival rate of the 2-stage operation technique is the result of the consolidation of the augmented bone. The advantages of immediate implant placement are not to be neglected, because a single operation means a great comfort to the patient. Besides that, 1-stage surgery is more cost effective and of course more time efficient, allowing a faster rehabilitation of the patient. On the other hand, the delayed approach after healing of the osteotomized and augmented alveolar bone allows further modification of the implantation area, such as the placement of additional graft material, above all because techniques like bone splitting, bone condensing, minimal invasive sinus floor elevation, and implant insertion with dental navigation systems have been developed and partially successfully applied.32-35 A better initial stability and optimal positioning of the implants can be achieved by these means bearing less risk of graft and implant loss.

Bone height in the molar region is of great importance since this region of the alveolar process is one of the most loaded areas during mastication and shows higher values of masticatory forces.36-39 In our study, the overall mean vertical bone resorption in the first molar region was 4.42 ± 2.72 mm (N = 32) (group A 4.5 ± 3.67 mm (N = 12), group B 4.45 ± 2.03 mm (N = 24)). Because after the osteotomy the grafted bone level in this region (group A 22.5 ± 3.18 mm (N = 12), group B 21.4 ± 3.39 mm (N = 24)) allowed placement of maximum size implants as needed, the stability of the implants was not endangered. However, 27 implants were lost. Seven of these implants were positioned in the premolar and molar region. Five of them were from group A. Four of all lost implants were from male patients, 2 in group A and 2 in group B. It seems worthwhile to mention that 10 of 14 implant failures in the 1-step group occurred in only 2 patients. Marginal bone levels mesial and distal to implants measured according to a 4-point scale showed also no great difference between the simultaneous and consecutive operation technique. One hundred twenty-five implants showed only minimal peri-implant bone loss. In most cases bone resorption was far less than one-third of the implant length. Implant stability was not endangered by excessive marginal bone loss. No peri-implant bone loss at all was shown by 51.2% of all implants.

In this study we could evaluate the outcome of the HLFO operation technique on 36 patients over a period of more than 10 years. The results of the study show that the patients could be rehabilitated successfully with implant-borne prostheses on a high treatment level. Implant survival is found to be high. Morbidity and complication rate are low. The results concerning denture retention, masticatory function, and esthetics are satisfying. The advantages of the reconstruction of the alveolar ridge and the jaw relationship by the horseshoe operation method compared to the conventional Le Fort I technique seem to be reliable. Furthermore we believe that even if no implant insertion is planned, patients with mucosally supported prostheses will benefit from the better retention of the denture, the restored facial esthetics, and—due to more oral volume for the tongue—the better speech and masticatory function.
CONCLUSION
Looking at the satisfactory long-term results of this study referring to implant osseointegration and dental and esthetic rehabilitation, we are encouraged to continue with the horseshoe Le Fort I osteotomy technique as an excellent treatment concept for the dental rehabilitation of patients with severely atrophied maxilla, reversed intermaxillary relationship, and a flat palatal vault. Although the 1-step operation method offers a greater convenience to the patient, we believe that delayed implant insertion after a healing period is the method of choice, allowing a precise implant placement with developed techniques and increasing the treatment success.

This paper is dedicated to Professor DrDr. Rolf Ewers for his 60th birthday.

REFERENCES

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