Graftless Full-Arch Implant Rehabilitation with Interantral Implants and Immediate or Delayed Loading—Part I: Reconstruction of the Edentulous Maxilla

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Purpose: To compare long-term survival and marginal bone loss of late interantral implants in the nonaugmented edentulous maxilla subjected to immediate vs delayed loading. Materials and Methods: One hundred twenty-two edentulous patients with implants in native, healed jawbone were subjected to either immediate loading (179 implants) or delayed loading (403 implants) of their four to six interantral implants (part I of 362 graftless maxillary cross-arch rehabilitations performed in the years 2004 to 2013). Kaplan-Meier survival estimates were computed, and marginal bone loss was evaluated in a stratified random sample of 20 patients per group. Results: Fifteen of 582 implants failed within the mean observation period of 4.7 years, and no difference in 8-year survival estimates could be seen between immediate (98.3% [95% CI: 96.4–100.0]) and delayed (96.7% [95% CI: 94.7–98.6]) loading protocols (P = .370). Mean marginal bone resorption following implant insertion did not differ significantly between the groups (1.1 ± 1.3 mm vs 1.4 ± 1.3 mm, P = .490). Conclusion: Immediate loading of interantral implants in the nonaugmented edentulous maxilla yields favorable results comparable to delayed loading and may be considered to shorten periods of removable provisional prostheses in maxillary edentulism.

Keywords: complete denture, dental implants, edentulous arch, immediate dental implant loading, implant-supported dental prosthesis, maxilla

Treatment of edentulism by means of dental implants represents an established therapy and has been shown to substantially improve patient satisfaction, masticatory performance, and oral health–related quality of life.¹ Available bone volume for implant placement, however, is frequently compromised in the atrophic maxilla by postextraction alveolar bone resorption and pneumatization of the maxillary sinus.² Bone augmentation procedures using either autogenous grafts or bone substitute materials have been developed to increase bone quantity³; however, they are associated with the issues of donor site morbidity,⁴ increase of surgical invasion, postoperative morbidity,⁵ and number of surgical interventions, as well as total treatment costs and duration.⁶ Interantral implant placement into the native jawbone of the edentulous maxilla—optionally combined with tilting of the distal implants according to the All-on-4 concept⁷—provides a minimally invasive treatment alternative associated with low surgical complication rates and high patient satisfaction.⁸

Immediate provisional restoration and functional loading of full-arch partial dentures is a patient-friendly approach that is considered to shorten periods of removable provisionalities in maxillary edentulism.⁹ Compared with conventional delayed loading concepts,¹⁰ however, an increased risk of osseointegration failure may result in cases of low initial stability due to decreased resistance to implant micromotions during the healing phase.¹¹ Bone density is the major patient-related determinant for primary implant stability¹²; however, it is routinely compromised in the edentulous maxilla along with bone quantity.¹³ Neugebauer et al.¹⁴ suggested refraining from immediate loading if a bridge insertion torque, eg, the mean value of individual insertion torques of all implants involved, of 35 Ncm cannot be reached. To date, there is a paucity of data in scientific literature that substantiate whether immediate loading must be considered a risk factor for biologic complications and in what situations it may
be preferable to stick to the conventional delayed protocol.

Success rates for rough-surfaced implants supporting fixed protheses in edentulous patients have been reported to range from 90% to 100% with immediate loading and from 95% to 100% with conventional loading protocols. Influencing variables related to patients (age, sex, smoking habits, history of periodontal disease) and implant sites (implant length, implant diameter, number of implants per patient, local bone quality), however, have rarely been investigated in a large patient sample. The aim of the present retrospective study was to compare implant survival and peri-implant marginal bone resorption in the edentulous maxilla when fixed cross-arch partial dentures are subjected to either immediate or delayed loading (Fig 1).

MATERIALS AND METHODS

Patient Selection

Graftless maxillary cross-arch rehabilitation was performed in a total of 362 patients in the years 2004 to 2013 (1,797 implants). Of the 122 patients with implants in native, healed jawbone, 37 patients were subjected to immediate loading and 85 patients to delayed loading of their 4 to 6 interantral implants (179 and 403 implants, respectively). Allocation to intervention groups occurred in the course of routine treatment decisions based on patient demands regarding provisional restoration and primary implant stability. Retrospective evaluation of implant survival was performed in collaboration with the referring dentists, and the study protocol was approved by the Ethics Committee of Vienna (EK 13-145-VK). Inclusion criteria involved (1) patients referred to the Academy for Oral Implantology (Vienna, Austria) for rehabilitation of their edentulous maxilla, (2) by means of dental implants inserted into native healed jawbone, (3) without prior or simultaneous application of bone augmentation procedures, (4) subjected to either immediate loading of their provisional full-arch (glass fiber reinforced) acrylic partial dentures at the day of implant placement or else to conventional delayed loading after a healing period of at least 3 months wearing removable complete dentures. For the evaluation of peri-implant marginal bone resorption, a random sample of 20 patients per group was drawn, and measurements were taken using Sidexis XG radiographic software (Version 2.3, Sirona Dental Systems). The baseline for bone resorption measurements was the day of implant insertion (rather than the timepoint of prosthetic rehabilitation).

Surgical and Prosthodontic Procedures

Preoperative cone beam computed tomographic scans were acquired using a Classic i-CAT (Imaging Sciences International, 0.25 voxel mode, high resolution). In the majority of cases, 6 to 10 radiopaque markers (gutta-percha balls of 1-mm diameter) were placed into polyvinyl-siloxane scanning templates to perform the double-scan technique: the first scan was of the maxilla with the scanning template in situ; the second scan was of the scanning template only. Computer-assisted implant treatment planning software (NobelClinician, Nobel Biocare) allowed superimposition of the two scans and determination of three-dimensional implant positions. The planning data were transferred to the dental laboratory to fabricate custom surgical templates with precision titanium tubes (NobelGuide, 16:
plants were placed in cases of high patient age\textsuperscript{17,18} (to guarantee a favorable biomechanical situation and short distal cantilevers. More than four implants per patient, the most distal ones were tilted up to 30 degrees to account for compromised osseous healing capacity). Of the four to six implants placed in each patient, the first maxillary molar was subjected to transmucosal healing after adaptation of their existing complete dentures. Definitive prosthetic restoration using screw-retained full-arch implant partial dentures (including cantilevers up to the first molar) was performed after at least 3 months in both groups.

### Statistical Analysis
Baseline characteristics were compared between the two study groups as well as between total collectives and random samples using Fisher exact and Wilcoxon rank sum tests. Estimates of 8-year implant survival including 95\% confidence intervals (95\% CI) were computed using the Kaplan-Meier method and compared using Mantel-Cox log-rank tests. Influence of variables (patient age and sex, smoking habits, history of periodontal disease, implant length and diameter, number of implants per patient, and bone quality) was evaluated in a Cox proportional hazards model. Predictors of peri-implant marginal bone loss were investigated by multiple linear regression. All analyses were performed at a significance level of .05 using R-project statistical software version 3.1.0 (R Foundation for Statistical Computing).

### RESULTS
A total of 122 patients (70 women, 52 men, mean age, 66.5 ± 10.1 years) received four to six interantral implants into native healed jawbone of their completely edentulous maxillae, of which 30.3\% were subjected to immediate prosthetic loading (37 patients, 179 implants) and 69.7\% to delayed loading (85 patients, 403 implants). Patient and implant characteristics did not differ significantly between the groups (Table 1) apart from a higher percentage of patients with a history of periodontal disease in the immediate loading group. A total of 15 implants failed within the observation period of 4.7 ± 2.1 years: in the immediate loading group, two implant failures occurred within the first year after implant placement (1.1\%), and one implant failed after the first year (0.6\%), while six early failures (1.4\%) and six late failures (1.4\%) occurred in the delayed loading group. No difference regarding implant survival rates (98.3\% vs 97.0\%, \( P = .571 \)) could be observed (Table 2).

Kaplan-Meier estimates of 8-year implant survival were 98.3\% [95\% CI 96.4\%–100.0\%] in the immediate loading group compared with 96.7\% [95\% CI: 94.7\%–98.6\%] in the delayed loading group (Fig 2) without significant differences (\( P = .370 \)). Survival rates were not associated with patient age (\( P = .399 \)) and sex (women: 98.4\%, men: 95.5\%, \( P = .057 \)), smoking habits (positive: 96.1\%, negative: 97.4\%, \( P = .320 \), or cantilevers at the day of implant placement. Implants in the delayed loading group were subjected to transmucosal healing after adaptation of their existing complete dentures. Definitive prosthetic restoration using screw-retained full-arch implant partial dentures (including cantilevers up to the first molar) was performed after at least 3 months in both groups.

**Table 1** Comparison of Patient and Implant Characteristics Between the Immediate Loading and Delayed Loading Groups and Related \( P \) Value

<table>
<thead>
<tr>
<th></th>
<th>Immediate Loading</th>
<th>Delayed Loading</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of implants</td>
<td>179</td>
<td>403</td>
<td>.112</td>
</tr>
<tr>
<td>No. of women</td>
<td>17</td>
<td>53</td>
<td>.112</td>
</tr>
<tr>
<td>No. of men</td>
<td>20</td>
<td>32</td>
<td>.112</td>
</tr>
<tr>
<td>Mean age at implant placement (y)</td>
<td>66.0 ± 11.0</td>
<td>66.7 ± 9.7</td>
<td>.878</td>
</tr>
<tr>
<td>Mean length of follow-up (y)</td>
<td>4.0 ± 2.1</td>
<td>4.3 ± 2.1</td>
<td>.794</td>
</tr>
<tr>
<td>Percentage of smokers</td>
<td>17.9%</td>
<td>29.1%</td>
<td>.300</td>
</tr>
<tr>
<td>History of periodontal disease</td>
<td>34.4%</td>
<td>10.9%</td>
<td>.011*</td>
</tr>
<tr>
<td>Mean no. of implants per patient</td>
<td>4.8 ± 0.9</td>
<td>4.7 ± 0.8</td>
<td>.503</td>
</tr>
<tr>
<td>Mean implant length (mm)</td>
<td>12.5 ± 1.5</td>
<td>12.0 ± 1.7</td>
<td>.582</td>
</tr>
<tr>
<td>Mean implant diameter (mm)</td>
<td>4.1 ± 0.3</td>
<td>4.1 ± 0.4</td>
<td>.717</td>
</tr>
<tr>
<td>Mean implant insertion torque (Ncm)</td>
<td>37.9 ± 13.2</td>
<td>39.4 ± 14.8</td>
<td>.070</td>
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</table>

*Indicates statistical significance (\( P < .05 \)).

**Table 2** Implant Survival and Marginal Bone Resorption

<table>
<thead>
<tr>
<th></th>
<th>Immediate Loading</th>
<th>Delayed Loading</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-year implant survival rate (Kaplan-Meier)</td>
<td>98.3% [95% CI: 96.4%–100.0%]</td>
<td>96.7% [95% CI: 94.7%–98.6%]</td>
<td>.370</td>
</tr>
<tr>
<td>Early failures</td>
<td>1.1%</td>
<td>1.4%</td>
<td>.571</td>
</tr>
<tr>
<td>Late failures</td>
<td>0.6%</td>
<td>1.4%</td>
<td></td>
</tr>
<tr>
<td>Marginal bone resorption</td>
<td>1.1 ± 1.3 mm</td>
<td>1.4 ± 1.3 mm</td>
<td>.490</td>
</tr>
</tbody>
</table>

No significant differences between immediate and delayed loading of four to six interantral implants in the nonaugmented edentulous maxilla could be observed with regard to implant survival and marginal bone resorption.
history of periodontal disease (positive: 92.8%, negative: 97.7%, \(P = .199\)). Implant survival did not differ between implant lengths (8 mm: 94.7%, 10 mm: 93.4%, 11.5 mm: 96.3%, 13 mm: 98.9%, 16 mm: 100%, \(P = .426\)), diameters (3.5 mm: 96.7%, 4.3 mm: 98.1%, 5.0 mm: 87.5\%, \(P = .571\)) and number per patient (four implants: 98.5\%, five implants: 95.8\%, six implants: 96.3\%, \(P = .363\)). Implants placed in bone qualities I, II, III, and IV showed similar survival rates of 96.4\%, 98.6\%, 95.8\%, and 97.5\%, respectively (\(P = .673\)).

In the immediate loading group, the random sample comprised 10 women and 10 men that did not differ significantly regarding mean age (65.3 ± 8.9 years, \(P = .055\)), sex distribution (\(P = .789\)), percentage of smokers (13.3\%, \(P = 1.000\)), history of periodontal disease (44.4\%, \(P = .552\)), mean implant length (12.3 ± 1.6 mm, \(P = .181\)), mean implant diameter (4.1 ± 0.4 mm, \(P = .812\)), mean number of implants per patient (4.8 ± 0.8, \(P = .657\)), mean implant insertion torque (37.0 ± 13.3 Ncm, \(P = .355\)), and bone quality (\(P = .876\)) compared with the total collective. In the delayed loading group, the random sample comprised 6 women and 14 men that also did not differ significantly regarding mean age (64.0 ± 7.7 years, \(P = .226\)), sex distribution (\(P = .611\)), percentage of smokers (26.7\%, \(P = 1.000\)), history of periodontal disease (6.3\%, \(P = 1.000\)), mean implant length (12.2 ± 1.3 mm, \(P = .283\)), mean implant diameter (4.1 ± 0.4 mm, \(P = .500\)), mean number of implants per patient (4.8 ± 0.7, \(P = .161\)), mean implant insertion torque (35.9 ± 12.6 Ncm, \(P = .539\)), and bone quality (\(P = .966\)) compared with the total collective.

Marginal bone loss was 1.1 ± 1.3 mm around immediate loaded implants (mean observation period 3.8 ± 2.1 years) and 1.4 ± 1.3 mm around delayed loaded implants (mean observation period 4.4 ± 1.7 years) without significant differences between the random samples (\(P = .490\)). Bone resorption did not differ between tilted and axially placed implants (\(P = .624\)). No differences regarding relevant confounding variables—patient age (\(P = .942\)), sex (\(P = .346\)), smoking (\(P = .918\)), implant length (\(P = .645\)) and diameter (\(P = .689\)), insertion torque (\(P = .247\)), and bone quality (\(P = .283\))—could be observed. Marginal bone resorption did not differ significantly between patients with four vs five to six implants (1.5 ± 1.5 mm vs 1.0 ± 1.2 mm, \(P = .249\)) and with history vs no history of periodontal disease (1.3 ± 1.3 mm vs 1.0 ± 1.5 mm, \(P = .750\)).

**DISCUSSION**

The present results suggest that immediate and delayed prosthetic loading yield comparable results in implant-supported fixed rehabilitation of the nonaugmented edentulous maxilla. Implant failures occurred in only 2.6\% within a mean observation period of 4.7 years and did not differ between the groups. No full-arch implant partial denture had to be refabricated, and 53\% of failures were recorded already prior to definitive prosthetic loading. The present results compare favorably to an implant survival rate of 96.6\% and prosthetic survival rate of 100\% reported in a recent clinical investigation of the NobelGuide All-on-4 treatment concept after 5 years of follow-up.\(^{20}\) Peri-implant marginal bone resorption was comparable (if not less) in the immediate loading group and—in line with very recent systematic reviews and meta-analyses\(^{21,22,23}\)—did not differ between straight and tilted implants. When choosing between loading paradigms for fixed implant rehabilitation of the edentulous maxilla, immediate provisional restoration may thus be favored to shorten periods of provisional removable prostheses.

Sufficient primary stability at implant placement is considered a prerequisite for immediate loading protocols. Based on the results of a minipig study, Neugebauer et al\(^{14}\) suggested refraining from immediate loading if a bridge insertion torque, eg, the mean
of individual insertion torques of implants involved, of 35 Ncm cannot be reached. Selection bias may for this reason be suspected to occur in the present comparative study, meaning that only patients with high primary implant stability were subjected to immediate loading. However, baseline comparison revealed that mean insertion torques were not higher in the immediate loading group (37.9 Ncm) compared with the delayed loading group (39.4 Ncm). Other potential confounders, such as implant length and diameter, did not prove to differ between the treatment groups, nor did the mean number of implants per patient (ranging between four and six). A recent biomechanical analysis aimed to show that four implants actually can suffice in terms of load distribution if the anterior-posterior-spread–cantilever-length ratio does not exceed certain limits.

Comparing graftless rehabilitation using tilted and axial implants in the residual interantral bone with sinus augmentation or sandwich graft procedures from the patients’ point of view, nongrafting options are naturally preferred. However, long-term implant survival rates in augmented bone may also be somewhat lower, ranging between 91.4% and 95.0%. In addition, graftless concepts carry a reduced risk of possible complications and potential compromise of maxillary sinus physiology. Implants in native nonaugmented jawbone also show favorable results in low bone quality—frequently encountered in the edentulous maxilla—as recently confirmed in a multicenter study that restored patients with atrophic maxillae and bone densities of III or IV with immediate fixed provisionals on six implants and yielded an implant survival rate of 96% after 3 years.

Limitations of the present investigation may arise from its retrospective design associated with inhomogenous follow-up and nonrandomized treatment allocation. To the best of the authors’ knowledge, however, no study comparing immediate vs delayed loading of fixed cross-arch partial dentures in the edentulous maxilla has yet been published reporting on follow-up periods longer than 6 years and a sample size of more than 50 patients. The 8-year implant survival rates of 98.3% following immediate loading and 96.7% following delayed loading observed in the present investigation may thus serve as a valuable prediction of long-term treatment success when implant-based rehabilitation without bone augmentation surgery is performed in the atrophic maxilla. The second part of the study—to be published in a separate article—compares immediate vs delayed loading in patients with immediate implants after extraction of their failing residual dentition.

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