Stability Evaluation of Implants Integrated in Grafted and Nongrafted Maxillary Bone: A Clinical Study from Implant Placement to Abutment Connection

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ABSTRACT

Background: Clinical studies have shown a higher degree of implant failures in grafted bone compared with normal nongrafted maxillary bone. Additionally, a prolonged time for integration of titanium implants in grafted block bone has been shown by means of resonance frequency analysis (RFA).

Purpose: The aim of this prospective study was to compare the stability of implants placed in particulate bone, onlay block bone, interpositional bone, and nongrafted maxillary bone during the early phase of osseointegration using RFA and implant failure.

Material and Methods: Thirty-five patients with edentulism in the maxilla were included in the study. In all, 260 Astra Tech TiOblast™ implants (Astra Tech AB, Mölndal, Sweden) were installed. Twenty-five of these patients had severe maxillary atrophy and were treated with iliac bone grafts 5 to 6 months prior to implant placement, 19 with lateral onlay block grafts on one side (group A, 38 implants) and particulate bone for lateral augmentation on the other (group B, 38 implants). These 19 patients also got bilateral sinus floor augmentation with particulate bone (group C, 76 implants). Six patients had an unfavorable sagittal relation between the jaws and underwent a LeFort I operation with interpositional bone blocks grafted to the nasal and sinus floors (group D, 48 implants). The remaining 10 patients could be treated with implants without bone augmentation and served as control (group E, 60 implants). RFA was performed at implant placement and abutment connection 6 months later and an implant stability quotient (ISQ) value was given for each implant.

Results: Four implants (1.5%) were found mobile at abutment connection and removed (two in group A and two in group D). RFA showed a slight increase in stability from installation to abutment connection but the differences were not statistically significant in any of the groups (Wilcoxon signed rank test for comparison of paired data).

Implants installed in group D had a significantly lower ISQ value at both measurements compared with the other groups (Wilcoxon Rank Sum test for comparisons of independent samples, $p = .05$).

Conclusion: It is concluded that TiO_2-blasted implants placed in nongrafted and grafted maxillary bone using a two-staged protocol show similar stability during the early phase of osseointegration. Patients reconstructed with interpositional bone graft after a LeFort I osteotomy showed lower implant stability values than nongrafted patients and other grafting techniques.

KEY WORDS: bone graft, implants, stability

INTRODUCTION

Prosthetic rehabilitation of the edentulous and resorbed maxilla may require bone augmentation to enable placement and integration of dental implants.

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Autogenous bone grafts are still considered "gold standard" even though the use of bone substitutes has increased in recent years. In severely resorbed jaws, block bone is frequently used and the implants can be installed either simultaneously with the graft or after some months of graft healing. In a series of studies on block bone grafts, Rasmusson and colleagues suggested that a staged approach is preferable since a better integration and stability of the implants was shown both histologically and by resonance frequency analysis (RFA).[1–3] If particulate bone is to be used, a stage procedure is of course compulsory since no mechanical support from the graft can be appreciated. In severe cases when more bone is needed than can be harvested in the maxillofacial region, a common donor site is the iliac crest. Corticocancellous block grafts can be harvested and shaped in to preferable size. In cases with severe maxillary resorption but with normal sagittal relation between the jaws, the graft can be used as a block or particulated for lateral onlay augmentation and for sinus lift. When there is sagittal discrepancy, the bone graft is usually placed as interpositional blocks in the nasal and sinus floors after a LeFort I osteotomy. The latter technique allows for correction of the sagittal relations since the whole maxilla is mobile.

The long-term implant survival rate for implants installed in grafted bone is generally not as good as for the nongrafted maxilla. There are several explanations for this. Resorption of the graft is common and the healing situation is complex since both successful healing of the graft and integration of the implants are required. Another reason for increased implant failure rates in bone grafts could be the slow remodeling and revitalization of cortical block grafts.[4]

The marginal bone level alteration during initial healing and loading is usually assessed using intraoral radiographs. Another way is RFA.[5,6] This technique implies a resonance frequency measurement of a transducer connected to the implant fixture or abutment. The value, implant stability quotient (ISQ) reflects the stability of the implant as a function of interface stiffness and is influenced by the distance from the transducer to the first contact of supportive marginal bone. This means that the bone support can be assessed also in the buccal-lingual aspect.[7] RFA is sensitive to changes in the marginal bone level and is usually used as a complement to intraoral radiographs.

To our knowledge, stability measurements on implants integrated in particulate bone grafts are lacking. Also, a comparison of stability changes between implants installed in onlay and interpositional block bone and particulate bone ought to be further evaluated.

The aim of this prospective study was to compare the stability of implants placed in particulate bone, onlay block bone, interpositional bone, and nongrafted maxillary bone during the early phase of osseointegration using RFA and implant failure.

MATERIALS AND METHODS

Subjects

Thirty-five consecutive patients with edentulism in the maxilla were included in the study. Twenty-five of these had severe maxillary atrophy, Class IV to VI according to Cawood and Howell,[8] and were reconstructed with iliac crest bone grafts 5 to 6 months before implant placement. The remaining 10 patients had sufficient maxillary bone volume for implant placement and served as control.

The study patients were divided into four groups. Nineteen patients (2 men and 17 women) were treated with lateral onlay block grafts on one side (group A) and particulate bone for lateral augmentation on the other (group B). These 19 patients also got bilateral sinus floor augmentation with particulate bone (group C). Six patients (4 men and 2 women) had an unfavorable sagittal relation between the jaws and underwent a LeFort I operation with interpositional bone blocks grafted to the nasal and sinus floors (group D). The remaining 10 patients (5 men and 5 women) could be treated with implants without bone augmentation and served as control (group E).

The mean age at implant surgery was 59 years (range 35–75) for groups A to D and 56 years (range 42–68) for group E.

Prior to inclusion in the study, all patients were examined according to a standardized protocol with clinical and radiographic examination.

The following inclusion criteria were used:

- Maxillary edentulism
- No alcohol abuse
- Smoking less than 10 cigarettes/day
- No medical contraindication to surgery and/or general anesthesia according to the American Society of Anesthesiologists standards

- Signed informed consent to participate in the study

The medical status of the patients was in general good. Three patients had osteopenia (one in groups A to C and two in group D) and three patients had well controlled type II diabetes mellitus (one in group D and two in group E). Fifteen patients were smokers prior to the treatment and four admitted smoking (<10 cigarettes/day) during the treatment and at the 1-year follow-up.

Bone Grafting Surgery

Bone grafting surgery was performed under general anesthesia and corticocancellous bone blocks were harvested from the medial side of the anterior superior iliac crest. The lateral side of the crest was left intact and the gluteus muscle was not interfered with. Bovine collagen, Lysotypt (Braun Surgical GmbH, Melsungen, Germany) was used to stabilize the coagulum on the open bone surface. The incision was closed in layers. The bone grafts were either used as onlay blocks, particulated lateral onlays, and sinus inlays or as interpositional blocks in the nasal and sinus cavities after a LeFort I osteotomy. The recipient site on the maxilla was freed from periosteum and prepared with round bur until small spots of bleeding were noted (groups A, B, and C) The block grafts were adjusted to fit the anatomy of the maxilla and secured with two 1.7 mm titanium screws (6–13 mm length). The particulate bone was either mixed with platelet rich plasma or venous blood and placed onto the buccal part of the maxilla. The buccal flap was elongated through a small incision on the periosteum to gain tension-free coverage of the grafted area. No additional membrane was used. The 38 sinus lifts (group C) had a residual vertical height of 2–5 mm and were augmented to at least 10 mm. In group D, bone blocks were shaped to fit into the sinuses and the nasal floor and secured with wires. The mucosa was in all cases closed with resorbable sutures. All patients were hospitalized 2 to 3 days after surgery. Antibiotics, clindamycin 300 mg × 3, were prescribed 7 days postoperatively together with analgesics.

Implant Placement

A total of 260 Astra Tech TiOblast™ implants (Astra Tech AB, Mölndal, Sweden) were installed, 9 to 17 mm in length and 3.5 mm in diameter. The implants were placed 5 to 6 months after bone grafting (groups A–D) and the abutments another 6 months later, both procedures under local anesthesia. A crestal incision was used to reflect buccal and palatal flaps. The same approach was used at abutment connection so that no soft tissue would interfere with the RFA transducer beam. Eight implants were installed in each patient in the grafted cases. In the control group (E), six implants were installed in each patient. All implants were regarded as stable at implant placement having an insert torque of at least 25 Ncm. Antibiotics were given 1 hour before implant surgery (2 g of phenoxmethylpenicillin or 600 mg of clindamycin) and then for 7 days (phenoxmethylpenicillin 1 g × 3 or clindamycin 300 mg × 3). Analgesics, non-steroid anti-inflammatory drugs (NSAIDs), were prescribed for the postoperative period. Dentures were not worn the first month following the grafting procedure and for 10 days after implant placement.

RFA

RFA was performed at implant placement and abutment connection 6 months later and an ISQ value was given for each implant. Measurements were made on fixture level on all implant fixtures at the two occasions. The RFA equipment was a standard Ostell™ (Integration Diagnostics Ltd, Sävedalen, Sweden) with a transducer fitting the implants used (Figure 1). The transducer beam was exited with a sinus wave ranging from 2 to 15 kHz in steps of 25 Hz. The resonance frequency is recorded as a peak in a frequency-amplitude plot. ISQ is a function of Hz and based on the underlying resonance frequency. ISQ represents a standardized unit and is

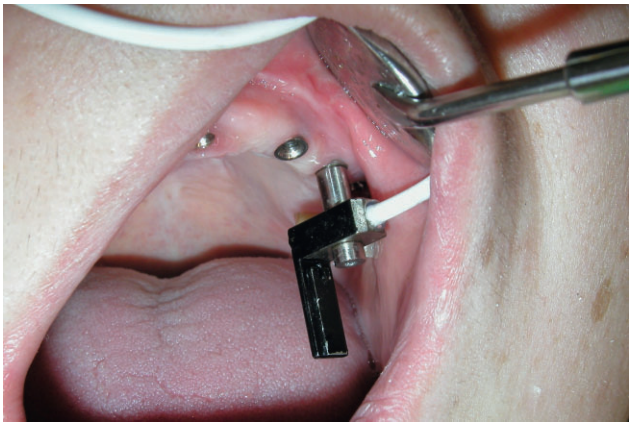

Figure 1 Resonance frequency transducer connected on fixture level in a grafted maxilla (particulate bone).

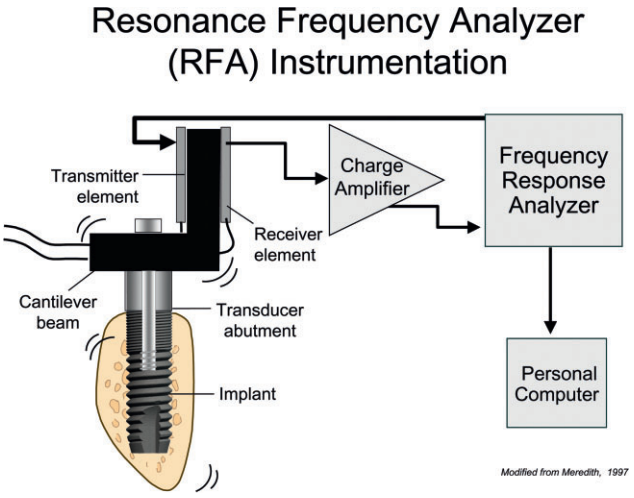

Figure 2 The principle of resonance frequency analysis (modified from Meredith[13]).

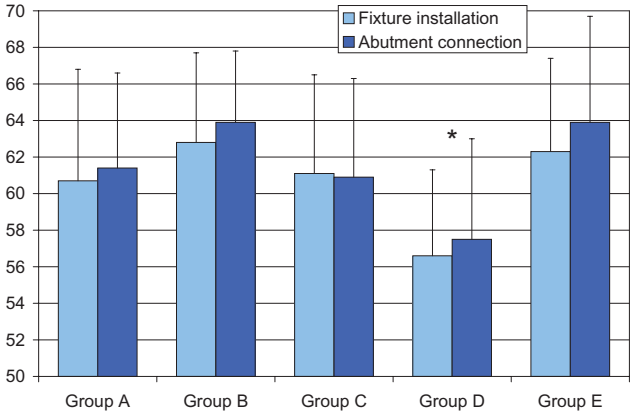

Figure 3 The mean resonance frequency analysis values at fixture installation and abutment connection. Group A: onlay block graft; group B: particulate onlay graft; group C: particulate sinus inlay; group D: interpositional block graft; group E: nongrafted maxilla. *$p = 0.05$.

presented as a value ranging from 1 to 100 where 1 is the lowest and 100 the highest value (Figure 2).

STATISTICS

For comparison of changes in ISQ between implant placement and abutment connection, the Wilcoxon Signed Rank test for paired data was used. For comparison between the groups (A, B, C, D, and E), the Wilcoxon Rank Sum test for comparisons of independent samples was used. A significant difference was considered if $p < .05$.

RESULTS

Clinical Observations

Infections after the bone grafting surgery were seen in two patients. The infected sites resolved with local drainage and clindamycin *per os* and no additional surgery had to be done.

The implant survival rate at abutment connection was 98.5%. Four out of 260 implants were found mobile at that stage and removed, two in group A and two in group D. The failed implants did not effect the planned prosthetic rehabilitation and were not replaced. All patients got fixed 10 to 12 unit superstructures.

RFA

All patients completed both RFA measurements. The resonance frequency registrations were performed on the 260 implants at fixture installation and on all implants except the four that were found rotation mobile at abutment connection ($n = 256$). The mean RFA values are presented in Figure 3 and were for the grafted patients at fixture installation ISQ 60.7 ± 6.1 (onlay block graft, group A), ISQ 62.8 ± 4.9 (particulate onlay graft, group B), ISQ 61.1 ± 5.5 (particulate sinus inlay graft, group C), and ISQ 56.9 ± 4.7 (interpositional block graft, group D). The nongrafted patients (group E) stability value was at implant placement in mean ISQ 62.3 ± 5.1. The corresponding values at abutment connection were ISQ 61.4 ± 5.2 (group A), ISQ 64.0 ± 3.8 (group B), ISQ 60.9 ± 5.4 (group C), ISQ 58.2 ± 4.7 (group D), and ISQ 63.9 ± 5.5 for the nongrafted patients ($p = .05$, group D vs other groups at both measurements).

No statistically significant difference was found between the first and second measurements in any of the groups.

DISCUSSION

The present study has shown that surgical reconstruction of the resorbed maxilla using a variety of autogenous bone grafting techniques will result in stable integrated implants. The implants were placed after an initial graft healing period of 5 to 6 months. The resonance frequency measurements at implant placement showed lower values for implants installed in interpositional block bone compared with the other groups and compared with the nongrafted control group. The reason for this is not known and on the contrary, one could expect lower values for implants installed in onlay bone grafts since the implants are installed

directly into the grafted bone, which is being continuously remodeled and has a lower density than the residual ridge in the interpositional situation. The resonance frequency findings in the present study are also contradictory to a study by Sjöström and colleagues where a lower initial value was seen for implants installed in normal maxillary bone compared with implants installed after grafting.[9] The difference between the groups in that study was explained by different final preparation diameter because in the grafted patients, a smaller diameter drill had been used. In the present study, the same final drill diameter was used for all groups, 3.2 mm.

Friberg and colleagues demonstrated in a longitudinal study increased stability for maxillary implants in nongrafted cases from placement to abutment connection.[10] The stability was increased up to 20 months postoperatively which is in accordance with the theory that bone formation and maturation may take up to one or one and a half year.[11,12] In a cross-sectional clinical study, RFA was used for stability measurements of implants installed in interpositional block grafts.[4] Increased stability was seen up to 4 years after functional load and a slow remodeling of the block graft was speculated to be the main reason for the prolonged evolvement of implant stability. The same pattern with initial stabilization up to abutment connection was seen in the study by Sjöström and colleagues and a further increase was recorded 1 year after loading.[9] In the present study, the RFA values did not significantly increase over time. This may be related to the implant macro design or surface texture. Also, the implants were not measured after loading in the present study. The initial implant stability is probably related more to bone density and preparation technique than the implant design or grafting technique used. The significantly lower values for the interpositionally grafted cases in the present study is most likely explained by the fact that these cases were the most severely resorbed jaws and not only the bone volume but also the mineral content was lower than in the other groups. Decreasing RFA values have previously been used to detect failing implants in grafted cases. In the present study, the mobile implants found at abutment connection were not measured but a low or uncertain value would have been expected. We find RFA a valuable tool for stability evaluation in grafted cases and further studies on stability evaluation in relation to bone density and implant design and surface would be beneficial.

It is concluded that TiO_2-blasted implants placed in nongrafted and grafted maxillary bone using a two-staged protocol show similar stability during the early phase of osseointegration. Patients reconstructed with interpositional bone graft after a LeFort I osteotomy showed lower implant stability values than nongrafted patients and other grafting techniques.

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