Cutting Torque Measurements in Conjunction with Implant Placement in Grafted and Nongrafted Maxillas as an Objective Evaluation of Bone Density: A Possible Method for Identifying Early Implant Failures?

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ABSTRACT

Background: Bone grafts are frequently used to enable the placement of dental implants in atrophied jaws. The biomechanical properties of bone grafts used in one- or two-stage implant procedures (in comparison with the use of nongrafted bone) are not well known.

Purpose: The purpose of this study was (1) to measure cutting torques during the placement of self-tapping dental implants in nongrafted bone and in bone grafts, either as blocks or in a milled particulate form, in patients undergoing implant treatment in an edentulous maxilla and (2) to identify implants with reduced initial stability and to correlate these findings with a clinical classification of jawbone quality.

Materials and Methods: The study included 40 consecutive patients with edentulous maxillas, 27 of whom were subjected to bone grafting prior to or in conjunction with implant placement (grafting group) and 13 of whom received implants without grafting (nongrafted group). Grafted bone from the iliac crest bone was used (1) as onlay blocks, (2) as maxillary sinus inlay blocks, or (3) in particulate form in the maxillary sinus. Implants were placed after 6 to 7 months of healing, except in the maxillary sinus inlay blocks, where implants were placed simultaneously. Cutting torque values were obtained from 113 grafted implant sites and from 109 nongrafted implant sites.

Results: Significantly lower cutting torque values were assessed in grafted regions than in nongrafted regions, irrespective of grafting technique. Lower values were also seen for implants placed in block grafts after 6 months when compared to other grafting techniques used. The cutting torque values revealed an inverse linear relation to the Lekholm and Zarb bone quality index.

Conclusion: The cutting torque values correlated well with the Lekholm and Zarb index of bone quality. Significantly lower cutting torque values were seen in grafted bone than in nongrafted bone.

KEY WORDS: clinical study, cutting torque, dental implants, grafted bone, implant failure, maxilla

Adequate bone quantity and bone quality have been recognized as being of major importance to the achieving of high initial stability when dental implants are placed and are thus important for preventing early failures.[1,2] The quantity of the jawbone can be evaluated clinically[3,4] and radiographically.[5–7] Bone quality is more difficult to assess preoperatively. For cases with insufficient quantities of alveolar bone (especially in the maxilla), different bone grafting techniques have come to into use.[8–11] The evaluation of simultaneous versus delayed placement of implants in relation to the bone grafting procedure has favored a delayed procedure.[12–14] In 1985 Lekholm and Zarb presented an index for the clinical assessment of bone

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quality and quantity, based on radiographic evaluation as well as on clinical evaluation during the drilling when implants are placed.[3] Alternatively, cutting resistance, registered as a function of the energy needed to place an implant, has been recommended for the assessment of bone quality.[15] This method of assessment was further evaluated in a number of articles by Friberg and colleagues.[16–18] Significantly higher torque values were seen in the mandible as compared to the maxilla.[18] In the same article a significant correlation between cutting torque values and the clinical evaluation of bone quality in nongrafted maxillary and mandible bone was revealed. This technique has also been used in the comparison of implant designs and in the modification of preparation techniques.[19]

Preliminary data from implant stability measurements using resonance frequency in bone-grafted maxillas indicate that implant stability increases with time after LeFort I procedures with interpositional bone grafts,[20] but initial stability with other procedures for bone grafting to the maxilla has not been evaluated.

The aim of this investigation was to assess the cutting torque for placing implants in maxillary edentulous bone-grafted patients when using (1) sinus inlay bone grafts in one- and two-stage procedures and (2) alveolar onlay grafts in two-stage procedures. It was hypothesized that placing implants in maxillas augmented with autogenous bone grafts, using two-stage procedures, would require the same torque energy as would placing implants in nongrafted regions. It was also hypothesized that simultaneous placement in conjunction with bone grafting using blocks of bone (a one-stage procedure) would need more cutting torque energy than would the placing of implants in block grafts after an initial healing period (a two-stage procedure). A further objective was to determine if there was a correlation between cutting torque and implant failure and between cutting torque and a clinical estimation of bone quality.

MATERIAL AND METHODS

Patients and Treatments

Forty consecutive patients in need of oral rehabilitation with implants in an edentulous maxilla were surgically treated by one surgeon during the period of June 1994 to May 1996; 27 patients with a maxillary alveolar process height of less than 5 mm were treated with bone grafts, and 13 patients were treated without bone grafts.[21] Age and gender were equally distributed within the groups of grafted and nongrafted patients. No patient had any history either of disease or of ongoing medication influencing bone metabolism.

Bone grafting to the atrophied maxilla was performed with either the inlay or the onlay technique, either as a one-stage or two-stage procedure.[8,22–24] The graft was always harvested from the superolateral part of the iliac crest.[25] Bone blocks contained mainly cortical bone and were shaped to fit the recipient site. Particulate graft contained mainly cancellous bone. Sinus inlay grafts were used to increase the vertical alveolar height in the posterior parts of the maxilla whereas buccal onlay procedures were performed to increase the horizontal alveolar width in the anterior parts of the maxilla.

The inlay technique was performed in two ways. In the one-stage procedure (30 implants) the graft was placed as a block in the inferior part of the maxillary sinus and was stabilized to the alveolar crest with the dental implant that was placed simultaneously. In the two-stage procedure (46 implants) the graft was milled into a particulate with a bone mill (Tessier Osseous Microtome®, Stryker Leibinger, Freiburg, Germany), packed in the inferior part of the maxillary sinus cavity, and left to heal for 6 months before the delayed placement of implants.

The onlay technique was performed as a two-stage procedure (37 implants). The bone graft was trimmed to a good adaptation to the alveolar process, stabilized with 2.0 mm osteosynthesis titanium screws (Leibinger), and left to heal for 6 months before implant placement.

Control measurements (109 implants) from nongrafted regions were obtained from patients without grafts (13 patients) and from nongrafted regions in grafted patients (16 patients). The perioperative regimens and the postoperative protocol described earlier[26,27] were followed.

Self-tapping implants (Brånemark System® Mk II, Nobel Biocare AB, Göteborg, Sweden) with lengths varying from 10 to 15 mm were used. The fixture sites were always prepared with standard drill sets to a final diameter of 3.0 mm. A gentle countersinking procedure was performed to maintain the marginal cortical layer. The flaps were repositioned and sutured, leaving the implants covered with soft tissue 6 to 7 months before abutment surgery. The prosthetic work was performed as described earlier.[21] Preoperative and postoperative antibiotics and postoperative analgesics were administered according to a protocol presented earlier by Johansson and colleagues.[26] For each implant site, bone quality was clinically defined according to the classification of Lekholm and Zarb.[3]

At the 1-year follow-up a clinical evaluation of each implant was performed, including registration of objective and subjective symptoms and radiologic investigation with an intraoral technique.[28] No individual implant stability control was routinely performed. Thus this study investigated and related its findings to implant survival,[29] and any unstable implant up to the connection of the prosthetic construction was regarded as a failure and was subsequently removed. However, in patients with local symptoms up to the 1-year follow-up or when radiologic investigation indicated a failure, an individual stability test was performed, and the implant was categorized either as survived or as failed.[26]

Torque Measurements

Registrations were performed during the insertion of each implant; the electric current was directly proportional to the torque exerted by the drilling anglepiece, as previously described.[15,16] The Torque Controller DEA 020® (Nobel Biocare) used for placing implants was modified to assess the actual current. The measurements were calibrated prior to each session by subtracting the basic current needed for the anglepiece to move without any load. The voltage over a known resistance and a known current was measured. A data logger was built for the storage of the voltage data on a memory card with 8-bit resolution. After each measurement, these data were transferred to a personal computer that featured a special software application to convert the voltage needed for torque measurements into torque power as expressed in newton-centimeters (Ncm). The cutting torque values for each implant were related to the length of the actual implant and were further separated into thirds of the threaded part of each implant. The torque values were presented as the mean values of the following threaded parts: E_1 (first third), the crestal bone; E_2 (second third), the trabecular bone in the middle; and E_3 (last third), the apical bone (Figure 1). The recorded values of each implant represented the true cutting torque and the friction torque.

Statistical Methods

In the statistical analyses the data were regarded as nondependent since the cutting torque values at each site in every patient depended on the local bone structure. The level of a torque value in one region was therefore not considered to be influenced by the value of another region in the same jaw. The impact of grafting compared to nongrafting on the outcome of variables E_1, E_2, and E_3 was estimated by analysis of variance (ANOVA) and with corresponding post hoc test (Tukey test) pair-wise comparisons.[30]

To analyze the impact of the specific types of graft, inlay/onlay, and 1-stage/2-stage procedures on E_1, E_2, and E_3 levels, a two-way ANOVA was performed.[30] ANOVA was also used to test the three quality categories (2, 3, and 4) with respect to the outcome variables E_1, E_2, and E_3. Planned comparison for trend analysis was used as a post hoc comparison to test the correlation between these quality levels and the energy measurements. To predict the outcome (failure or nonfailure), E_1, E_2, and E_3 levels have been used as possible predictors, discriminant and analyzed by logistic regression, estimating the odds ratio.[30] For the statistical analysis the software program *STATISTICA*®

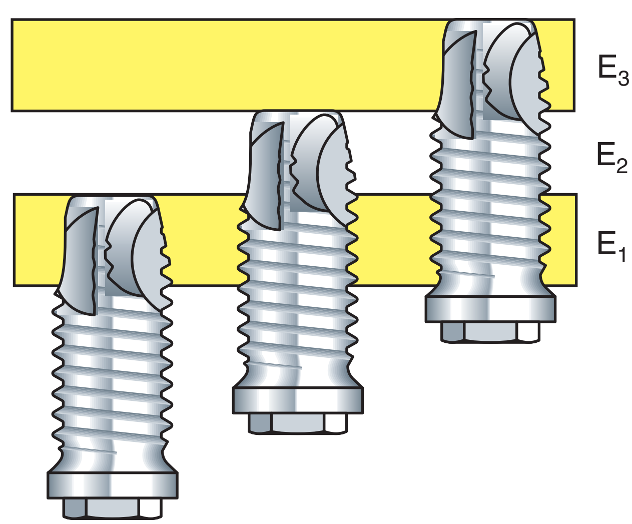

Figure 1 The levels of E_1, E_2, and E_3 represent the mean torque when inserting the Mk II implant in the first, second, and third sections of the site. Because of its conical design the apical tip of the implant is excluded from the measurements. (Published with permission from Lars Sennerby, Sweden.)

TABLE 1 Cutting Torque Values* in the Four Grafted Situations†

	1-Stage Inlay Block	2-Stage Onlay Block	2-Stage Inlay Particulate	Nongrafted (Control)
	Mean (SD) (*n* = 30)	Mean (SD) (*n* = 37)	Mean (SD) (*n* = 46)	Mean (SD) (*n* = 109)
E_1	18.7 (6.2)	**11.2 (5.5)**	14.7 (8.0)	21.3 (8.6)
E_2	**27.9 (15.6)**	**17.8 (9.8)**	**21.9 (13.3)**	43.1 (23.3)
E_3	**43.9 (30.3)**	34.7 (15.1)	**41.1 (26.0)**	73.0 (40.3)

n = number of implants.
*Expressed as newton-centimeters (Ncm).
†Torque values from grafted regions are marked in bold type.

5.5 (StatSoft, Inc., Tulsa, OK, USA) was used. The level of significance was set to $p < .05$ (two-sided test).

RESULTS

Clinical Findings

Five implants in the grafted groups and three implants in the nongrafted group were excluded because of technical problems during registration or because an alternative type of implant was used, which resulted in a study group of 113 implants and 109 implants from nongrafted regions. Thirty implants were found to be mobile during the period from the abutment surgery to the 1-year control. Of the failed implants, 15 were registered before loading and were regarded as early failures; the remaining 15 failed implants were classified as late failures. Twenty of the failures occurred in four patients. The overall survival rate was 87%.

Cutting Torque Measurements

The measurements were separated into four categories: one-stage inlay, two-stage inlay, two-stage onlay, and implants in nongrafted regions (controls). The registrations for E_1, E_2, and E_3 are presented as means and standard deviations in Table 1. Each of the grafting techniques showed a linear increase of energy needed for implant placement within the three levels of registration (E_1, E_2, and E_3). The measurements were further divided into groups representing total failures, early failures, and surviving implants; the torque energies for each group are shown in Table 2. The material was also divided into quality levels (2 to 4) according to the Lekholm and Zarb classification (Table 3).

Statistical Analyses

Mean cutting torque values within the E_1, E_2, and E_3 levels in the regions grafted with the three grafting procedures were compared to each other and to the mean values of the nongrafted regions (see Table 1). A comparison of inlay (particulate) grafts and onlay (block) grafts in the two-stage groups after 6 months of healing revealed that significantly higher torque values were needed for placing implants in particulate (inlay) grafts than for placing implants in block (onlay) grafts ($p < .001$). The analyses of the two variants of

TABLE 2 Cutting Torque Values* for All Failures, Early Failures, and Survivor Implants

	All Failures	Early Failures	Survivors
	Mean (SD) (*n* = 28)	Mean (SD) (*n* = 15)	Mean (SD) (*n* = 194)
E_1	18.0 (8.3)	14.3 (7.0)	17.2 (8.3)
E_2	25.9 (14.8)	21.9 (13.1)	29.0 (18.5)
E_3	44.1 (28.5)	34.8 (23.0)	52.8 (31.6)

n = number of implants.
*Expressed as newton-centimeters (Ncm).

TABLE 3 Cutting Torque Values* in Relation to Bone Quality According to Lekholm and Zarb Classification

	Quality 2	Quality 3	Quality 4
	Mean (SD) (*n* = 31)	Mean (SD) (*n* = 135)	Mean (SD) (*n* = 56)
E_1	23.3 (8.0)	17.9 (8.4)	13.6 (6.1)
E_2	43.7 (19.8)	28.6 (17.8)	20.2 (11.0)
E_3	82.9 (36.6)	50.4 (27.9)	37.1 (22.8)

Adapted from Lekholm U, Zarb GA.[3]
*Expressed as newton-centimeters (Ncm).

TABLE 4 Statistically Significant Correlations between the Different Regions of Grafted and Nongrafted Maxillary Bone

Graft and Region	Correlation	Significance
2-stage onlay E_1	Less torque than control E_1	S, $p < .001$
2-stage onlay E_2	Less torque than control E_2	S, $p < .001$
2-stage inlay E_2	More torque than 2-stage onlay E_1	S, $p < .001$
2-stage inlay E_3	More torque than 2-stage onlay E_2	S, $p < .001$
1-stage inlay E_2	More torque than 2-stage onlay E_1	S, $p < .001$
1-stage inlay E_3	More torque than 2-stage onlay E_2	S, $p < .001$

E_1 = crestal region; E_2 = middle region; E_3 = apical region; S = significance.

block grafts (ie, one-stage inlay and two-stage onlay) demonstrated that significantly higher torque values were required for the one-stage inlay procedures. In relation to the control procedure, significantly lower torque values were seen for the delayed block graft two-stage onlay procedure (Table 4). When torque measurements were compared with clinical estimates of bone quality according to the Lekholm and Zarb classification, a strong correlation was seen on all levels ($p < .001$). At all levels, the placement of implants in type 4 bone required the least torque, and placing implants in type 2 bone needed the most. In the analyses of implant failures (total and early, before loading), lower torque values were registered as compared to those for clinically stable implants. However, these differences were not statistically significant.

DISCUSSION

A strong and statistically significant inverse correlation between bone quality and cutting torque values ($p < .001$) for all levels of the implant sites (E_1 to E_3) was demonstrated (see Table 4). The relevance of the clinical and subjective assessment of bone quality with the Lekholm and Zarb index could in this way be arbitrarily verified by an objective measuring technique, as shown earlier.[16] Placement of implants in type 4 bone demanded the least torque, which seems reasonable as this bone density is morphologically characterized by only a thin layer of cortical bone surrounding a core of low-density trabecular bone.[3] Probably because of the limited size of the material, as in the study by Friberg and colleagues in 1999, it was not possible to confirm previous results[2,31] showing that the majority of failures occurred in type 4 bone. Cutting torque values were lower for placing implants in grafted bone than for placing implants in nongrafted regions. The difference between nongrafted and grafted particulate bone after 6 months (two-stage procedure) was, however, not statistically significant. The least torque was needed for placing implants in onlay block grafts after 6 months of healing. Six months is a too-short period of healing, probably due to the fact that revascularization and the normalization of mechanical properties take longer for a block graft than for a cancellous graft.[32,33] Also, when torque values for one-stage and two-stage block grafts were compared, the grafts that were performed after 6 months of healing needed significantly lower torque. That the morphologic changes of a one-stage block graft after 4 months of healing explains these differences has been shown in an autopsy case report.[34] It was also found that particulate bone grafts after 6 months needed higher cutting torque values for placing implants than block grafts did after 6 months. Particulate cancellous bone grafts have been shown to have a faster revascularization time than block grafts have and to be biologically more active after 6 months.[13,32] In the clinical situation, delayed placement of implants has therefore been recommended.[14]

In all regions the cutting torque values for failed implants were lower than the corresponding values for survived stable implants, but the differences were small and could not be statistically verified. Looking specifically on the early failures, before loading, no significant difference was seen as compared to nonfailures. Early failures can be regarded as host related and due to biologic causes.[35] However, implants fail for several reasons; it is unlikely that a single evaluation of the local alveolar bone density can single out one of these reasons. Individualizing the length of the healing period in accordance with the results of torque measurements seems reasonable and should probably also be adapted to the level of occlusal load as stated by Friberg and colleagues.[36]

The "early-failed" implants in this study could not be related to any particular clinical event during surgery or during the healing period. A careful control of the occlusal load factors on implants placed in bone grafts until complete bone remodeling has occurred is probably mandatory.

CONCLUSION

The possible use of cutting torque measurements in determining bone quality in bone-grafted maxillas was demonstrated in this study although it was not possible to identify implants that were at risk of failure. A low torque value, in combination with other negative prognostic influencing factors, should necessitate extra checkups. The results from this study rejected our initial hypothesis since maxillary bone grafts, used as blocks or in particulate form after milling, did not achieve biomechanical properties similar to those of nongrafted maxillary bone as assessed with cutting torque measurements. The hypothesis that delayed implant placement in block grafts, after 6 months of healing, results in lower cutting torque values than does simultaneous implant placement in block grafts was confirmed and supports earlier results showing that the incorporation and remodeling of cortical block grafts takes longer than 6 months.[32]

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