Implant Stability during Initiation and Resolution of Experimental Periimplantitis: An Experimental Study in the Dog

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ABSTRACT

Background: Histologic studies have demonstrated the possibility to reestablish direct bone-implant contacts after ligature-induced periimplantitis. The influence of the reosseointegration on the stability of implants is not known.

Purpose: The aim of the present investigation was to study bone tissue and associated implant stability alterations that occurred during induction and resolution of periimplantitis using resonance frequency analysis (RFA), radiography, and histology.

Materials and Methods: Three implants with smooth (turned) or roughened (SLA®) surfaces were placed in each side of the edentulous mandible of four dogs. Experimental periimplantitis was induced for 3 months. Five weeks later, the animals were treated with antibiotics and surgical therapy and were followed for another 6 months. Periapical radiographs and RFA were used to evaluate marginal bone levels and implant stability throughout the study period. After termination, the tissue-implant interface was evaluated by light microscopy in ground sections.

Results: There was a linear relationship between radiographic and RFA findings because continuous loss of marginal bone and a decrease in implant stability were observed for both implant surfaces during the periimplantitis period. Antibiotic treatment and surgical therapy resulted in some reosseointegration, which was more marked for the SLA surface. The resonance frequency values corresponded well to the histometric measurements because reosseointegration resulted in an increase in implant stability.

Conclusions: The findings from the present study indicate a linear relationship between marginal bone level and resonance frequency value. It is suggested that the RFA technique is sensitive and may be used to detect even a minor change in the level of bone-implant contact.

KEY WORDS: bone loss, radiography, reosseointegration, resonance frequency analysis

The soft and mineralized tissues that surround implants placed in the fully or partially edentulous patient are continuously exposed to microbiologic and biomechanical challenges. The host response to such exposure includes the establishment of inflammatory and/or adaptive lesions in the periimplant tissues, which eventually may include events of bone resorption. Continued bone loss may jeopardize implant stability and function. In such cases, it is mandatory to identify and remove the cause of the lesion and, ideally, to regenerate bone tissue and restore osseointegration.

In experiments involving various animal models, it was documented, using radiographic and histologic means, that periimplantitis lesions may be predictably produced—by ligature placement and plaque accumulation—and be successfully treated by measures that included débridement of the implant surface

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and curettage of the bone defect (for a review, see Klinge and colleagues[1]). Furthermore, at implants with a modified (roughened) surface topography, treatment of such lesions enabled new bone to form not only in the periimplant defect but also on most of the previously exposed implant surface, that is, de novo osseointegration occurred.[2–4]

Marginal bone level measurements in intraoral radiographs are commonly used to evaluate the clinical performance of oral implants.[5] Resonance frequency analysis (RFA) is another and more recently developed technique for monitoring of implants.[6] With this technique, the resonance frequency (RF) of a transducer attached to the implant is measured. The RF value reflects the implant stability as a function of interface stiffness and is influenced by the distance from the transducer to the first bone contact.[7] Thus, the technique is sensitive to changes in the marginal bone level[6,8] and may be used as a complementary technique to radiography.

The aim of the present investigation was to study bone tissue and associated implant stability alterations that occurred during induction and resolution of periimplantitis using different assessment techniques.

MATERIALS AND METHODS

Four beagle dogs were used in the study. The mandibular first, second, third, and fourth premolars were extracted 12 months prior to the start of the experiment (Figure 1).

Surface Topography

Implants (solid screw, 8 × 3.3 mm, ITI Dental Implant System®, Straumann AG, Waldenburg, Switzerland) with either an SLA® (roughened; Straumann AG) or a turned (smooth) surface topography were used in the study. Prior to the start of the study, one SLA and one turned implant were selected and examined by using an interferometer (MicroXam, Phase-Shift, Tucson, AZ, USA) (Figure 2). The Sa values (the absolute values of the surface departures from a mean plane) of the SLA and turned surfaces were found to be 2.29 ± 0.59 μm and 0.35 ± 0.17 μm (Table 1). This indicates that the surface of the turned implants used in the current study was smoother than that of commercially available implants (A. Wennerberg, personal communication, 2005). The corresponding Sds values (number of peaks per area unit) were 0.06 ± 0.04 (SLA) and 0.09 ± 0.02 (turned). The Sdr values that describe the ratio between the developed surface area and a flat reference area were 115.8 ± 55% for the SLA and 5.7 ± 3.7% for the turned surface.

Experimental Periimplantitis

Six implants were placed in the edentulous regions of the mandible, three implants with a turned surface (left side) and three implants with an SLA surface (right side). After implant installation, the remaining teeth and the implants were cleaned twice a week. Three months after implant installation, the plaque control program was terminated and plaque was allowed to form. Periimplantitis was induced by placing cotton ligatures in a submarginal position and in accordance with methods previously described.[9] Ligatures were replaced every third week for 3 months, at which interval the ligatures were finally removed. Regenerative therapy, including open flap débridement and cleaning of the implant surfaces, was performed 4 weeks later (for details, see

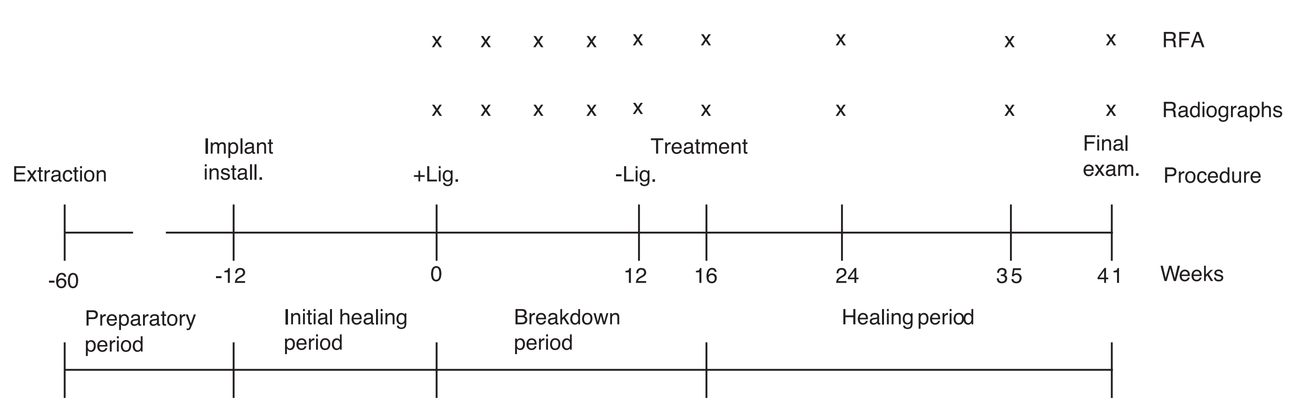

Figure 1 The outline of the experiment. Ligatures were placed around the implants at 0 weeks (+Lig.) and removed at 12 weeks (−Lig.). Treatment was performed at 16 weeks. Biopsies were obtained at 41 weeks. RFA = radiofrequency analysis.

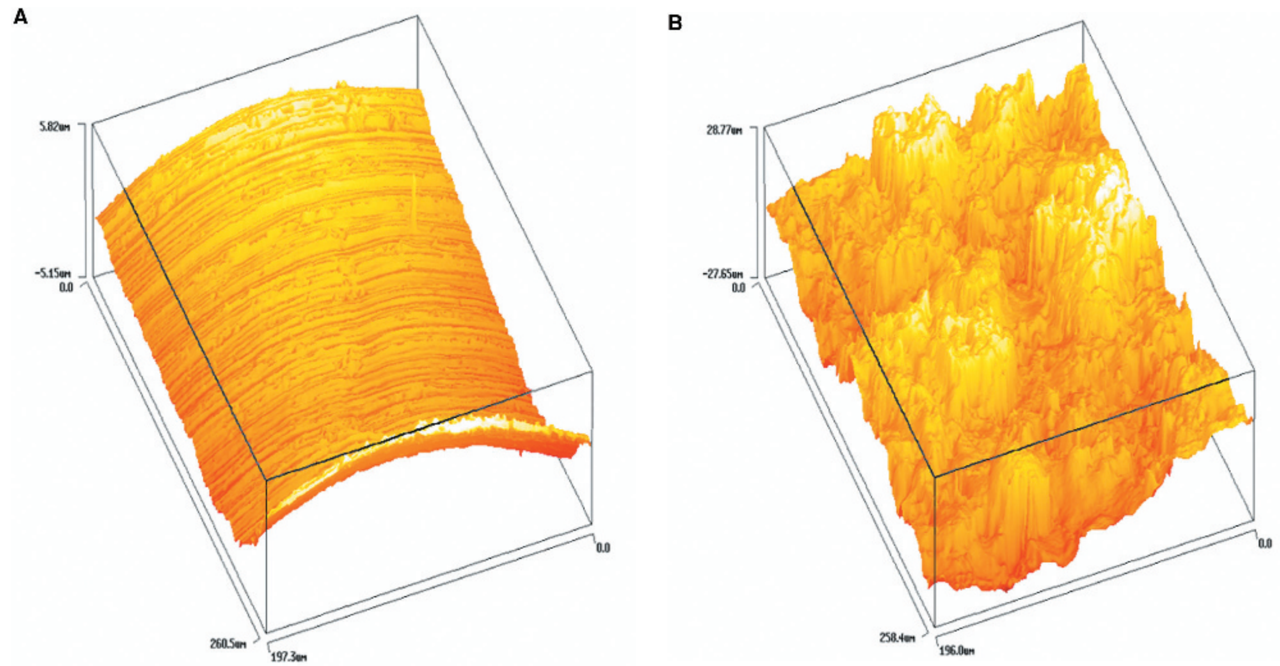

Figure 2 *A*, Three-dimensional illustration of the surface of a turned implant as obtained from interferometry. *B*, Three-dimensional illustration of the surface of an SLA implant as obtained from interferometry.

Persson and colleagues[3,4]). Twenty-five weeks after treatment, the final examinations were performed and biopsies were obtained and prepared for histologic examination (for details, see Persson and colleagues[3]).

Radiographic Examinations

Standardized radiographs were obtained from each experimental site at different intervals (see Figure 1) using individualized film holders (Hawe-Super-Bite, Hawe-Neos Dental, Bioggio, Switzerland). The radiographs were analyzed using a computerized image system (Image Access, Bildanalys AB, Stockholm, Sweden). The distance from the implant shoulder (rIS) to the marginal bone level (rBL) next to the implant was measured at the mesial and distal aspects of the implant.

Resonance Frequency Analysis

RF measurements were performed immediately after each radiographic examination (see Figure 1) and according to a method described by Meredith and colleagues.[6] In brief, the resonance frequency of an L-shaped transducer attached to the implant was measured by means of a frequency response analyzer (IA296-Implant Analyser, Prototype unit version, Macro Design Ltd, London, England) (Figure 3). Measurements were made both perpendicular and parallel to the long axis of the implant.

TABLE 1 Results from the Topographic Analyses of Turned and SLA Surfaces

Implant	Sa (μm)	Sds (*n*)	Sdr (%)
Turned	0.35 (0.17)	0.09 (0.04)	5.7 (3.7)
SLA	2.29 (0.59)	0.06 (0.02)	115.8 (55.0)

Mean values and standard deviation for measurements at three locations.

Histologic Examinations

The histologic examination was performed in a Leitz DM-RBE microscope (Leica, Solms, Germany) equipped with an image system (Qwin, Leica). The following landmarks were used for the linear measurements: implant shoulder (IS), base of the defect (BD), the marginal level of bone in contact with the implant, and the adjacent bone crest (BC).

Data Calculation

Mean values were calculated for each variable, implant, animal, and examination interval.

RESULTS

Radiographic Findings

The mean rIS and the rBL of the adjacent bone (marginal bone level; see Figure 3) prior to ligature placement (week 0) was 3.7 ± 2.05 mm at the SLA and 2.8 ±

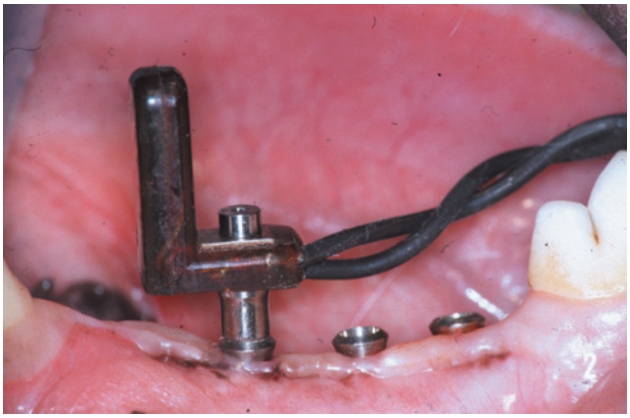

Figure 3 Clinical photograph showing the radiofrequency analysis transducer attached to an implant.

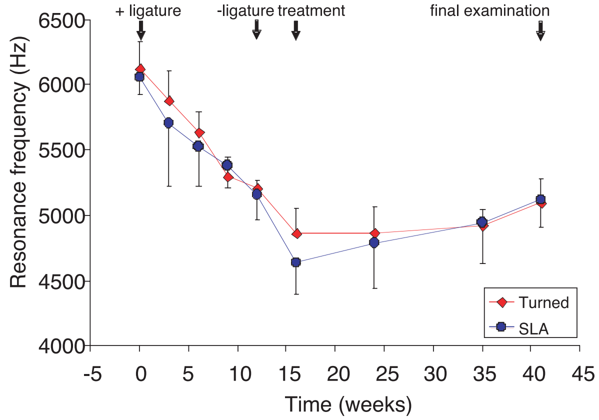

Figure 5 Changes in implant stability during ligature-induced breakdown and following surgical treatment (mean ± SD).

0.15 mm at the turned implant sites (Figure 4). During the period of experimental periimplantitis (weeks 0–12), an additional reduction in the rBL occurred. Thus, in this interval, the rIS to rBL distance increased, on average, 3.1 ± 1.2 mm (SLA) and 3.4 ± 0.3 mm (turned). Before treatment, the rIS to rBL distances were 6.7 ± 0.91 mm (SLA sites) and 6.1 ± 0.22 mm (turned sites). During the healing phase following treatment, there was some gain of bone. The reduction in the rIS to rBL distance in the interval between weeks 16 and 41 was 1.1 ± 0.5 mm (SLA sites) and 1.0 ± 0.3 mm (turned sites).

RF Values

During the phase of ligature-induced periimplantitis (weeks 0–12), the RF values at all implant sites markedly decreased (Figure 5). This reduction was more pronounced at SLA sites (1,424 ± 201 Hz) than at the turned sites (1,266 ± 186 Hz). During the healing phase

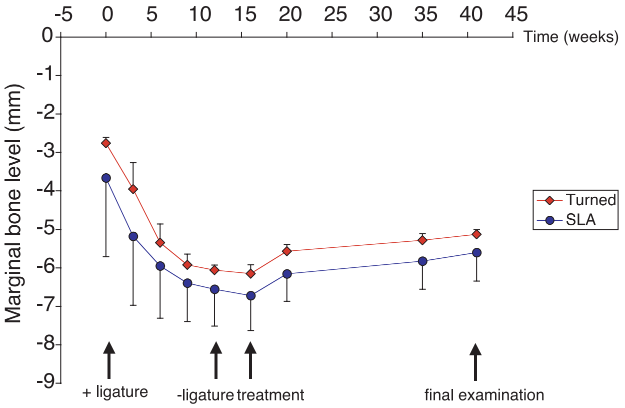

Figure 4 Changes in marginal bone level in radiographs with time (mean ± SD).

(weeks 16–41), the RF values increased more at the SLA (483 ± 172 Hz) than at the turned (238 ± 161 Hz) implant sites.

At the end of the experiment, the mean RF values of the two different sites were almost identical: 5,099 ± 182 Hz and 5,119 ± 210 Hz.

Histologic Findings

The mean distance between the IS and the BD at the experimental sites was 6.23 ± 0.73 mm (SLA) and 5.66 ± 0.25 mm (turned) (Table 2). The mean depth of the experimentally produced bone defect (BD–BC) was 1.69 ± 0.48 mm (SLA sites) and 2.07 ± 0.38 mm (turned sites). At SLA sites, the mean height of the zone of reosseointegration was 1.17 ± 0.29 mm, whereas the corresponding zone at the turned sites measured 0.44 ± 0.12 mm.

DISCUSSION

The results from the present experimental study disclosed that, during the phase of experimental periimplantitis,

TABLE 2 Results from the Histometric Measurements

Measurement	Turned Sites	SLA Sites
IS–BD	5.66 (0.25)	6.23 (0.73)
BD–BC	2.07 (0.38)	1.69 (0.48)
Reosseointegration (A-B)	0.44 (0.12)	1.17 (0.29)

BD–BC = base of the defect to the bone crest (depth of the defect); IS–BD = distance from the implant shoulder to the base of the defect; A–B = base of the defect to the most coronal bone contact.
Mean values and standard deviations for turned and SLA sites in millimeters.

SLA and turned implant sites exhibited pronounced bone loss and reduced implant stability. Healing following regenerative surgery was characterized by improved implant stability that was more pronounced at SLA than at turned implant sites. The histologic data confirmed the outcome of the RF determinations and documented that during healing, substantially more reosseointegration had occurred at SLA than at turned implants. No differences could be observed between the two types of implants, however, regarding radiographic bone level change during the various phases of the experiment. It is suggested that repeated RF determinations may disclose even a discrete bone level change that occurs at implants during breakdown and buildup of periimplant bone tissue.

The RF value is determined mainly by two factors.[7] One factor is related to the stiffness of the bone-implant system (interfacial stiffness) and the second to the distance between the transducer and the most marginal level of bone-implant contact (the effective implant length). The implants used in the present experiment were in part placed in dense mandibular bone. This resulted in high initial implant stability. Most of the RF value change that occurred in the present experiment can probably be explained in terms of a change in effective implant length. During the phase of experimental periimplantitis, between 3.1 and 3.4 mm of bone was lost. In the same interval, the RF values, and hence implant stability, decreased between 1,266 and 1,424 Hz units. The results thus indicate that there seemed to be a linear relationship between bone loss and a decrease in RF values. This assumption is in agreement with results from previous studies.[6,8] Based on measurements performed on all implant sites included in the current experiment, it could be estimated that 1 mm of bone loss corresponded to a decrease in the RF value that amounted to 413 Hz. The difference in bone loss that occurred in the interval week 0 and week 12 between the SLA and turned implant sites amounted to 0.3 mm. This difference would correspond to an estimated RF change of 124 Hz, a value that is close to the measured difference between the sites of 158 Hz.

During healing following treatment, the RFA measurements indicated a more marked improvement in the stability of the SLA than of the turned implants (483 vs 238 Hz). The RF value for the SLA implants corresponded well to the expected increase based on the radiographic measurements and the calculations discussed above. Because the turned implant sites exhibited a degree of bone gain in the radiographs similar to that of the SLA sites, a similar increase in the RF value may have been expected. This, however, did not occur. The reason for this reduced increase in the RF value at the turned sites may be explained by observations made in histologic sections representing week 41. Both at SLA and turned implant sites, most of the bone defects were resolved during healing by the formation of new bone. At the turned implant sites, in contrast to the SLA sites, however, this new bone was consistently separated from the implant surface by a thin capsule of connective tissue. The above data thus indicate that the RFA technique is sensitive and may be used to detect even a minor change in the level of bone-implant contact.

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