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Does excessive occlusal load affect osseointegration? An experimental study in the dog

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Abstract

Aim: The purpose of this study was to evaluate the effect of excessive occlusal load following placement of titanium implants in the presence of healthy peri-implant mucosal tissues.

Materials and methods: Mandibular bilateral recipient sites in six Labrador dogs were established by extracting premolars and molars. After 3 months, two TPS (titanium plasma sprayed) implants and two SLA (sandblasted, large grit, acid etched) implants were placed on each side of the mandible in each dog. Three implants were lost in the initial healing phase, leaving 45 implants for evaluation. Following 6 months of healing, gold crowns were placed on implants on the test side of the mandible. The crowns were in supra-occlusal contact with the opposing teeth in order to create excessive occlusal load. Implants on the control side were not loaded. Plaque control was performed throughout the experimental period. Clinical measurements and standardised radiographs were obtained at baseline and 1, 3 and 8 months after loading. At 8 months, the dogs were killed and histologic analyses were performed.

Results: At 8 months, all implants were osseointegrated. The mean probing depth was 2.5 ± 0.3 and 2.6 ± 0.3 mm at unloaded and loaded implants, respectively. Radiographically, the mean distance from the implant shoulder to the marginal bone level was 3.6 ± 0.4 mm in the control group and 3.7 ± 0.2 mm in the test group. Control and test groups were compared using paired non-parametric analyses. There were no statistically significant changes for any of the parameters from baseline to 8 months in the loaded and unloaded implants. Histologic evaluation showed a mean mineralised bone-to-implant contact of 73% in the control implants and 74% in the test implants, with no statistically significant difference between test and control implants.

Conclusion: In the presence of peri-implant mucosal health, a period of 8 months of excessive occlusal load on titanium implants did not result in loss of osseointegration or marginal bone loss when compared with non-loaded implants.

Osseointegration is a term defined as a direct bone deposition on implant surfaces at the light microscopic level (Brånemark et al. 1977). This functional unit, able to transmit occlusal forces to the alveolar bone, has also been described as 'functional ankylosis' (Schroeder et al. 1981). The 'direct structural and functional connections between ordered, living bone and the surface of a load-bearing implant' (Listgarten et al. 1991) is a more comprehensive way of characterising this unique bonding of a foreign body to living bone.

Following the preparation of an implant bed, osseointegration generally follows three stages: (1) incorporation by woven

bone formation, (2) adaptation of bone mass to load lamellar and parallel-fibred deposition and (3) adaptation of bone structure to load (bone remodelling), (for a review, see Schenk & Buser 1998).

During the third stage of osseointegration when functional loading has been initiated, the bony structures will adapt to the load by improving the so-called 'quality' of bone replacing pre-existing, necrotic and/or initially formed more primitive woven bone with mature viable lamellar bone. This leads to a functional adaptation of the bony structures to load by changing dimensions and orientation of the supporting elements.

The process of osseointegration may be jeopardised by a variety of factors associated with surgical trauma or preparation of implant sites. Thus, tissue necrosis may result during early phases of healing, leading to the loss of the implant. Usually, these implant failures are referred to as early failures and are generally not encountered beyond a period of 3–6 months following implant installation. However, the causes for late implant complications leading to failure, i.e. tissue disintegration following functional loading, are still under exploration.

There is ample evidence that bacterial colonisation on the implant surface leads to mucositis (Berglundh et al. 1992; Ericsson et al. 1992; Pontoriero et al. 1994) and, if the peri-implant bony levels are affected, to peri-implantitis (Lindhe et al. 1992; Lang et al. 1993). If untreated, these conditions may progress and lead to the necessity of implant removal. Evidence for bacterial aetiology in the role of peri-implant infections has recently been reviewed at the Third European Workshop on Periodontology in 1999 (Mombelli 1999). In brief: (1) Experimentally induced plaque accumulation on implant surfaces leads to peri-implant mucositis (Berglundh et al. 1992; Pontoriero et al. 1994). (2) Distinctive quantitative and qualitative differences in the microbiota associated with successful or failing implants have been documented (Rams & Link 1983; Rams et al. 1984; Mombelli et al. 1987; Becker et al. 1990; Sanz et al. 1990; Alcoforado et al. 1991; George et al. 1994; Augthun & Conrads 1997; Salcetti et al. 1997). (3) The peri-implant microbiota is established shortly after implant placement, and no shifts in microbial composition over time are observed with successful implants (Adell et al. 1986; Mombelli et al. 1988; Apse et al. 1989; Bower et al. 1989; Mombelli & Mericske-Stern 1990). (4) Periodontal pathogens may be transmitted from residual periodontal pockets to peri-implant sulci (Apse et al. 1989; Quirynen & Listgarten 1990; Koka et al. 1993; Leonhardt et al. 1993; Kohavi et al. 1994; Mombelli et al. 1995). (5) Induction of peri-implant infections by placement of plaque retentive ligatures in animals was successful in inducing marginal bone resorption resulting in angular bony defects (Lindhe et al. 1992; Lang et al. 1993; Schou et al. 1993). (6) Therapy aimed at a reduction of the peri-implant microbiota improved the clinical health of the peri-implant tissues (Mombelli & Lang 1992; Ericsson et al. 1996; Schenk et al. 1997; Mombelli et al. 2001). (7) More bone resorption was identified around fixtures in edentulous patients with poor oral hygiene than in subjects with good oral hygiene (Lindquist et al. 1988). (8) Antimicrobial therapy resulted in bone fill into peri-implant angular lesions (Persson et al. 1999; Wetzel et al. 1999). New experiments have revealed the possibility of reosseointegration to the previously contaminated implant surface under specific conditions (Persson et al. 2001).

In the light of this overwhelming evidence of the infectious nature of peri-implant lesions, it is reasonable to assume that most peri-implant bone losses may be attributed to the development of an opportunistic infection in the peri-implant sulcus.

Nevertheless, speculations regarding occlusal overload being a causative or contributing factor in late implant failures continue to be a point of discussion (Sanz et al. 1991; Quirynen et al. 1992). However, evidence for this theory is almost completely lacking. On the contrary, in the absence of infection, neither statically nor dynamically applied forces in experimental models have resulted in the induction of peri-implant bone loss (Gotfredsen et al. 2001a, 2001b, 2001c, 2002).

There is, however, one animal experiment providing evidence for the implication of occlusal load in the pathogenesis of peri-implant bone loss. Implants placed in loosely trabecular bone or with a limited bone-to-implant contact were, indeed, losing osseointegration along the entire implant surface (Isidor 1996, 1997).

The aim of the present investigation was, therefore, to study the effect of excessive occlusal load following placement of titanium oral implants and in the absence of peri-implant infection.

Materials and method

Animal model

A Labrador animal model was used to study the effect of chewing forces at osseointegrated titanium oral implants. The research proposal was approved by the Animal Ethics Committee of the Faculty of Odontology, University of Lund, Malmö, Sweden. The experimental outline of the study is presented in Fig. 1.

Mandibular bilateral recipient sites were prepared for implant installation in six dogs following removal of the first and second molars and all premolars. After a healing period of 3 months, full thickness flaps were elevated, and a total of eight titanium implants (ITI Dental Implant System, length 8 mm, diameter 4.1 mm) were placed in each dog. On each mandibular side, two titanium plasma sprayed (TPS) implants and two titanium, sandblasted and acid etched (SLA) implants were placed (Fig. 2A). The installation was performed according to the manufacturer's recommendation, and healing was allowed in a

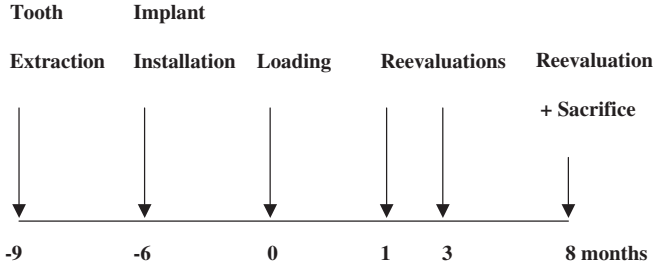

Fig. 1. Experimental outline: animals $n = 6$; implants $n = 48$.

non-submerged, transmucosal modality. Sutures were removed 1 week postsurgically. A stringent mechanical (daily implant brushing) and chemical plaque control programme (daily 0.2% chlorhexidine spray) was instituted and maintained for the entire duration of the experiment.

'Excessive loading'

After 6 months of healing (Fig. 2B), impressions were taken and gold crowns were fabricated and fitted to the implants on the test side of the mandible. Implants on the control side of the mandible did not receive crowns. The crowns to be incorporated were waxed up with a supra-occlusal contact pattern and oblique occlusal planes to ensure premature contacts with opposing teeth in order to create an occlusal load that was expected to exceed that of the normal physiologic range (Fig. 2C). The control implants and remaining front teeth did not yield occlusal contacts during mastication. Hence, the definition of 'excessive load' used in this study was the reconstruction of the dog's centric occlusion in a 'hypercontact' with an increased vertical dimension of at least 3 mm.

Clinical parameters

At the time the crowns were placed on the test implants, baseline clinical measurements and standardised radiographs were obtained following fixation of an acrylic film holder and aiming device to the implants. The clinical measurements included the modified plaque index (Mombelli et al. 1987) and the presence or absence of bleeding on probing (BOP) (Lang et al. 1986) using a 0.2 N standardised pressure. Furthermore, the distance from the implant shoulder to the mucosal margin (DIM) and the distance from the mucosal margin to the bottom of the sulcus/pocket (peri-implant probing depth, PPD) were measured using the same standardised probing pressure. These measurements were repeated after 1, 3 and 8 months following loading of the test implants. Probing measurements were obtained at four sites per implant (mesial, distal, buccal and lingual). At the same observation intervals, standardised radiographs were obtained after unscrewing the gold crowns and fixing the acrylic film positioners to the implants using screw retention. Subsequently, the aiming device was applied and the radiographs were obtained using identical exposure geometry. After the standardised radiographs were taken, the single gold crowns were again screw retained to the implants.

At the final observation period, i.e. 8 months following loading, the dogs were killed by an overdose of sodium-pentothal (Abbot Laboratories, Chicago, IL, USA). Immediately after the clinical and radiographic measurements, the dogs were perfused through the carotid arteries with a fixative consisting of a mixture of 5% glutaraldehyde and 4% formaldehyde buffered to pH 7.2 (Karnovsky 1965). The mandibles were then removed, immersed in fixative (10% formalin) and transferred to the histology laboratory (University of Berne, Switzerland).

Histologic preparation

Block biopsies of each implant site were dissected, and the tissue blocks were fixed in 4% neutral buffered formalin for at least 48 h. The specimens were then rinsed in running tap water, trimmed and dehydrated in a graded series of increasing ethanol concentrations. Subsequently, they were embedded in methylmethacrylate without prior decalcification. Tissue blocks were cut into 400–500 µm thick vertical sections in the long axis of the implants buccolingually using a slow-speed diamond saw (Varicut ®VC-50; Leco, Munich, Germany). After mounting the sections onto acrylic glass slabs, they were ground and polished to a final thickness of 80 µm (Knuth-Rotor-3; Struers, Rødovre/Copenhagen, Denmark) and surface stained with toluidine blue (Schenk et al. 1984).

Histomorphometry

Three representative sections were chosen for analysis from each block. Linear measurements were carried out directly in the light microscope at a magnification of 30-fold. The following measurements were made on both the buccal and lingual sides of each section: (1) Implant length, i.e. distance from the implant shoulder to the base of the implant. (2) Distance from the base of the implant to the most coronal point of bone-to-implant contact. (3) Distance from the base of the implant to the alveolar bone crest (Fig. 3). This allowed the height of bone in relation to fixed landmarks on the implant to be determined.

Further histometric measurements were performed in order to calculate the percentage of mineralised bone in contact with the implant surface (A) and 1 mm distant to the implant surface (B) (Fig. 3). These measurements were performed in the light microscope at a magnification of 160-fold using an optically superimposed eyepiece test

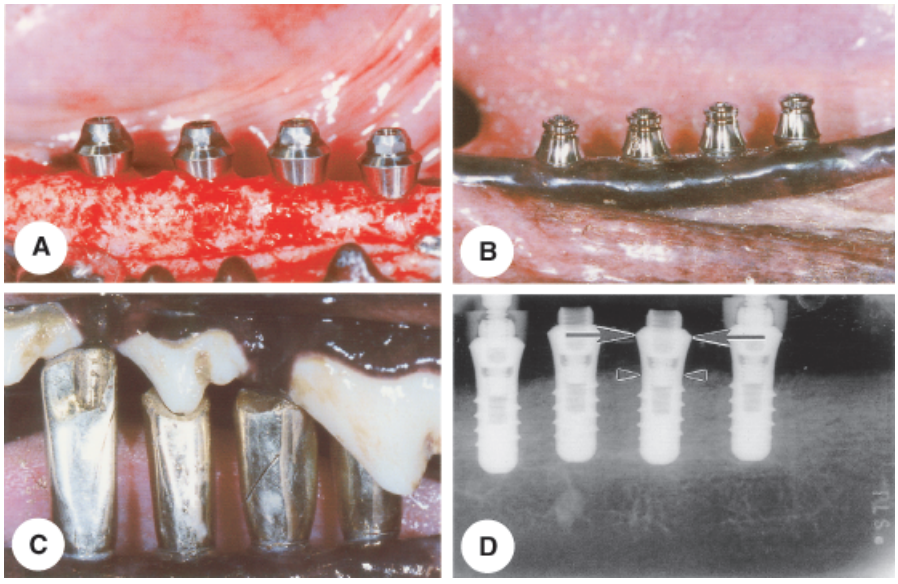

Fig. 2. (A) Clinical view of four ITI® implants at the time of placement in one side of the mandible. (B) Clinical view of ITI® implants after 6 months of non-submerged healing. (C) Clinical view of the test side of the mandible in one dog. Note the four single gold crowns in supra-occlusal contact with opposing teeth. (D) Standardised radiograph illustrating the level of the implant shoulder (arrows), and the first bone-to-implant contact visible in the radiograph (arrowheads), at the mesial and distal surfaces of the implant.

grid composed of 100 points and 10 cycloid lines (Schenk & Olah 1980; Weibel 1980). The test grid was superimposed over the implant section, and the number of points of intersection between the test lines and the outlines of mineralised bone and non-mineralised tissue were recorded. These parameters were measured both on the buccal and lingual sides in the coronal and apical half of the histologic sections. The morphometric analysis was performed twice in 10% of the sections to ensure that the intra-examiner reproducibility was not lower than 95%. All measurements were performed by one examiner (SG), who was unaware of the assignment to test and control implants. The values for the three representative sections were averaged for each implant.

Radiographic assessment

Linear measurements were made on the standardised and digitised radiographs using a computer program (Brägger et al. 1992). Measurements were performed at the mesial and distal aspects of each implant. The distance from the implant shoulder to the first bone-to-implant contact (DIB) visible in the radiograph was measured at baseline and after 8 months (Fig. 2D). Repeated measurements were also made 1 day later to ensure that the intra-examiner reproducibility was not lower than 95%. All measurements were performed by one examiner (LH), who was unaware of the assignment to test and control implants.

Statistical analysis

Non-parametric paired tests were used for statistical analyses. Paired tests were used to test for differences over time within control and test groups and for differences between test and control implants within each dog. They were also used to test for differences between TPS and SLA surfaces and buccal and lingual aspects. The Wilcoxon matched pairs signed-ranks test was used for paired tests. The level of significance was set at $P<0.05$.

Results

During the initial healing phase of tissue incorporation, three implants were lost after 3 months. In one animal, one TPS implant of the test group and one SLA implant of the control group were lost. Another TPS implant of the test group was lost in another animal. This left 45 implants for evaluation: 22 test and 23 control implants. The test implants consisted of 12 SLA and 10 TPS implants.

All of the 45 implants incorporated successfully after 3 months were stable at the 6–month examination. This constituted the baseline for the experiment, since the test implants were loaded at that time. Following an observation period of another 8 months (end of the experimental period), all implants were clinically stable and histologically osseointegrated (Fig. 4).

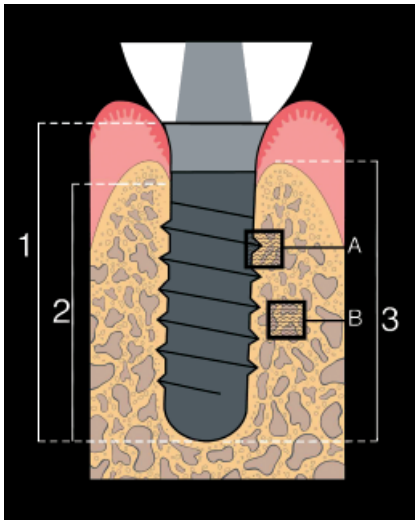

Fig. 3. Diagramatic representation of histomorphometric measurements. (1) Implant length, i.e. distance from the base of the implant to the implant shoulder. (2) Distance from the base of the implant to the most coronal point of bone-to-implant contact. (3) Distance from the base of the implant to the alveolar bone crest. (A) Percentage of mineralised bone density in contact with the implant surface. (B) Percentage of mineralised bone 1 mm distant to the implant surface.

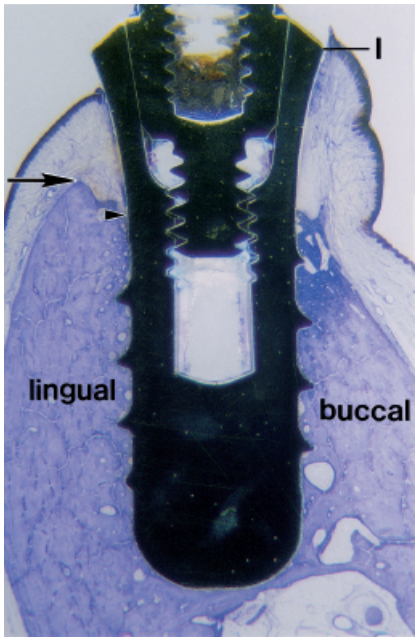

Fig. 4. Histologic view of a sandblasted, large grit, acid etched implant and the surrounding peri-implant tissues on the test side of the mandible in one dog. I: implant shoulder; arrowhead indicates the most coronal point of bone-to-implant contact; arrow indicates the level of the alveolar crest.

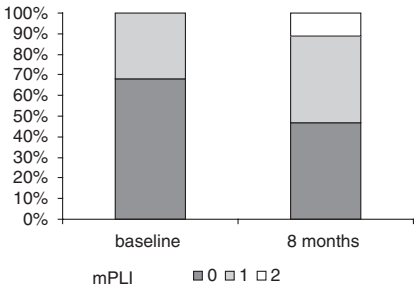

Fig. 5. Percentage of implant sites with modified plaque index (mPLI) = 0, 1, 2 at baseline and at 8-month reevaluation.

Clinical parameters

At baseline, 68% of the implant sites were completely plaque free (mPLI = 0), while 32% showed only mPLI = 1. At baseline, 35% of the peri-implant sulci bled on probing (BOP + ve).

At the 8-month reevaluation, very low plaque scores were also observed with 47% of the implant sites being plaque free, while only 11% of sites showed some visible plaque (mPLI = 2) (Fig. 5). This was reflected by the low incidence of BOP, with only 18% of the sites scoring positive.

At baseline, PPD averaged 2.5 mm (SD 0.5) for the control and 2.2 mm (SD 0.5) for the test sites. This difference was statistically significant ($P<0.05$). After 8 months, the PPD was 2.5 mm (SD 0.3) for the control sites and 2.6 mm (SD 0.3) for the test sites. This difference did not reach statistical significance (Table 1).

Table 1 also yields the mean scores for probing attachment levels (PAL = DIM + PPD). There were no statistically significant differences in PAL between the test and control groups at baseline or at 8 months. On a longitudinal basis, no changes in PPD or PAL were statistically

Table 1. **Clinical and radiographic parameters at baseline and at 8-month reevaluation for control and test implants; mean ± standard deviation (SD) (mm)**

	Mean PPD (mm)	Mean PAL (mm)	DIB (mm)	DIB (mm)	Mean DIB (mm)
Control					
Baseline	2.5 (0.5)*	3.2 (0.9)	3.6 (0.4)	3.5 (0.4)	3.5 (0.4)
8 months	2.5 (0.3)	3.2 (0.5)	3.8 (0.2)	3.6 (0.4)	3.6 (0.4)
Test					
Baseline	2.2 (0.5)*	2.9 (0.6)	3.6 (0.5)	3.6 (0.2)	3.7 (0.2)
8 months	2.6 (0.3)	3.0 (0.6)	3.7 (0.4)	3.6 (0.2)	3.7 (0.2)

PPD: probing depth; PAL: probing attachment level; m DIB: distance from implant shoulder to first bone-to-implant contact at mesial surface; d DIB: distance from implant shoulder to first bone-to-implant contact at distal surface; mean DIB: mean value of the mesial and distal measurements.
*$P < 0.05$ significant difference between mean PPD at baseline between test and control implants.

significant for either the test or the control sites. Figure 6 illustrates the distribution of PPD at all implant sites. At both baseline and at the 8-month reevaluation, there were very few sites with a PPD > 3 mm. At baseline, 55% (99) of the sulci measured PPD = 2 mm and 9% (16) measured PPD = 1 mm. In all, 32% (58) of the sulci had a PPD = 3 mm and only 4% (7) measured PPD = 4 mm. After 8 months, 13% (23) scored PPD = 1 mm and 31% (56) scored PPD = 2 mm. A total of 47% of the sites yielded PPD = 3 mm and 9% (17) showed PPD = 4 mm.

Radiographic parameters

The distances from the implant shoulder to the first bone-to-implant contact (DIB) visible radiographically under magnification at the mesial and distal surfaces of each implant and the mean of these values are also presented in Table 1. The DIB varied from 3.5 to 3.6 mm at baseline, and from 3.6 to 3.8 mm at the 8-month reevaluation. There were no statistically significant differences between the test and control implants at baseline or at 8 months. There were no statistically significant changes for test or control implants in radiographic bone levels observed over time.

Histomorphometric analysis

The linear measurements for the height of alveolar bone in relation to implant length varied between 61.6% and 71.6% (Table 2). Generally, the alveolar bone height was slightly greater at the lingual than at the buccal aspects. These differences were statistically significant for TPS surfaces in the control and test groups and for SLA surfaces in the test group ($P = 0.03$).

When comparing control with test implants, which had been subjected to 8 months of excessive load, again, no statistically significant differences in alveolar bone height were observed either for the buccal or lingual sites, or for the TPS or SLA surfaces. Similarly, within the control and test groups a comparison of the two implant surfaces did not reveal any statistically significant differences.

Table 3 describes the bone level, i.e. the most coronal point of histological bone-to-implant contact in relation to the total length of the implant. These values were generally slightly below those of the alveolar bone height (Table 2) for all sites and surfaces in both the test and control implants.

The bone levels were higher at the lingual aspects compared with the buccal aspects of the implants. This was statistically significant for TPS fixtures in the control group and SLA fixtures in the test group ($P = 0.03$). The bone level varied a maximum of 2.9% between TPS and SLA surfaces. No statistically significant differences were observed between test and control implants or between implants with SLA and TPS surfaces.

Table 4 summarises the histomorphometric analyses for control (unloaded) and test (loaded) implants. The percentages of mineralised bone in contact with the implant surface (A) and 1 mm distant to the implant surface (B) are presented for both control and test implants with either TPS or SLA surfaces. After 8 months of observation, the mean percentages of mineralised bone in contact with the control and the test implant surfaces were 72.6% and 73.9%, respectively. One millimetre distant to the implant surface, the corresponding values of mineralised bone density for the control and the test implants were 77.4% and 81.8%, respectively. The differences in percentages of mineralised bone density between control and test implants were not statistically significant. In the test group, at the lingual aspect there was a statistically significant higher mineralised bone in contact with the SLA surfaces compared with the TPS surfaces ($P = 0.03$). One millimetre distant to the implant surface, there were no statistically significant differences observed at the different implant surfaces within test and control groups.

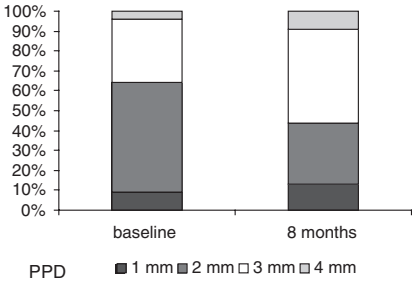

Fig. 6. Percentage of implant sites with PPD = 1, 2, 3, 4 mm at baseline and at 8-month reevaluation.

Discussion

The findings of this investigation demonstrated that titanium ITI® implants subjected to 8 months of excessive occlusal load in conjunction with a plaque control regimen were clinically stable with healthy peri-implant tissues. All implants were histologically osseointegrated and did not exhibit marginal bone loss radiographically. Only minor changes in periimplant bone levels, as assessed radiographically, were observed over 8 months, which may be attributed to the adaptive bone remodelling process following implant installation. The changes observed longitudinally correspond

Table 2. **Alveolar crest bone height in relation to the total length of the implant % for control and test implants with a titanium plasma sprayed (TPS) or sandblasted, large grit, acid etched (SLA) surface at buccal and lingual surfaces at 8 months**

	Buccal		Lingual	
	TPS	SLA	TPS	SLA
Control	61.6%*	64.1%	69.9%*	69.1%
Test	65.7%*	60.3%*	71.6%*	70.2%*

No statistically significant differences between the test and control implants or TPS and SLA surfaces.
*Significant difference between buccal and lingual aspects at TPS surfaces in control and test groups, and at SLA surfaces in the test group, $P = 0.03$.

Table 3. **Bone level (the most coronal point of histologic bone-to-implant contact) in relation to the total length of the implant % for control and test implants with a titanium plasma sprayed (TPS) or sandblasted, large grit, acid etched (SLA) surface at buccal and lingual surfaces at 8 months**

	Buccal		Lingual	
	TPS	SLA	TPS	SLA
Control	57.9%*	60.8%	67.5%*	67.1%
Test	63.1%	59.2%*	68.3%	68.0%*

No statistically significant differences between the test and control implants or TPS and SLA surfaces.
*Statistically significant difference between buccal and lingual aspects of TPS surfaces in the control group and SLA fixtures in the test group, $P = 0.03$.

Table 4. **Mineralised bone density (%) and standard deviations (SD) in contact with the implant surface (A) and 1 mm distant to the implant surface (B) for control (unloaded) and test (excessively loaded) implants with a titanium plasma sprayed (TPS) or sandblasted, large grit, acid etched (SLA) surface at buccal and lingual surfaces at 8 months**

	Buccal			Lingual			Mean		
	TPS	SLA	Total	TPS	SLA	Total	TPS	SLA	Total
(A)									
Control	71.5	79.6	75.5	65.9	73.3	69.7	68.7	76.4	72.6
SD	(10.1)	(10.2)	(9.7)	(8.6)	(12.8)	(10)	(8.9)	(10.9)	(9.4)
Test	67.8	78.6	73.5	67.1*	80.5*	74.5	67.4	79.5	73.9
SD	(11.9)	(8.2)	(8.5)	(12.4)	(10.1)	(10.9)	(10.9)	(9.0)	(9.4)
(B)									
Control	71.7	70.4	70.4	86.0	82.8	84.6	78.9	76.6	77.4
SD	(11.0)	(17.4)	(13.0)	(10.4)	(7.2)	(7.3)	(8.3)	(7.2)	(7.4)
Test	77.2	69.8	73.8	90.9	87.8	89.7	84.0	78.8	81.8
SD	(10.5)	(20.2)	(13.7)	(9.4)	(7.6)	(5.7)	(7.5)	(13.1)	(8.4)

*Statistically significant difference between TPS and SLA surfaces at the lingual aspect within the test group, $P = 0.03$.
(B) No statistically significant differences between test and control groups, TPS and SLA surfaces, or buccal and lingual aspects were observed.

very well with results from previous clinical reports of slight initial radiographic bone loss of the ITI dental implant system (Weber et al. 1992; Brägger et al. 1998).

The results of the present study are in direct contrast to those described by Isidor (1996, 1997). In this experimental study involving four monkeys, loss of osseointegration and subsequent implant failure attributed to loading was observed in one animal, while in another, bone-to-implant contact was reduced when compared with non-overloaded controls. However, in the fourth monkey, no difference was encountered between overloaded and non-overloaded implants with respect to bone-to-implant contact (Isidor 1996, 1997). Furthermore, the bone loss pattern around the only failed dynamically overloaded implant was characterised by the presence of a narrow zone of connective tissue separating the implant surface from the adjacent periimplant bone and extending around the entire implant. The author explained this bone loss to be a result of bone strains exceeding the physiologic threshold of bone adaptation (Frost 1994). It should be emphasised, however, that this single implant had been placed in a loosely trabecular bone, while other implants were placed in alveolar bone of higher trabecular density. Thus, evidence supporting the association between overload and loss of osseointegration appears, indeed, very limited.

A number of clinical and review papers have suggested that load may cause marginal bone loss at implants (Lindquist et al. 1988; Sanz et al. 1991; Naert et al. 1992; Quirynen et al. 1992; Rangert et al. 1995). However, the majority of experimental studies using various animal models confirm the results of the present investigation. These studies have not been able to demonstrate periimplant bone loss following occlusal loading (Ogiso et al. 1994; Barbier & Schepers 1997; Miyata et al. 1998), orthodontic load (Roberts et al. 1984, 1989; Wehrbein & Diedrich 1993; Asikainen et al. 1997; Wehrbein et al. 1997; Akin-Nergiz et al. 1998; Hürzeler et al. 1998; Majzoub et al. 1999; Melsen &

Lang 2001; Gotfredsen et al. 2001a, 2001b, 2001c, 2002) or load produced by poor fit of the supra-structures (Carr et al. 1996; Michaels et al. 1997).

There are two studies (Hoshaw et al. 1994; Miyata et al. 2000), however, that have provided evidence of marginal bone loss associated with occlusal and repetitive loading, respectively, in the absence of peri-implantitis.

Hoshaw et al. (1994) reported bone loss around the neck of the implants 12 weeks following axial loading with a triangular waveform (10–300 N, 330 N/s) for 500 cycles per day for 5 consecutive days. Furthermore, a decreased percentage of mineralised bone tissue was observed in a 350 μm wide zone around the implants.

In the present investigation, there were no statistically significant differences between dynamically loaded and control implants in the percentages of mineralised bone density in contact with the implant surface or 1 mm distant to the implant surface. In contrast, Gotfredsen et al. (2001a, 2001b, 2001c, 2002), in a series of experimental studies, demonstrated that titanium implants subjected to a static lateral expansion load showed an increased bone density and mineralised bone-to-implant contact compared with control implants.

Another variable investigated in the present study was the implant surface and its response to load. It has been suggested that the nature of the surface topography of an implant surface may affect stress transfer to the adjacent bone (Pilliar et al. 1991; Al-Sayyed et al. 1994; Hämmerle et al. 1996; Vaillancourt et al. 1996; Hansson 1999). The influence of implant surface characteristics was investigated by Gotfredsen et al. (2001b). These authors revealed a difference in peri-implant bone contact when using a TPS and a machined, turned surface, respectively, following static loading. At the machined but not at the TPS implant sites, angular bony defects were frequently observed. Furthermore, there were higher levels of mineralised bone-to-implant contact at the bone/implant interface as well as a higher percentage of mineralised bone density at the implants with a TPS than at the implants with a machined surface. In the present study, TPS and SLA surfaces were compared in both test and control implant groups, and no statistically significant differences were observed, with the exception of a slightly higher percentage of mineralised bone in contact with the implant surface at SLA surfaces in the test group. This, in turn, means that the TPS and the relatively recently launched SLA implant have surface characteristics suitable for the magnitude and duration of the excessive load applied in the present study.

It was not possible, however, to determine accurately the magnitude of the load applied to the implants in the present study. The definition of excessive load, therefore, concentrated on a functional occlusal pattern generated by an increase in vertical dimension of at least 3 mm in centric occlusion. Signs of occlusal wear were clearly evident on the occlusal surfaces of the gold crowns, documenting excessive occlusal contacts having been applied. So far, in previous reports 'occlusal overload' or 'excessive occlusal forces' have not been defined. Hence, it is desirable that future studies performed to elucidate a potential role of occlusal factors in the tissue disintegration of osseointegrated implants apply forces outside a 'normal physiologic range' of chewing forces and clearly define the order of magnitude of occlusal overload.

It is important to note that in the present study, a strict plaque control regimen was administered throughout the experimental period. This included daily implant brushing and application of chlorhexidine spray (0.2%). While there is ample evidence that peri-implant marginal bone loss may result from the development of an opportunistic bacterial infection, the aim of this study was to evaluate the effect of excessive occlusal load in the absence of mucositis or peri-implantitis. Therefore, the present study did not explore the possibility of excessive occlusal load as a contributory factor to the pathogenesis of peri-implant bone loss of infectious origin. Thus, no comparisons can be made with other investigations where ligature-induced peri-implantitis was combined with repetitive mechanical trauma (Hürzeler et al. 1998) or static load (Gotfredsen et al. 2002).

In conclusion, the results of the present study demonstrated that the peri-implant bone levels at the TPS and SLA titanium ITI® implants could not be affected in any way by excessive occlusal load. In the light of the overwhelming evidence of the bacterial role in the development of peri-implant bone loss, the results of the present study support the notion that excessive occlusal forces may present only a very minor, if any, risk for the integrity of osseointegrated implants.

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Résumé

Le but de cette étude a été d'évaluer l'effet d'une charge occlusale excessive après placement d'implants en titane en présence de tissus muqueux paroïmplantaires sains. Des sites receveurs bilatéraux mandibulaires chez six chiens labradors ont été créés par l'avulsion des prémolaires et molaires. Après trois mois, deux implants TPS (titane plasma-spray) et deux SLA (sablés, large grain, mordançage) ont été placés de chaque côté de la mandibule de chaque chien. Trois implants ont été perdus lors de la phase initiale de guérison laissant 45 implants pour l'évaluation. Après six mois de guérison, des couronnes en or ont été placées sur les implants du côté test. Les couronnes étaient en contact sus-occlusal avec les dents opposées afin de créer une charge occlusale excessive. Les implants du site contrôle n'étaient pas chargés. Le contrôle de la plaque dentaire a été effectué durant toute l'étude. Des mesures cliniques et des radiographies standardisées ont été obtenues lors de l'examen de départ et un, trois et huit mois après la mise en charge. Après huit mois, les chiens ont été euthanasiés et des analyses histologiques effectuées. Après huit mois, tous les implants restants étaient ostéointégrés. Les profondeurs moyennes au sondage étaient respectivement de 2,5 ± 0,3 mm et de 2,6 ± 0,3 mm aux implants non-chargés et chargés. Radiographiquement, la distance moyenne de l'épaule implantaire à l'os marginal était de 3,6 ± 0,4 mm dans le groupe contrôle et de 3,7 ± 0,2 mm dans le test. Les deux groupes ont été comparés en utilisant les analyses non-paramétriques par paires. Il n'y avait aucune variation statistiquement significative pour aucun des paramètres entre l'examen initial et après huit mois au niveau de tous les implants. L'évaluation histologique a montré une moyenne d'os minéralisé

en contact avec l'implant de 73% au niveau des contrôles et de 74% au niveau des tests sans différence significative. En présence de muqueuse paroïmplantaire saine, une période de huit mois de charge occlusale excessive sur des implants en titane ne n'entraînait pas de perte d'ostéointégration ou de perte osseuse marginale lorsqu'elle était comparée aux implants non-chargés.

Zusammenfassung

Ziele: Das Ziel dieser Arbeit war, direkt nach dem Setzen von Titanimplantaten den Einfluss von übermässigen okklusalen Belastungen auf die Gesundheit der periimplantären Weichgewebe zu untersuchen.
Material und Methode: Bei 6 Labradorhunden bereitete man durch die Extraktion der Prämolaren und Molaren beidseits im Unterkiefer Empfängerbette vor. Nach drei Monaten setzte man bei jedem Hund und auf jeder Seite des Unterkiefers je 2 TPS-Implantate (titanplasmabesprayt) und 2 SLA-Implantate (sangestrahlt, grobkörnig, säuregeätzt). In der initialen Einheilphase gingen 3 Implantate verloren, so dass 45 Implantate ausgewertet werden konnten. Nach einer 6-monatigen Heilphase, implantierte man auf der Testseite des Unterkiefers auf jedes der Implantate eine Goldkrone. Die Kronen hatten zur Gegenbezahnung okklusale Vorkontakte, damit unnatürlich hohe okklusale Kräfte entstanden. Die Implantate auf der Kontrollseite wurden nicht belastet. Während der gesamten Experimentierphase erhielten die Tiere eine professionelle Plaquekontrolle. Die klinischen Messungen und die standartisierten Röntgenbilder führte man zu Beginn sowie 1, 3 und 8 Monate nach Belastung durch. Nach 8 Monaten wurden die Hunde geopfert und histologische Analysen durchführt.
Resultate: Nach 8 Monaten waren alle Implantate osseointegriert. Die mittlere Sondierungstiefe betrug bei den unbelasteten Implantaten 2.5 + 0.3 mm und bei den belasteten 2.6 + 0.3 mm. Bei der Kontrollgruppe betrug auf den Röntgenbildern der mittlere Abstand zwischen Implantatschulter und marginalem Knochen 3.6 + 0.4 mm und in der Testgruppe betrug er 3.7 + 0.2 mm. Die Kontroll- und Testgruppen verglich man mit gepaarten, nichtparametrischen Analysen. Verglich man belastete und unbelastete Implantate, fand man zwischen den Anfangswerten und den Werten nach acht Monaten bei keinem dieser Parameter statistisch signifikante Veränderungen. Die histologischen Untersuchungen zeigten einen mineralisierten Knochen-Implantatkontakt von 73% bei den Kontrollimplantaten und 74% bei den Testimplantaten. Diese Unterschiede zwischen Test und Kontrolle waren statistisch nicht signifikant.
Zusammenfassung: Bei gesunden periimplantären Schleimhautverhältnissen führte eine 8-monatige Zeitspanne mit übermässiger okklusaler Belastung um Titanimplantate, verglichen mit unbelasteten Implantaten, nicht zu einem Verlust der Osseointegration oder zu marginalem Knochenverlust.

Resumen

Intención: La intención de este estudio fue evaluar el efecto de una carga oclusal excesiva tras la colocación de implantes de titanio en presencia de tejidos mucosos periimplantarios sanos.
Material y métodos: Se establecieron lugares receptores mandibulares bilaterales en 6 perros Labrador por medio de la extracción de los premolares y los molares. A los 3 meses se colocaron 2 implantes TPS (pulverizados con plasma de titanio) y 2 implantes SLA (chorreados con arena, grano grande, gravado con ácido) en cada lado de la mandíbula de cada perro. Se perdieron 3 implantes en la fase inicial de cicatrización, dejando 45 implantes para evaluación. Tras 6 meses de cicatrización, se colocaron coronas de oro en los implantes del lado de prueba de la mandíbula. Las coronas estaban en sobreoclusión con los dientes oponentes en orden a crear una carga oclusal excesiva. Los implantes en lado de control no se cargaron. Se llevó a cabo control de placa durante todo el periodo experimental. Se obtuvieron mediciones clínicas y radiografías estándar al inicio, y a los meses 1, 3 y 8 tras la carga. A los 8 meses se sacrificó a los perros y se llevaron a cabo análisis histológicos.
Resultados: Todos los implantes se osteointegraron a los 8 meses. La profundidad media de sondaje fue de 2.5 ± 0.3 mm y 2.6 ± 0.3 mm en los implantes sin carga y con carga respectivamente. Radiograficamente, la distancia media desde el hombro del implante al nivel del hueso marginal fue de 3.6 ± 0.4 mm en el grupo de control y de 3.7 ± 0.2 mm en el grupo de prueba. Los grupos de prueba y de control se compararon usando análisis de pareja no paramétrico. No hubo cambios estadísticamente significativos para ninguno de los parámetros desde el inicio hasta los 8 meses en los implantes cargados y los sin carga. La evaluación histológica mostró un contacto mineralizado hueso a implante medio del 73% en los implantes de control y del 74% en los implantes de prueba sin diferencias estadísticamente significativas entre los implantes de prueba y de control.
Conclusión: En presencia de una mucosa periimplantaria sana, un periodo de 8 meses de sobrecarga oclusal sobre implantes de titanio no resultó en perdida de la osteointegración o pérdida de hueso marginal cuando se comparó con implantes sin cargar.

要旨
目的：本研究の目的は、健全なインプラント周囲粘膜組織の存在下で、チタン製インプラントを埋入した後の、過剰な咬合圧荷重の影響を評価することであった。
材料と方法：６頭のラブラドール犬において下顎両側の前臼歯と後臼歯を抜去してインプラント床を形成した。３ヶ月後ＴＰＳ（チタン・プラズマ溶射）インプラント２本とＳＬＡ（サンドブラスト、大きな粒径、酸エッチング処理）インプラント２本を各犬の下顎各側に埋入した。最初の治癒期間中に３本のインプラントが失われ、残り４５本を評価した。治癒６ヶ月後、下顎の実験側のインプラントにはゴールド･クラウンを装着した。クラウンは対合歯と過剰咬合となるように高く装着し、対照側のインプラントには荷重をかけなかった。実験期間中プラーク・コントロールを続けた。臨床的測定と標準放射線撮影をベースライン、荷重後１、３、８ヵ月後に行った。８ヶ月後に犬を屠殺し、組織分析を行った。
結果：８ヶ月後に全てのインプラントは骨性結合していた。平均プロービング深さは非荷重側、荷重側で各々２．５±０．３ｍｍ、２．６±０３ｍｍであった。放射線像では、インプラント・ショルダーから辺縁骨レベルまでの距離は対照側では３．６±０．４ｍｍ、実験側では３．７±０．２ｍｍであった。ペアード・ノンパラメトリック分析によって対照群と実験群の比較を行った。荷重インプラントと非荷重インプラントの間に、ベースラインから８ヶ月までの期間中、どのパラメータにも統計的に有意な変化は認められなかった。組織学的評価によると、石灰化骨とインプラントの平均接触率は対照側では７３％、実験側では７４％であり、両群に統計的有意差はなかった。
結論：健康なインプラント周囲粘膜の存在下では、８ヶ月間のチタン製インプラントの過剰な咬合圧荷重は、非荷重インプラントに比べて、骨性結合の喪失や辺縁骨の吸収をもたらさなかった。

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