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# Mobility Assessment with the Periotest System in Relation to Histologic Findings of Oral Implants

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The relationship between mobility assessment with the Periotest system and histologic findings was evaluated for oral implants. Five screw-type implants of pure titanium were placed in the mandibles of four monkeys. Two implants in each monkey were occlusally overloaded. These implants were brushed once a week. Plaque was allowed to accumulate around unloaded implants with abutments in the same monkeys. During the experiment, six of eight implants with occlusal overload showed increased manually detectable mobility. Two of these were lost. After 18 months of experimentation, the mobility was assessed using the Periotest system. Sections of the implants and surrounding tissue were cut. For the excessive occlusally loaded implants with manually detectable mobility, positive Periotest values were recorded, and for all other implants the values were negative (range = -7 to -2). All implants with plaque accumulation were histologically osseointegrated but showed marginal bone loss. Two of the implants with occlusal overload had lost osseointegration completely, and two other implants were osseointegrated in the apical part only. A statistically significant association between the Periotest values and the histologic bone level or the proportion of bone-implant contact was observed. If only clinically stable implants (ie, without manually detectable mobility or with a negative Periotest value) were included in the analysis, no significant correlation was found. The Periotest values revealed only slightly more information concerning the osseointegration of implants than manual mobility assessments.

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**Key words:** alveolar bone loss, bone resorption, dental implants, diagnostic accuracy, histology, mobility assessment, occlusal overload, osseointegration, peri-implantitis, plaque accumulation, traumatic occlusion

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An osseointegrated oral implant is characterized by lack of clinical mobility. After healing, obvious mobility of an implant is a sign of primary failure; at follow-up examinations, it is a sign of secondary failure.<sup>1-3</sup>

A device known as the Periotest system has been developed for the purpose of evaluating the mobility of teeth, but this device has also been applied to oral implants.<sup>4</sup> The Periotest device consists of a handpiece with a rod that moves back and forth 16 times in 4 seconds. With the patient's head in a vertical position, the head of the rod is placed perpendicular to the tooth or implant/abutment. The rod taps the tooth or implant abutment, and the time required to

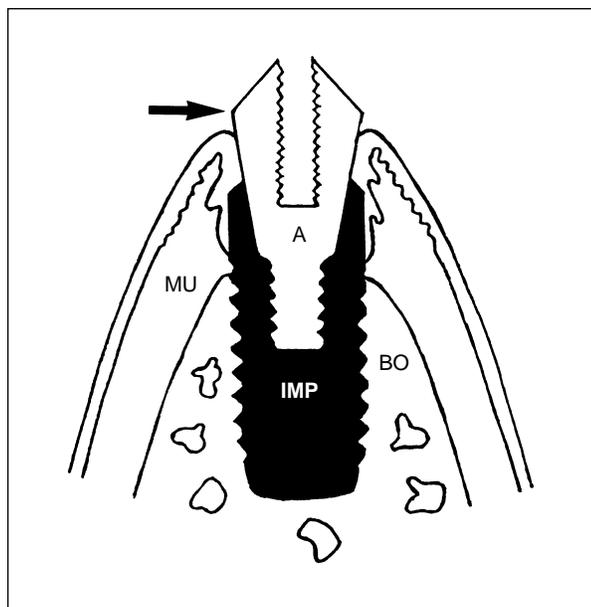
stop the rod (the braking time), which is based on the damping effect of the implant and surrounding tissues, is converted into a Periotest value. An implant with a Periotest value of +5 or less is considered to be osseointegrated, while higher values indicate fibrous integration.<sup>5</sup> Although the relationship between the Periotest value and the degree of osseointegration is not fully known, the Periotest system has been proposed to be capable of making an objective quantification of the ankylotic link between an oral implant and bone,<sup>4,6</sup> and can thus record changes in osseointegration.<sup>4</sup>

A failing implant may display an increased Periotest value before any radiographic signs are evident.<sup>7</sup> Even osseointegrated implants can show slight mobility because of the elasticity of the bone, particularly the cancellous bone.<sup>8,9</sup> The range from a clinically firm implant to barely tangible mobility therefore represents a problem for diagnosis.<sup>10</sup> Consequently, it is of great clinical importance to have the capability to detect even small differences in mobility if such differences represent inadequate bone support of an oral implant.

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**Fig 1** Schematic drawing of an implant (IMP) and abutment (A) after bone loss has occurred at both sides of the implant. The tapping part of the Periostest system was placed midbuccally on the abutment and held perpendicular to the implant (arrow), while the head of the monkey was in an upright position (BO = peri-implant bone; MU = peri-implant mucosa).

It has recently been demonstrated<sup>11,12</sup> that occlusal overload can result in loss of osseointegration of oral implants in monkeys. The loss of osseointegration was observed clinically 4 1/2 months to 15 1/2 months after the occlusal overload was initiated. In the same monkeys, nonloaded implants with plaque accumulation enhanced by ligatures all osseointegrated after 18 months of observation, although a loss in bone height was observed both radiographically and histologically.

The aim of this study was to evaluate the relationship between mobility assessment with the Periostest system and histologic findings of oral implants in monkeys following excessive occlusal load or plaque accumulation.

## Materials and Methods

Eight months after the first molars, premolars, and incisors were extracted in the mandibles of four monkeys (*Macaca fascicularis*), five screw-type implants of commercially pure titanium (Astra Tech AB, Mölndal, Sweden) were placed in the edentulous areas of each animal. The coronal margins of the implants were placed at or slightly below the level of the alveolar bone crest. Two implants were placed in the right molar-premolar region, two in the left molar-premolar region, and one in the area of the central incisors. The

implants were self-tapping and had a diameter of 3.5 mm and a length of 8 mm. In each molar-premolar region, one implant had a titanium dioxide (TiO<sub>2</sub>)-blasted (air abrasion with TiO<sub>2</sub> particles) surface and the other a machine-produced surface. All implants in the incisor region were TiO<sub>2</sub>-blasted.

Six months after placement, the implants were surgically exposed. Abutments (titanium Uni abutment 45, Astra) with 0.0 mm cuff and a 45-degree tapered top were placed on all implants (Fig 1).

A fixed partial prosthesis fabricated from silver-palladium alloy (Pallorag, Cendres & Métaux SA, Biel-Bienne, Switzerland) was mounted on two implants in one of the lateral segments of each monkey. The prosthesis was in supraocclusal contact with a metal splint (Pallorag) covering the premolars and molars in the maxilla, resulting in an excessive lateral occlusal load. The implants retaining the prosthesis were brushed once a week. Gentle mechanical cleaning and irrigation of the pockets with saline were performed once a month after the prostheses were removed, but with the abutments still in place.

To promote plaque accumulation, cotton cords were placed around implants in the incisal area and contralateral to the fixed partial prosthesis. The cotton cord was placed in contact with the mucosa beneath the prominence of the abutment and secured with a knot. Clinical and radiographic examinations, including manual mobility assessment (MA),<sup>13</sup> were performed 1 month after abutment placement, when the fixed partial prostheses were placed or plaque formation was enhanced, and every 3 months thereafter. The intraoral radiographs were taken with the paralleling technique. The radiographic bone level was measured on both proximal surfaces from the margin of the implant. Known landmarks on the implants (smooth part and threads) were used to give the bone level in absolute numbers to the nearest 0.5 mm. After 18 months of observation, mobility of the implants was evaluated using the Periostest system (Periostest, Siemens AG, Bensheim, Germany). The tapping part of the Periostest system was placed midbuccally on the abutment and held perpendicular to the implant (Fig 1). The head of the monkey was in an upright position. The recording was performed twice and, if the readings differed, the average value was designated as the recording of the implant. The prostheses were removed before testing. All clinical and statistical procedures were performed by the author.

The animals were then sacrificed with an overdose of pentobarbital 10% and perfused with 10% neutral buffered formalin through the carotid arteries. The jaws were removed, and tissue blocks containing the implants were made. These blocks were dehydrated and subsequently embedded in acrylic

resin (Technovit 7.200 VLC, Kulzer, GmbH, Friedrichsdorf, Germany). The Exakt cutting-grinding system (Exakt Apparatebau, Norderstedt, Germany) was used to make approximately 50- $\mu$ m-thick sections of the implants and surrounding tissues from the buccal aspect and in the long axis of the implants.<sup>12</sup> A minimum of two sections through the midportion of the proximal surfaces was available. The sections were stained with 0.4% basic fuchsin and counterstained with 0.2% light green.

**Histomorphometric Evaluation.** Two sections from the midportion of each implant were used for histomorphometric evaluation. The histomorphometric evaluation was performed by two laboratory technicians who had no knowledge of the recorded Periotest values. Marginal bone loss, ie, the distance from the margin of the implant to the most coronal bone in direct contact with the implant, was measured on each proximal surface in the microscope at a magnification of 125 $\times$ .

The bone-implant contact was recorded as a proportion of the total implant surface area. The bone density (ie, the proportion of mineralized bone tissue from the implant surface to a distance 1 mm lateral to this surface) apical to the most coronal bone in direct contact with the implant was also assessed. Assessments of the proportions were made by a computer (magnification on the screen 100 $\times$ ) by means of a video camera mounted on an Olympus BX 50 microscope (Olympus Danmark A/S, Glostrup, Denmark) and a software program called Cast Grid Ver 1.0 (Olympus Danmark A/S).

For each parameter, the score for the surface was calculated as a mean of the values from the two sections, and the score for the implant was the mean value of the two surfaces.

**Statistical Analysis.** Correlations between the various histologic parameters and the Periotest values, or the manual mobility assessments, were analyzed by means of Spearman's rank correlation coefficient corrected for ties and by calculation of Kendall's partial rank correlation coefficient, the latter of which calculates the correlation between two variables when a third is kept constant. The computer program Medstat version 2.12, which statistically analyzes the results of controlled therapeutic trials and other types of clinical research (Astra), was used for the analyses.

## Results

At the time of surgical exposure (second-stage surgery), 2 of the 20 implants were not osseointegrated, and therefore were removed. At the remaining implants, the bone level was localized at the top margin of the implant after abutment placement.<sup>11</sup>

No significant differences in any of the parameters were found between the implants with a TiO<sub>2</sub>-blasted or machined-produced surface structure. For instance, for implants with plaque accumulation, the proportion of bone-implant contact was on average 49%, and for TiO<sub>2</sub>-blasted and machined-produced surfaces, bone-implant contact was 46% on average. Therefore, the results for the two types of implants are presented together.

During the experiment, two excessively occlusally loaded implants were manually detected to be mobile (MA = 2) and were unscrewed from the jawbone during removal of the fixed partial prosthesis (Table 1). In another monkey, one of the overloaded implants was manually detected to be mobile (MA = 2) after 15 months, and the other loaded implant in the same monkey displayed a questionable increased manually detectable mobility (MA = 0 to 1). In a third monkey, both overloaded implants were manually detected to be mobile (MA = 2) after 15 1/2 months.

A gradually increasing radiographic marginal bone loss was observed at implants with enhanced plaque accumulation. At baseline, when plaque formation was enhanced, no bone loss was recorded. After 6, 12, and 18 months, bone loss of 1.1 mm, 1.5 mm, and 1.8 mm was observed, respectively.<sup>11</sup> The evident mobility of five excessively occlusally loaded implants was associated with a distinct radiolucency surrounding the implants. The implant with a questionable increased manually detectable mobility (monkey 2, region 6), likewise, exhibited a dubious peri-implant radiolucency.

The Periotest values (Table 1) obtained at the 18-month examination were negative for all implants with plaque accumulation (between -7 and -2). For the overloaded implants with manually detectable mobility, positive values between 18 and 45 were recorded. At the dubious manually mobile implant, a positive value of 6 was recorded. Both of the overloaded implants in the fourth monkey exhibited a value of -7.

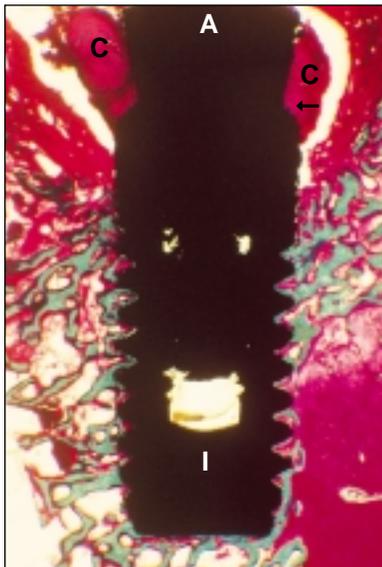
The average histologic bone loss was 2.4 mm (range = 0.8 mm to 4.0 mm) for the 10 implants with plaque accumulation (Fig 2 and Table 1). Of the six excessively loaded implants available for histologic analysis, two implants in one monkey (no. 3) that manifested clinical and radiographic signs of lost osseointegration also had histologic evidence of a complete loss of osseointegration (Fig 3 and Table 1). The two implants in monkey 2 with evident or possible clinical and radiographic signs of having lost osseointegration were only osseointegrated in the apical half of the implants (Fig 4 and Table 1). Only a minor proportion (11%) of the surface of these implants was in contact with mineralized bone tissue. In these few areas with bone-implant contact, bone resorption was

**Table 1** Manual Mobility Assessment, Periostest Value, Histologic Marginal Bone Loss, Proportion of Bone-Implant Contact for the Total Implant Surface Area, and Bone Density\* Apical to the Most Coronal Bone in Direct Contact With the Implant for the Individual Implant With Excessive Load or Plaque Accumulation

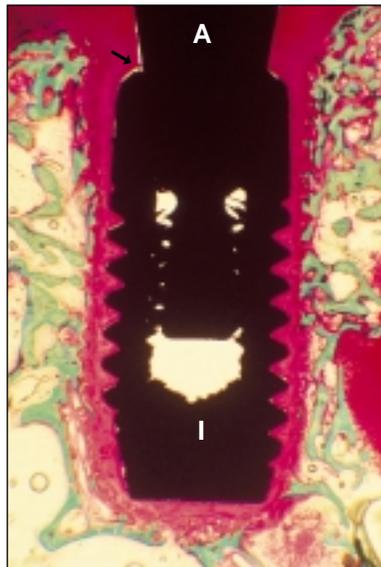
Monkey	Excessive load								Plaque accumulation									
	1		2		3		4		1		2		3		4			
	M <sub>1</sub>	P <sub>1</sub>	P <sub>1</sub>	I <sub>1</sub>	M <sub>1</sub>	P <sub>1</sub>	I <sub>1</sub>	M <sub>1</sub>	P <sub>1</sub>	I <sub>1</sub>								
Removed	+	+																
Manual mobility assessment			0-1	2	2	2	0	0	0	0	0	0	0	0	0	0		
Periostest value			6	18	45	25	-7	-7	-6	-5	-6	-7	-2	-5	-5	-4	-6	-5
Marginal bone loss (mm)			4.8	4.0	8.0	8.0	1.9	1.8	2.3	2.6	3.5	0.8	1.4	1.8	2.5	2.2	2.6	4.0
Bone-implant contact (%)			11.1	11.6	0	0	62.7	72.8	45.8	28.3	30.7	66.0	51.3	45.0	39.7	65.9	64.5	39.9
Bone density (%)			47.5	45.5			61.2	66.2	33.6	21.5	35.6	40.5	43.2	39.8	28.6	60.9	48.2	33.7

\*Bone density values given are for the proportion of bone tissue from the implant surface to a distance of 1 mm lateral to this surface.

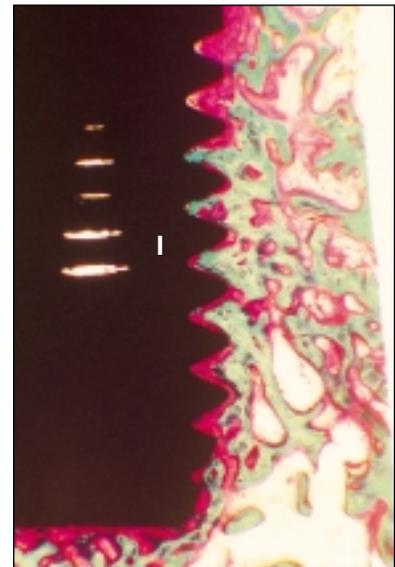
\*\*M<sub>1</sub> = first molar; P<sub>1</sub> = first premolar; I<sub>1</sub> = central incisor.



**Fig 2** Histologic section of an osseointegrated implant with abutment after plaque accumulation. This implant had a Periostest value of -6. Mineralized bone is green and soft tissue is red. The marginal bone level is located apical to the margin of the implant on both sides (I = implant; A = abutment; arrow = margin of implant; C = cotton cord) (basic fuchsin and light green stain, magnification × 13.5).



**Fig 3** Histologic section of an excessively loaded implant with abutment. The implant has lost osseointegration completely. A Periostest value of +25 was recorded at this implant. Mineralized bone is green and soft tissue is red. The bone crest is located near the margin of the implant, and a rather narrow zone of fibrous tissue is interposed between the implant and surrounding bone (I = implant; A = abutment; arrow = margin of implant) (basic fuchsin and light green stain, × 13.5).

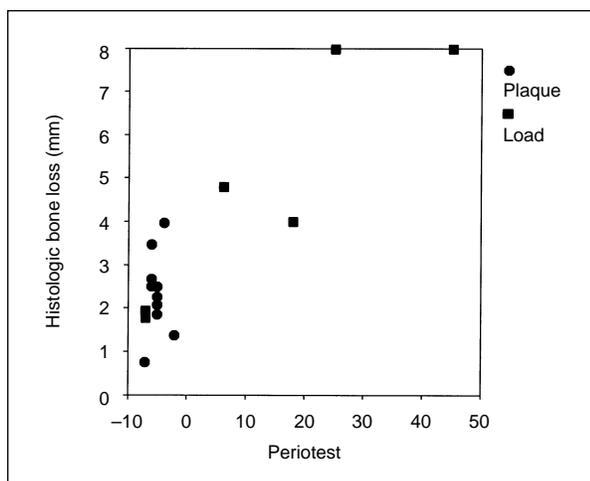


**Fig 4** Microphotograph from the apical part of an excessively loaded implant that has lost osseointegration in the marginal part. This implant had a Periostest value of +6. Mineralized bone is green and soft tissue is red. Bone in contact with the implant surface is minimal in this area. Bone resorption is observed near the implant surface (arrows) (I = implant) (basic fuchsin and light green stain, × 22.5).

often observed. Furthermore, portions of bone tissue in contact with the implant surface seemed not to have contact with the remaining bone.<sup>12</sup> The two excessively loaded nonmobile implants in monkey 4 had a histologic marginal bone loss of 1.8 to 1.9 mm. Both at the implants with complete loss of osseointegration and at those with partial loss of osseointegration, the bone crest was located near the top margin of the implant, resulting in a rather narrow zone of

fibrous tissue between the implant and surrounding bone (Fig 3).

On average, 48% (range = 28% to 66%) of the total surface area of implants with plaque accumulation was in contact with mineralized bone tissue (Table 1 and Fig 2). The two excessively loaded implants that were osseointegrated only in the apical half of the implants had only a minor proportion (11%) of the implant surface in contact with mineral-



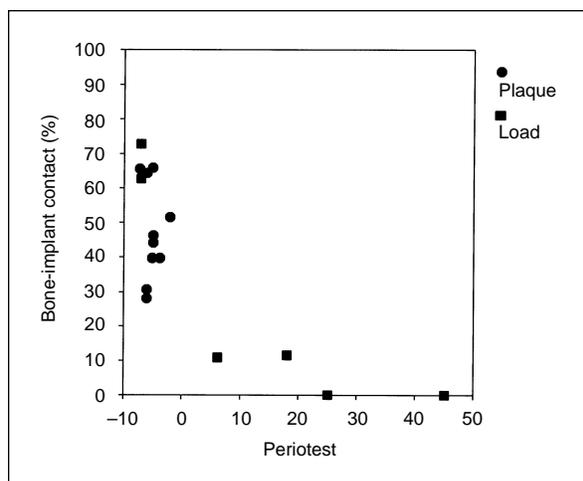
**Fig 5** Correlation plot between the histologic bone loss and the Periostest values. All implants: Spearman's rank correlation coefficient = .65;  $P < .01$ ; implants with plaque accumulation: Spearman's rank correlation coefficient =  $-.03$ ;  $P > .50$ ; implants with excessive occlusal load: Spearman's rank correlation coefficient = .91;  $P < .05$ .

ized bone tissue (Fig 4). The two excessively loaded nonmobile implants in monkey 4 had 63% and 73% of the total implant surface area in contact with mineralized bone tissue.

The bone density apical to the most coronal bone in direct contact with the implant was on average 38% (range = 21.5% to 60.9%) for implants with plaque accumulation, and on average 55% (range = 45.5% to 66.2%) for the four excessively loaded implants available for this analysis (Table 1).

**Relationships Between Mobility Assessments and Histologic Findings.** The Periostest values showed a statistically significant correlation (Spearman's rank correlation coefficient = .65;  $P < .01$ ) with the histologic bone loss (Fig 5) for all implants. When only implants with plaque accumulation ( $n = 10$ ) or only implants without manually detectable mobility (or a negative Periostest value) ( $n = 12$ ) were included in the analysis, no significant correlation was found. However, when the excessively loaded implants were evaluated alone, a statistically significant correlation (Spearman's rank correlation coefficient = .91;  $P < .05$ ) between the Periostest value and the histologic bone loss was observed.

The proportion of bone-implant contact had a statistically significant inverse correlation with the Periostest values (Fig 6) for all implants (Spearman's rank correlation coefficient =  $-.74$ ;  $P < .002$ ) and for excessively loaded implants only (Spearman's rank correlation coefficient =  $-.91$ ;  $P < .05$ ). For implants with plaque accumulation ( $n = 10$ ) or implants without manually detectable mobility ( $n = 12$ ), no signifi-



**Fig 6** Correlation plot between the proportion of bone-implant contact and the Periostest values. All implants: Spearman's rank correlation coefficient =  $-.74$ ;  $P < .002$ ; implants with plaque accumulation: Spearman's rank correlation coefficient =  $-.05$ ;  $P > .50$ ; implants with excessive occlusal load: Spearman's rank correlation coefficient =  $-.91$ ;  $P < .05$ .

cant correlation between the proportion of bone-implant contact and the Periostest values was observed.

The correlation between Periostest values and histologic bone losses, calculated while the proportion of bone-implant contact was kept constant (using Kendall's partial rank correlation coefficient), did not reach the significance level ( $.05 < P < .10$ ), while the correlation between the Periostest values and the proportions of bone-implant contact calculated with the histologic bone levels kept constant was statistically significant ( $P < .05$ ).

Other relationships were examined in the data, and although these are not illustrated with figures, the results of these analyses are provided below. The manual mobility assessments (Table 1) were significantly correlated with the histologic bone level (Spearman's rank correlation coefficient = .72;  $P < .005$ ) and inversely correlated with the proportion of bone-implant contact (Spearman's rank correlation coefficient =  $-.72$ ;  $P < .005$ ) for all implants.

The bone density apical to the most coronal bone in direct contact with the implant (Table 1) was not significantly associated with the Periostest values nor with the manual mobility assessments.

The Periostest values and the manual mobility assessments (Table 1) were significantly correlated for all implants (Spearman's rank correlation coefficient = .74;  $P < .002$ ) and for the excessively loaded implants (Spearman's rank correlation coefficient = .94;  $P < .05$ ).

## Discussion

In the present study, an association was observed between the Periotest values and the histologic bone level or the proportion of bone-implant contact. Among the loaded implants only, a similar correlation was found. However, when only clinically stable implants, ie, those without manually detectable mobility, were considered, no correlation between the histologic findings and the Periotest values was found.

The manual mobility assessments were also significantly associated with the histologic bone level or the proportion of bone-implant when all implants were considered, but not for loaded implants only. Only one value for manual mobility assessments (MA = 0) can be assigned to well-osseointegrated implants and, consequently, all implants with plaque accumulation received a manual mobility assessment value of 0. It is therefore not worthwhile to perform a correlation analysis for this parameter at these implants. In general, it is difficult to demonstrate a significant correlation between two parameters when only three different values can be assigned to one of them, eg, manual mobility assessment.

Clinical studies have suggested that bone quality influences Periotest values, since the Periotest values for implants placed in the mandible are less than are those for implants in the maxilla.<sup>7,14-16</sup> Furthermore, the amount of bone cortex in contact with the implants (ie, if the coronal and/or apical part of the implant is in contact with cortical bone) also appears to influence the Periotest values<sup>17</sup> as well as the medullary bone-implant contact.<sup>16,17</sup> The results from the present study only partially support this point of view, since the proportion of bone-implant contact was significantly associated with the Periotest values for all implants (including the failing implants), but not when only histologically osseointegrated (or clinically stable) implants were included in the analysis. The Periotest system seems to be able to reliably distinguish between only large differences in bone-implant contact. This observation is supported by a clinical study in which no correlation between Periotest values and bone density was found when biopsies were examined.<sup>18</sup> In the present study, where all implants were placed in the mandible, the bone density near the implant was not significantly associated with the Periotest values nor the manual mobility assessments.

In accordance with Danish legislation, the number of animals involved in animal experiments must be as small as possible. Furthermore, the study protocol, handling procedures, and animal housing/keeping must be sanctioned by veterinary authorities. In spite of the small numbers of monkeys and implants included in the present study, it has been possible to

demonstrate variations in the histologic findings among implants with similar Periotest values and, therefore, to illustrate the problems in using Periotest values to diagnose small differences in the bone support of an oral implant.

Several clinical studies have shown that Periotest values decrease over time.<sup>15,17-19</sup> These findings may be explained by the increasing mineralized bone-implant contact over time as observed in rabbit tibiae.<sup>20</sup> The results of the present study do not support this interpretation, since the Periotest values, all obtained 24 months after placement of the implants or 18 months after surgical exposure, did not correlate with the bone-implant contact or the bone density when osseointegrated implants were analyzed. Decreasing Periotest values observed over time may, therefore, be attributed to maturation of the surrounding bone, rather than a change in bone-implant contact.

In some clinical studies, a tendency toward a decreasing Periotest value has been observed with an increasing length of the osseointegrated part of the implant.<sup>5,14,15</sup> In other studies,<sup>16,19,21</sup> such a correlation has not been found. In the present study, Periotest values only correlated with the histologic bone level if the failing implants were included in the analysis. If only clinically stable implants (or osseointegrated implants) were considered, this association was not observed. Furthermore, the proportion of bone-implant contact seemed to influence the Periotest values slightly more than did the histologic bone level, when all implants were analyzed.

An increased abutment length or distance from bone margin to point of measurement has been shown to increase the Periotest value significantly in several studies.<sup>5,6,14,15</sup> Similarly, various implant designs may influence the Periotest values.<sup>16</sup> These variables cannot have influenced the result in the present study, since only one implant design and length were used and all implants were mounted with the same length of abutment on which the measurement was performed.

Implants with a clinically osseointegrated appearance, but with an increased Periotest value (between 0 and +8) at the time of abutment connection have shown a higher failure rate when occlusally loaded than have implants with low Periotest values. Therefore, it has been proposed that the Periotest value at the time of surgical exposure reflects the degree of initial osseointegration.<sup>22</sup>

When only clinically stable implants, ie, those without manually detectable mobility, are considered, no correlation was found between the histologic findings and the Periotest values in the present study. However, with the applied histologic technique, only

information about bony anchorage on the mesial and distal aspects of the implants was revealed. The osseointegration of implants on the facial or lingual aspect was not determined in this study, but it influences the manually detectable mobility and Periotest value, since the bone contact at the entire circumference of an implant will have an impact on its anchorage. The histologic sections in the present study were chosen to resemble the radiographic appearance of oral implants. One might assume that coherence between the histologic findings related to the osseointegration on the buccolingual and proximal surfaces exists, since the attachment level for buccolingual and proximal surfaces was similar.<sup>11</sup>

An implant with a Periotest value of +5 or less has been considered to be osseointegrated, whereas higher values indicate fibrous integration.<sup>5,14</sup> Furthermore, various implant systems have a median Periotest value of around or below 0.<sup>5,16</sup> In a clinical study, all implants that clinically and radiographically were considered to be encapsulated by a soft tissue layer showed rather high Periotest values (greater than 9), when compared to those that were in direct contact with bone.<sup>15</sup> A similar observation was found in the present study, where all osseointegrated implants showed negative Periotest values. The two implants that had lost osseointegration completely had positive Periotest values of 25 and 45, and those with almost no bone-implant contact had positive values of 6 and 18. The manual mobility assessments showed a similar distinction between the implants.

## Summary

The main advantage of using the Periotest system, compared to assessing mobility manually at implants where osseointegration already has been achieved, seems to be the reassurance of recording an objective score, especially at implants with a questionable manually detectable mobility.

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