Comparative Value of Attachment Measurements in Implant Dentistry

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Purpose: *In implant dentistry, the level of bone attachment is normally assessed by clinical and radiologic parameters. In the literature, however, the accuracy of these measurements has been a source of controversy. The purpose of this study was to assess the reliability of attachment measurements in the beagle dog model.* ***Materials and Methods:*** *In 6 beagle dogs, a total of 60 implants were placed. Bony defects resulting from plaque accumulation were treated surgically. All defects were evaluated at the time of surgery (T3) and 4 months later (T4). Evaluation included standardized measurements on radiographs, pressure-forced implant probing, and histometry. Furthermore, both conventional and digital radiographic techniques were used.* ***Results:*** *Both radiographic techniques showed very similar results at T3 and T4. At time T4, pressure-forced probing revealed statistically significantly different values than those obtained with radiography and histometry. When radiographic and histometric measurements were compared, no significant differences were found at either time T3 or time T4.* ***Discussion:*** *In this study, histometry showed better accordance with radiography than with pressure-forced probing. These results support the hypothesis that peri-implant attachment should be evaluated with a combination of both clinical and radiologic parameters.* ***Conclusion:*** *The exclusive use of radiography cannot be recommended for the measurement of peri-implant attachment.* INT J ORAL MAXILLOFAC IMPLANTS 2004;19:208–215

Key words: *alveolar bone attachment levels, dental implants, dental radiography, histometry, periodontal probing*

In recent years, there has been increasing interest in new methods for bone regeneration in the field of implant dentistry. Normally, the assessment of treatment outcome is based on clinical and radiologic parameters. In the literature, however, the accuracy of radiologic measurements has been a controversial subject.[1–3] While Eickholz and Benn[2] were able to document good reproducibility when standardized radiographs were used, Grunder and coworkers[3] found metric underestimation of the horizontal and vertical bone loss in the radiograph, which resulted in an overestimation of the prevailing bone attachment. As a result, in some studies, evaluation of new implant treatment is based either on histomorphometry[4–6] or on radiography.[7,8] Moreover, microbiologic considerations suggest that clinical evaluation by means of pocket probing must be considered carefully.[9]

With regard to the risks of x-ray radiation, the question arises as to whether radiography is still routinely appropriate for the evaluation of periimplantitis treatment. Therefore, this experimental study was undertaken to evaluate the relationship between attachment measurements around implants, as performed with pressure-forced probing, and the bone level in standardized dental radiographs, as referenced to histometrically verified attachment measurements.

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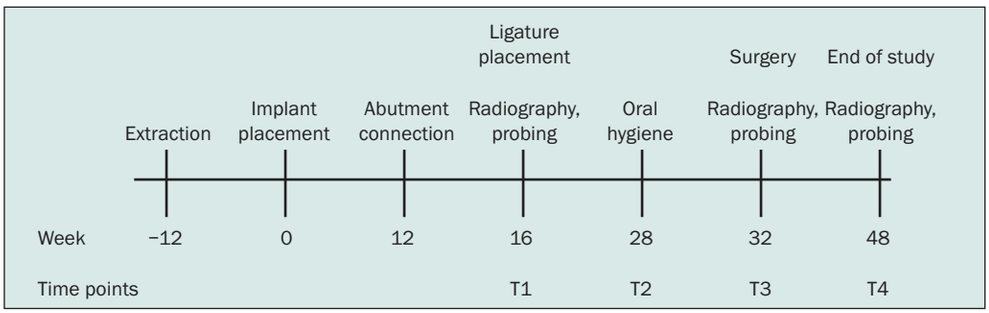

Fig 1 Timeline of the experiment. At 16 weeks, ligatures were placed around the implants to induce peri-implantitis. Oral hygiene was carried out for 4 weeks before surgery. Standardized radiographs and clinical probings were obtained at both T3 and T4.

MATERIALS AND METHODS

Experimental Protocol

The study was performed in a total of 6 female beagle dogs (Fig 1). Five plasma-sprayed titanium implants were placed in each hemimandible (Frialit-2, 3.8 × 11 mm; Friadent, Mannheim, Germany). The implants were uncovered 12 weeks after placement.

After 4 weeks of oral hygiene (ie, T1/week 16; Fig 1), standardized radiographs were obtained to determine the distance from the implant shoulder to the marginal bone crest at the mesial and distal aspects of each implant. After radiographs were obtained, cotton floss ligatures were positioned around the implants,[10] allowing gross plaque accumulation (T1 = beginning of the defect induction). Another 12 weeks later (ie, T2/week 28; Fig 1), the ligatures were removed, and for 4 weeks, a daily oral hygiene regimen was performed (T2 = beginning of the hygiene phase). After this 4-week period of oral hygiene, surgery was performed (ie, T3/week 32; Fig 1). New standardized radiographs and clinical examination revealed that between 30% and 50% of the peri-implant bone had been lost.

Immediately after the radiographs and clinical assessment, surgical treatment was carried out with standard procedures for conventional or carbon dioxide (CO_2) laser-assisted implant decontamination (T3 = surgical intervention).[10] The surgical treatment consisted of granulation tissue removal, including decontamination of the implant surface by 3 different methods. Twenty implants (group 1) were decontaminated conventionally by an air-powder abrasive (Prophy-Jet; Dentsply, York, PA) for 60 seconds. Another 20 implants (group 2) were decontaminated by CO_2 laser treatment alone (λ = 10.6 µm, continuous wave, 2.5 watts, 6 times at 10 seconds each). The last 20 implants, group 3, were treated conventionally by the Prophy-Jet for 60 seconds and then lased with the specified parameters for another 60 seconds. In each hemimandible, only 1 mode of treatment was performed.[10]

During the following 16 weeks, no other therapeutic measures were carried out, other than daily mechanical oral hygiene. After this 16-week period, ie, 16 weeks after treatment of the peri-implant defects, the animals were anesthetized and sacrificed by intravenous injection of 20 mL Narcoren (80 mg/kg pentobarbital sodium; Rhone Merieux, Laupheim, Germany). At this time, standardized radiographs were also obtained and the clinical condition assessed (T4 = end of study). Histologic specimens were prepared according to the method of Donath and Breuner[11] to serve as the gold standard.

Clinical Parameters

The clinical parameter of peri-implant bone destruction, assessed immediately prior to surgical treatment of the peri-implant defects (T3) and at the end of the healing phase (T4), was the clinical attachment level (AL) derived from pressure-forced pocket probing. The probing depth (PD)[12] was measured with a periodontal probe (PCP 11; Aesculap, Tuttlingen, Germany). Since the probings were carried out in anesthesized animals, they could be obtained under forced pressure. This parameter was measured in millimeters at the lingual, distal, buccal, and mesial aspects.

The distance from the "implant shoulder" (the upper edge of the Frialit-2 implant) to the marginal mucosa (DIM)[12] was measured, similarly, in millimeters at the lingual, distal, buccal, and mesial aspects. Positive values indicate that the implant protruded from the mucosa, and negative values indicate a submucosal position of the upper edge of the implant. Consequently, the value for the attachment level is the sum of the PD and the DIM: AL = PD + DIM (Fig 2).[12] The clinical AL parameter is

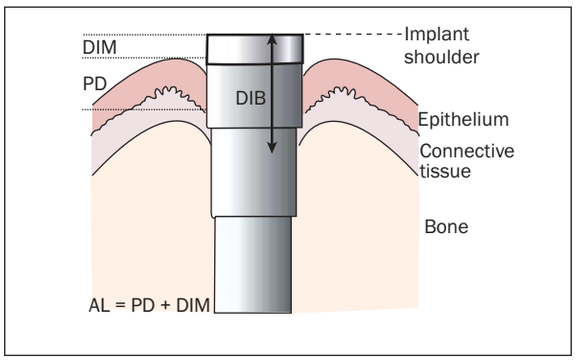

Fig 2 Schematic visualization of clinical (PD, DIM, AL) and radiographic (DIB) parameters according to Buser and coworkers.[12]

an important indicator of resorptive changes in the tissue.

At T3, on all implants, the 3 clinical parameters were evaluated (n = 120). At T4, only those implants with dehiscent mucosa could be subjected to probing (n = 42).

Radiology

A Siemens x-ray tube (Heliodent MD; Sirona, Bensheim, Germany) with a cone length of 25 cm was used to take the radiographs. Conventional Agfa Dentus M 2 films (Agfa, Mortsel, Belgium) as well as digital radiographs (Digora; Soredex, Helsinki, Finland) were used. Therefore, it was possible to compare the accuracy of both radiologic techniques with the gold standard of histometry. Both the conventional and digital systems were calibrated before the radiographs were taken. Therefore, with each of the 2 systems, reference radiographs were taken using a standardized test object. Optical densities of the resulting radiographs were compared. An exposure time of 0.2 seconds at 7 mA and 60 kV resulted in comparable optical densities for both the conventional and digital systems.

The software of the digital system provided a special mode for calibration. This mode converted the analog data to a total of 255 greytones. Therefore, imaging plates had a wide dynamic range, as well as some x-ray generators. The calibration was used to adapt the tenfold range (10% to 100%) of the scanner to the range of the imaging plates and x-ray generators. The calibration routine of the scanner controlled the sensitivity of the photo detector (photomultiplier tube) by adjusting its high voltage. The imaging plates (3 × 4 cm) were scanned with the use of a helium-neon laser (maximum power output 2 mW, wavelength 632.8 nm).

Custom-made film holders were fixed to the cone as well as to the abutments that were connected to the implants. Each film was positioned with the aid of an acrylic resin template.

The conventional films were developed in a Periomat developer for 5 minutes at 20°C (Dürr Dental, Bietigheim-Bissingen, Germany). Measurement of the distance between implant and bone (DIB) was carried out according to the method described by Buser and coworkers.[12] The DIB value over time provides information on resorption or apposition of the peri-implant marginal bone. The measurements were made with the aid of a magnifying glass (HRP, 4×; Heine Optotechnik, Herrsching, Germany) and calipers (Züricher Modell; Dental-Liga, Zürich, Switzerland) on a backlit screen in a darkened room to an accuracy of ± 0.5 mm. The peri-implant bone level was marked at the mesial and distal aspects, and the distance to the reference point, the implant shoulder, was measured. For correction of the magnification factor, the distance from the implant shoulder to the tip of the implant was used as the reference length.

With the digital radiography system, the measurements were similarly carried out on a 15-inch monitor (Nokia, Bochum, Germany) that provided a resolution of 800 × 600. The software enabled adjustment of brightness and contrast. Therefore, radiographic images were activated and arranged with the use of special software tools. Brightness and contrast were changed until the most coronal level of bone could clearly be identified. According to the manufacturer, the measurement accuracy was ± 0.1 mm.

Histometry

Ground sections were stained with toluidine blue. This stain is particularly well suited to identify bone regeneration and destruction. Mature bone stains pink to purple, and newly regenerated, immature bone takes on a dark blue color.[10,13]

The specimens were photographed (magnification ×2, Ektachrome 100 HC daylight; Kodak, Rochester, NY). The resulting slides were scanned at 5× magnification (SprintScan 35; Polaroid, Waltham, MA) using Micrografics Picture Publisher 4.0 (Microsoft, Redmond, WA) and stored as bitmap data on a personal computer. A monitor was connected to the personal computer and provided a resolution of 800 × 600 pixels. Special software (Photoshop 5.0; Adobe Systems, San Jose, CA) allowed for computer-based histomorphometric analyses with a zoom of 2.5.[10]

Measurements were recorded from the mesial and distal aspects of each implant to evaluate the amount of reappositioned bone. Thus, the length of implant embedded in new bone was determined by

measuring the distance between the most apical level of new bone in direct contact with the implant surface and the most coronal level of new bone in direct contact with the implant surface. Distances of areas without direct contact to the bone were then measured and subtracted. Since the lengths of the implants were known, the distances measured could be easily converted to their actual dimensions in millimeters.

Correlations and Statistics

This study was undertaken to assess the correlation between pressure-forced measurements of bone levels and those derived with radiologic and histometric methods. As described above, stained histologic sections provided exact bone level data at the time of surgical treatment (T3) and at the end of the healing phase (T4), but not at T1 and T2. Consequently, comparison of the pressure-forced measurements with radiologically and histologically determined bone levels was based on analyses performed at T3 and T4.

Two measured values were considered unchanged if they did not differ by more than 0.5 mm. The following comparisons were carried out. First, the bone levels were compared, as determined with conventional versus digital radiograph modes. A further comparison encompassed the frequency of accordance between the conventional radiograph mode of bone level determination with the values obtained with pressure-forced measurement and with histometrically determined attachment levels.

The individual measurements were performed by an experienced examiner, who had no knowledge of whether the histologic sections and the radiographs were control (group 1) or experimental (groups 2 and 3). Morever, it was unknown whether the radiographs were taken at time T3 or T4.

Statistical analysis was performed using a commercial computer program (Excel, version 97; Microsoft). Two-tailed Student *t* tests for small sample sizes permitted comparison of the values obtained with radiographic, histometric, and pressure-forced methods. To circumvent the fact that multiple measures within the same animal are not statistically independent, mean values within each animal were used. A *P* value less than or equal to .05 in the 2-tailed test was considered to indicate statistical significance.

RESULTS

Comparison of Conventional and Digital DIB Values

Tables 1 and 2 and Figs 3 and 4 show that there was accordance between the DIB values yielded with conventional and digital radiographic modes, with an accuracy of ± 0.5 mm, in 74.8% of values at T3 and 62.8% of values at T4.

The correlation between defect depth (DIB) values as determined with conventional and digital radiography was good; 2-tailed *t* tests resulted in a *t* value of 0.25 at T3 and a *t* value of 0.67 at T4 (Tables 3 and 4). Accordingly, at T3 and T4, there was no statistically significant difference at the 5% level between the 2 radiographic methods; thus at T3 and T4, the 2 radiographic techniques rendered similar results.

Comparison of Conventional DIB Values with Pressure-Forced AL Values

Tables 1 and 2 and Figs 3 and 4 demonstrate that at T3, with a measurement accuracy of ± 0.5 mm, there was accordance between the conventionally measured DIB values and the pressure-forced measurements in 53.2% of values and at T4 in 36.1% of values.

Correlation of conventional radiographs and pressure-forced measurements of the defect depths using the 2-tailed *t* test yielded a *t* value of 1.48 at T3 and 3.52 at T4 (Tables 3 and 4). Accordingly, there was no statistically significant difference between the 2 methods at T3, but at T4 there was a statistically significant difference ($P \leq .05$).

Comparison of Conventional DIB Values with Histometrically Determined Values

Tables 1 and 2 and Figs 3 and 4 show that at T3, with a measurement accuracy of ± 0.5 mm, there was accordance between the conventionally measured DIB values and the histometrically determined measurements in 43.3% of values; at T4, accordance was 45.2%.

Correlation of conventional radiograph and histometric measurements of the defect depths using the 2-tailed *t* test yielded *t* values of 1.65 at T3 and –0.22 at T4. Accordingly, at T3 and T4, there was no statistically significant difference at the 5% level between the radiographically and histometrically determined values; thus at T3 and T4, the 2 techniques rendered similar results.

Table 1 Frequency Distribution of Measurement Deviations (%) Between the 4 Evaluation Techniques at Surgery (T3)

Deviation (mm)	Accordances of measurements			
	CR/DR (n = 111)	CR/P (n = 111)	CR/H (n = 104)	P/H (n = 113)
< –1.5	0.9%	0.0%	2.9%	3.6%
–1.5 to –1.1	0.0%	1.8%	2.9%	7.1%
–1.0 to –0.6	9.0%	6.3%	10.6%	10.7%
–0.5 to 0.5	74.8%	53.2%	43.3%	47.8%
0.6 to 1.0	9.0%	23.4%	16.3%	16.0%
1.1 to 1.5	4.5%	9.9%	6.7%	6.8%
> 1.5	1.8%	5.4%	17.3%	8.0%

CR = conventional radiography; DR = digital radiography; H = histometry; P = pressure-forced probing.

Table 2 Frequency Distribution of Measurement Deviations (%) Between the 4 Evaluation Techniques at End of Study (T4)

Deviation (mm)	Accordances of measurements			
	CR/DR (n = 110)	CR/P (n = 36)	CR/H (n = 102)	P/H (n = 40)
< –1.5	0.9%	8.3%	3.9%	15.0%
–1.5 to –1.1	1.8%	0.0%	6.8%	10.0%
–1.0 to –0.6	6.3%	13.9%	18.6%	15.0%
–0.5 to 0.5	62.8%	36.1%	45.2%	32.5%
0.6 to 1.0	15.6%	11.1%	11.8%	10.0%
1.1 to 1.5	5.4%	13.9%	9.8%	10.0%
> 1.5	7.2%	16.7%	3.9%	7.5%

CR = conventional radiography; DR = digital radiography; H = histometry; P = pressure-forced probing.

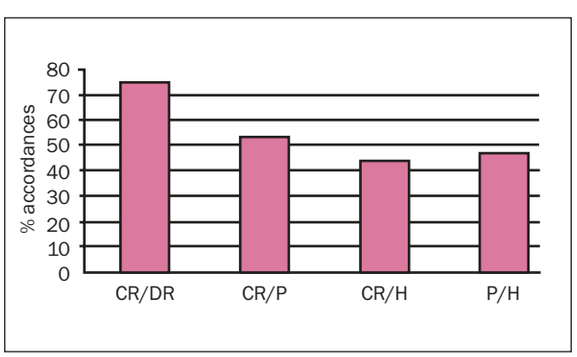

Fig 3 Accordances of measurements at T3 (surgery). The best accordances were found between conventional radiography (CR) and digital radiography (DR). Values obtained with CR or probing (P) were in clinically acceptable accordance with the values obtained by histometry (H).

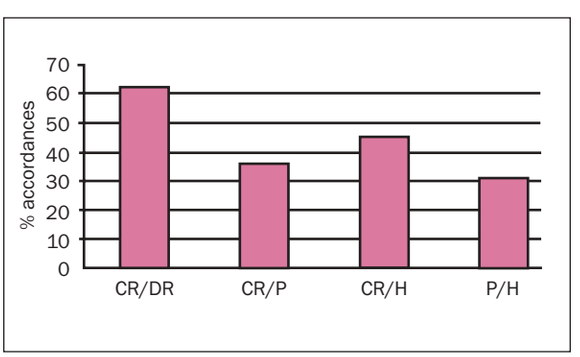

Fig 4 Accordances of measurements at T4 (4 months after surgery). Again, the best accordances were found between conventional radiography (CR) and digital radiography (DR). At this point in time, histometry (H) showed better accordance with CR than with pressure-forced probing (P).

Table 3 Mean Values and Standard Deviations of Histometric Measurements (H), Pressure-Forced Probing (P), and Conventional (CR) or Digital Radiographic (DR) Measurements at Time of Surgical Procedure (T3)

Methods	Means ± SD (mm)	Accordance at ± 0.5 mm accuracy	*t* value	Statistically significant difference?
CR/DR	2.92 ± 0.51/2.97 ± 0.44	74.8% (n = 120)	0.25	No
CR/P	2.92 ± 0.51/3.50 ± 0.87	53.2% (n = 120)	1.48	No
CR/H	2.92 ± 0.51/3.29 ± 0.50	43.3% (n = 113)	1.65	No
P/H	3.50 ± 0.87/3.29 ± 0.50	47.8% (n = 113)	–0.93	No

Statistical analysis indicated that both conventional radiology and probing resulted in values that were comparable to those obtained with histometry (no statistically significant difference at the 5% level).

Table 4 Mean Values and Standard Deviations of Histometric Measurements (H), Pressure-Forced Probing (P), and Conventional (CR) or Digital (DR) Radiographic Measurements at 4 Months After Surgery (T4)

Methods	Means ± SD (mm)	Accordance at ± 0.5 mm accuracy	*t* value	Statistically significant difference?
CR/DR	2.71 ± 0.65/2.92 ± 0.69	62.8% (n = 120)	0.67	No
CR/P	2.71 ± 0.65/3.39 ± 0.43	36.1% (n = 42)	3.52	Yes ($P \leq .05$)
CR/H	2.71 ± 0.65/2.65 ± 0.60	45.2% (n = 113)	–0.22	No
P/H	3.39 ± 0.43/2.65 ± 0.60	32.5% (n = 42)	–2.75	Yes ($P \leq .05$)

Statistical analysis indicated that both conventional radiology and probing resulted in values that were comparable to those obtained with histometry (no statistically significant difference at the 5% level).

Comparison of Pressure-Forced AL Values with Histometric Values

Tables 1 and 2 and Figs 3 and 4 show that at T3, with a measurement accuracy of ± 0.5 mm, there was 47.8% accordance between the pressure-forced AL measurements and the histometrically determined measurements; at T4, accordance was 32.5%. The correlation of the pressure-forced AL measurements with the histometric values using the 2-tailed *t* test yielded *t* values of –0.93 at T3 and –2.75 at T4. Accordingly, at T3, there was no significant difference between the 2 methods, but at T4 there was a significant difference at the 5% level.

Comparison of Accordances

At both points in time, there was close accordance between the conventionally and digitally determined radiographic values. Moreover, there was no statistically significant difference between the radiologically determined values and those determined histometrically at either the time of surgical treatment (T3) or at the end of the healing phase (T4). The pressure-forced AL values and those determined radiologically were in accordance at T3, but there was a statistically significant difference between these 2 methods at T4 on the 5% level (Tables 3 and 4). This finding was corroborated by the statistically significant difference between pressure-forced probing and histometry at T4 at the 5% level.

DISCUSSION

Several published studies have examined the reliability of radiologically determined values of marginal bone loss. Radiologic techniques have been used to assess the success of dental implants,[8,9] as well as to validate treatment of peri-implant bone loss.[1,3,7,10,14] In spite of the guidelines for radiation safety, the use of this method is justified by the fact that histometric data cannot be obtained on a clinical basis. Consequently, in view of restrictive policies governing the use of radiologic procedures, the question arises as to whether a clinical evaluation alone is sufficient for validation of new therapeutic approaches for peri-implantitis.

Comparison of the conventionally and digitally determined defect depths showed no significant differences at T3 and T4; that is, both methods could be regarded as equivalent. This observation is consonant with that reported in the literature. Schmage and coworkers investigated the periodontal condition with conventional and digital radiographic techniques.[15] These authors also regarded the

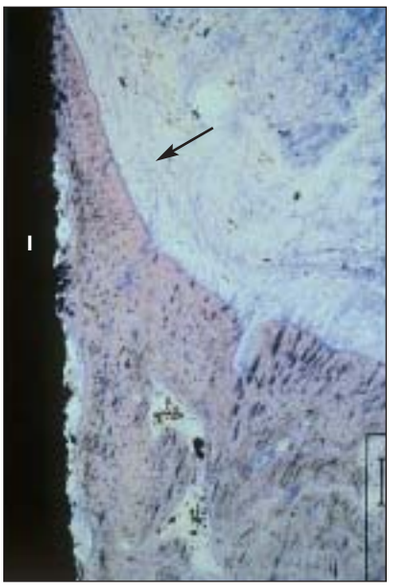

Fig 5 Implant after CO_2 laser–assisted implant decontamination. Large areas of newly formed vertical bone *(arrow)* are in direct contact with the implant (I) (new bone stained darker than old bone). Connective tissue is apparent in the upper right of the sample (toluidine blue; bar = 50 µm).

Digora System as potentially useful for periodontal diagnostics.

The lesser extent of accordance between conventional and digital techniques found in this study at T4 appears to be attributable to overexposure of the very thin lamella of newly formed bone by the Digora System in spite of digital processing (Tables 1 and 2). Therefore, in this study, the values of the conventionally measured defect depths were used for subsequent correlations. In concordance with Schmage and coworkers, conventional radiography still appears to yield the most reliable results.[15]

The comparison of the pressure-forced measurements and those determined radiologically yielded no statistically significant differences at T3 but found differences at T4, indicating that the values for these 2 techniques were not comparable posttreatment. Moreover, accordance of the values, within the measurement accuracy of ± 0.5 mm, was poor (just 36.1% at T4). The probing was carried out while the animals were under general anesthesia; clinical evaluation by probing without anesthesia may give even less evidence about the defect situation.

As referenced to the "gold standard" of histometric evaluation, conventional radiographs showed acceptable accordances with histometrically determined values at T3 (43.3%) and T4 (45.2%). This was corroborated by the results of statistical analysis, which showed no significant differences between these 2 methods. Therefore, radiographic evaluation may be considered a reliable method for detection of bone loss.[7]

Accordance between pressure-forced probing and histometry was clinically acceptable at T3 (47.8%) but poor at T4 (32.5%). Accordingly, there was no statistically significant difference found between these 2 methods at T3; but at T4 there was a statistically significant difference at the 5% level. This can be accounted for by the histologically documented vertical bone reapposition seen along the implant surface (Fig 5). Caused by the pressure-forced probing technique, it must be assumed that the tip of the probe slides past the thin vertical newly formed bone until it is stopped by the horizontal bone shelf. Moreover, the stepped form of the Frialit-2 implant precluded probing strictly parallel to the axis of the implant. Hence, this pressure-forced probing did not reliably reflect the actual amount of reapposition.

Statistical analysis (Tables 3 and 4) was based on a small effective sample size (n = 6). Nevertheless, the results of this study indicated that, at both T3 and T4, the bone level could be accurately determined with radiologic techniques. However, values obtained with pressure-forced probing were in clinically acceptable accordance with radiography and histometry at T3 but not at T4. These findings are consonant with the results of Grunder and associates,[3] who found inaccurate estimations when radiography was compared with clinically determined probing depths.

If, within the scope of a clinical study, histometric evaluation cannot be carried out for practical reasons, then radiologic and pressure-forced attachment measurements probably should be employed to assess the treatment outcome. In this study, for the assessment of smaller areas of bone reapposition after treatment of peri-implantitis (analogous to T4), the radiologic methods appeared better suited than pressure-forced probing because of the vertical apposition of newly formed bone. At this point in time, histometry showed better accordance with conventional radiology than with pressure-forced probing. However, it is not clear whether this vertical type of bone reapposition will also occur in humans. Consequently, to enable the most reliable assessment, peri-implant changes in bone should be evaluated clinically, radiologically, and, if possible, histometrically.[16] A lessening of these requirements by virtue of a restrictive use of x-ray radiation does not appear warranted at this time.

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