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# Clinical and Histologic Evaluation of Submerged and Nonsubmerged Hydroxyapatite-Coated Implants: A Preliminary Study in Dogs

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A clinical and histologic study was performed to evaluate the differences in the healing of submerged and nonsubmerged hydroxyapatite-coated 2-piece implants. Three foxhounds were used for this evaluation. Mandibular premolars 1, 2, 3, and 4 were extracted. Three months later, 2 submerged implants were placed on one side of the mandible, and 2 nonsubmerged implants were placed on the other side of the mandible. After 3 months of healing, the submerged implants were exposed, and a third implant was placed on each side of the mandible in a nonsubmerged procedure. Clinical parameters were recorded, the animals were sacrificed 6 months after placement of the first implants, and histologic and histometric analyses were performed. Results of the evaluation of the clinical parameters showed only minor differences among the different treatment groups.

Regarding the percentage of bone-to-implant contact of the different treatment groups, the submerged implants showed a bone-to-implant contact of 63.4%, the nonsubmerged implants showed 70.3% contact, and the late nonsubmerged implants demonstrated a bone-to-implant contact of 58.7%. The average distance from the implant neck to the first bone-to-implant contact (fBIC) for submerged implants was 0.58 mm, for nonsubmerged implants it was 1.09 mm, and it was 1.13 mm for late nonsubmerged implants. The vertical distance between the gingival margin and the apical extent of the junctional epithelium (aJE) varied from 1.14 mm to 1.28 mm in the different groups. The distance from the aJE to fBIC was 1.00 mm for the submerged group, 1.08 mm for the nonsubmerged group, and 1.00 mm for the late nonsubmerged group. Generally, it can be concluded that the clinical and the histologic behavior of submerged or nonsubmerged 2-piece implants utilized in this experiment do not differ. (INT J ORAL MAXILLOFAC IMPLANTS 1999;14:824-834)

**Key words:** animal experiment, clinical evaluation, histologic evaluation, hydroxyapatite-coated implants, nonsubmerged (transmucosal) implants, osseointegration, 2-piece implants

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**E**xperimental and clinical studies have shown that endosseous dental implants are a predictable treatment method for the replacement of lost teeth.<sup>1-7</sup> Implant placement is recognized as a treatment method for edentulous patients,<sup>8</sup> partially edentulous patients,<sup>9-11</sup> or patients with a single missing tooth.<sup>12,13</sup>

Direct bone-to-implant contact is called osseointegration<sup>14</sup> or functional ankylosis.<sup>15,16</sup> To obtain this close contact, Brånemark postulated

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that it is best achieved by initially submerging the implant (ie, the implant is covered after placement with the elevated flap<sup>1,14</sup>) to eliminate possible peri-implant infection and epithelial downgrowth. In this condition, the implant can integrate without movement and absence of the oral microflora. A second surgical procedure is necessary to uncover the implant and to attach an abutment for prosthetic rehabilitation.

This philosophy has not been supported by others. The International Team for Oral Implantology, using the Bonefit implant system (Straumann, Waldenburg, Switzerland), for example, did not intentionally submerge implants at the time of placement.<sup>10,11,17,18</sup> The nonsubmerged placement of implants did not compromise hard and soft tissue integration or long-term success.<sup>19</sup> Similar observations have been made with single-crystal sapphire implants<sup>20</sup> and screw implants.<sup>21</sup> Gotfredsen et al<sup>22,23</sup> compared the healing of submerged and nonsubmerged Bonefit implants in monkeys and evaluated peri-implant reactions adjacent to the nonsubmerged implants. They were able to demonstrate that there were no radiographic differences or differences in bone-to-implant contact between the submerged and nonsubmerged implants during healing.

The main advantage of nonsubmerged placement of implants is that they do not require a second surgical procedure for placement of the transmucosal abutment, thus reducing the costs and treatment time while allowing further maturation of the tissues around the implant.

There are also groups that report the use of 2-stage implants placed in a 1-stage fashion.<sup>24,25</sup> These studies suggest that over the observation periods reported (1 to 5 years), the clinical performance of the 1-stage procedure compares favorably with the traditional 2-stage procedure. Recently, a new implant system was introduced (Paragon Implant Surgical System, Paragon Implant Company, Encino, CA) and reported to be usable in a 2-stage as well as in a 1-stage technique. Until now no data have been available concerned with the clinical behavior and histologic outcome of that implant system. Therefore, this preliminary animal experiment was conducted to compare the nonsubmerged placement of 2-piece implants of this system with submerged placement of the implants.

## Materials and Methods

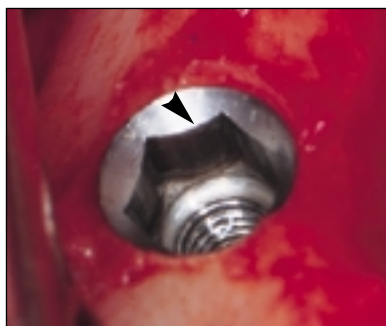
Prior to the start of the study, the protocol was approved by the University of Texas Animal Wel-

fare Committee at Houston. The study was performed in accordance to the Good Laboratory Practice specified by the U.S. National Institutes of Health.

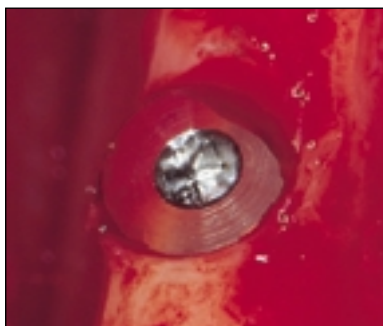
Three female foxhounds, 4 to 6 years old, were used in this investigation. The animals were examined by a veterinarian for their health status. They were maintained on a soft diet for the entire study period. At the beginning of the study, mandibular premolars 1, 2, 3, and 4 were extracted. For the extractions and implant surgeries, the dogs were sedated intravenously with a 5:2 mixture of ketamine and acepromazine (Ketalar, Parke-Davis, Morris Plains, NJ) and then placed under general anesthesia with isoflurane gas/oxygen gas at a concentration of 0.5% to 1%. The operated areas were infiltrated locally with 2% xylocaine with 1:100,000 epinephrine for hemostasis. The teeth were separated and subsequently carefully removed with the use of a forceps to minimize trauma. The flaps were sutured back with resorbable sutures.

After a healing period of 3 months, the animals were placed under general anesthesia, and 2 implants were placed on each side of the mandible in the region of the former second and third premolars. On both mandibular quadrants a midcrestal incision was made, extending from the distal of the mandibular canine to the mesial of the mandibular first molar. A full-thickness flap was then raised buccally and lingually. On one side of the mandible, 2 hydroxyapatite- (HA) coated screw implants (Paragon Screw-Vent HA-Coated Selective Surface, 3.7 mm diameter, 13 mm length) were placed in a submerged procedure (submerged treatment group). The healing collars were removed and replaced with cover screws (Figs 1a and 1b). The flaps were closed with silk sutures using horizontal mattress and interrupted sutures. The implants were covered entirely by the mucoperiosteal flap.

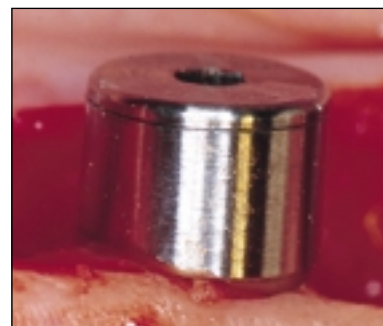
On the opposite side of the mandible, 2 implants of the same type were placed using a nonsubmerged procedure (nonsubmerged treatment group). These implants were placed with the pre-mounted friction-fitted healing collars acting as the transmucosal abutments (Fig 1c). The mucoperiosteal flaps were closed tightly around the healing abutments with horizontal mattress and interrupted sutures. For the first 2 postsurgical weeks, the dogs' oral cavities were rinsed daily with 0.12% chlorhexidine. In addition, the dogs were fed a soft diet and water ad libitum. The sutures were removed after 7 to 10 days. After 14 days, an oral hygiene program was started, which consisted of plaque removal 7 times a week with a



**Fig 1a** Implant placed 3 months after tooth extraction into healed alveolar ridge (*arrowhead* = internal hex).



**Fig 1b** Submerged implant with the cover screw attached.



**Fig 1c** For the nonsubmerged implant, a transmucosal abutment was connected to the implant.

soft toothbrush and pumice soaked with 0.12% chlorhexidine. This maintenance program was followed strictly throughout the entire study. Healing was allowed for 3 months.

After 3 months of healing, a midcrestal incision was made on the side with the submerged implants, the implants and the distal alveolar ridge were exposed, and the abutments were connected. On the nonsubmerged site, a full-thickness flap was raised distal to the most distal implant. In each quadrant, 1 additional screw implant was placed in a nonsubmerged procedure distal to the other implants in the former region of the fourth premolars (late nonsubmerged implant group). The flaps were closed around the transmucosal abutments with interrupted sutures, and an additional healing period of 3 months was allowed. Thus, in each animal 2 implants were placed submerged, 2 implants nonsubmerged, and 2 implants late nonsubmerged. The design of this investigation allowed the comparison of bone healing between the submerged procedure and the nonsubmerged procedure after 6 months, and it permitted comparison of soft tissue healing between the submerged implant placement with the late nonsubmerged placement after 3 months. Figure 2a depicts the outline of the experiment.

**Clinical Records.** The implants were divided into 3 different treatment groups: group 1 with implants #5 and #6, which were placed nonsubmerged for 180 days (ie, nonsubmerged group); group 2 with implants #2 and #3 placed submerged for 90 days and exposed for 90 days (ie, submerged group); and group 3 with implants #1 and #4 placed nonsubmerged for 90 days (ie, late nonsubmerged group). Implant #1 was the distal implant placed late nonsubmerged in the same quadrant where implants #2 and #3 had been

placed, implant #2 was the mesial implant placed submerged, and implant #3 was the middle implant placed submerged. Implant #4 was placed late nonsubmerged in the same quadrant where implants #5 and #6 were placed, implant #5 was the mesial implant placed nonsubmerged, and implant #6 was the middle implant placed nonsubmerged. Figure 2b presents the alignment of the implants. For each group of implants, 2 implants were placed per animal. The following clinical information was recorded at monthly intervals for 4 implant sites (mesial, buccal, lingual, and distal): (1) Plaque Index<sup>26</sup>; (2) Gingival Index<sup>27</sup>; (3) probing depth; (4) clinical attachment level using a North Carolina periodontal probe (Hu-Friedy Instruments, Chicago, IL) to the nearest mm; and (5) implant mobility (Periotest, Siemens, Bensheim, Germany).

Six months after placement of the first implants, the animals were sacrificed by exsanguination under general anesthesia. The heads of the animals were perfused with 10% neutral buffered formalin. The jaws were removed en bloc and placed in 10% formalin for further fixation.

**Histologic Preparation and Histomorphometric Evaluation.** Preparation of the histologic sections has been described elsewhere.<sup>28</sup> Briefly, after completion of the fixation, the mandibles were cut buccolingually, with each block including 1 implant, using a band saw equipped with a diamond-coated band and further processed according to the cutting-grinding technique of Donath and Breuner.<sup>29</sup> The undecalcified sections had an initial thickness of 200 to 300  $\mu\text{m}$ . With the grinding unit, the thickness was reduced to approximately 30  $\mu\text{m}$ . The sections were stained with toluidine blue and examined under a light microscope (Zeiss, Oberkochen, Germany). Histometric evaluation of the area around the implants was performed at

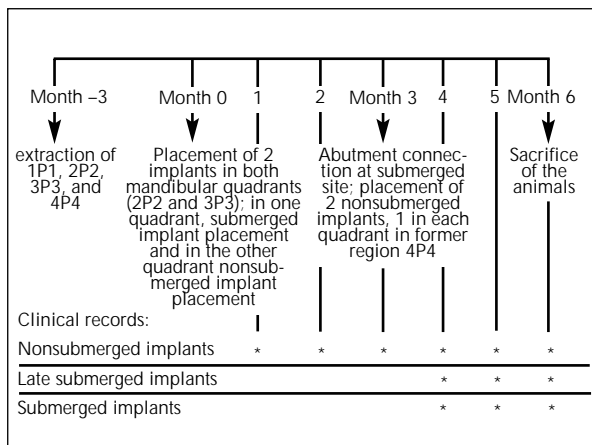


Fig 2a Outline of the experiment (n = 3).

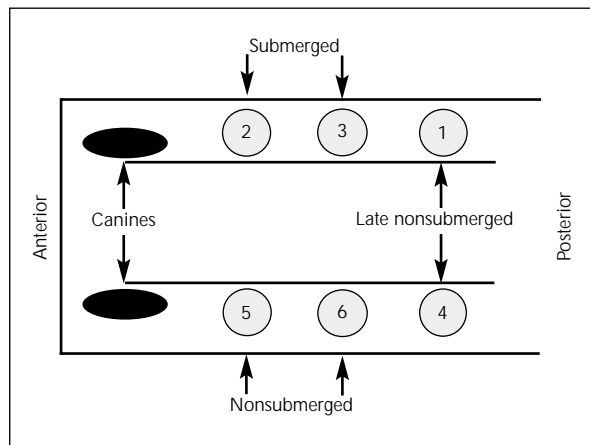


Fig 2b Illustration of a dog mandible showing arrangement of the implants.

40 $\times$  magnification. Histometric data were collected using AnalySiS 2.1 software (Soft-Imaging Software GmbH, Münster, Germany). The following measurements were performed (Fig 3):

1. Percentage of the entire implant surface in contact with bone, with the reference point being the connection of the friction-fitted abutment and the implant (implant-abutment junction/implant neck, or IN);
2. First contact of the implant with bone measured from the implant neck (IN-fBIC);
3. Vertical distance between gingival margin (GM) and the apical extent of the junctional epithelium (aJE) (GM-aJE);
4. Apical extent of the junctional epithelium from the implant neck (IN-aJE);
5. Distance from the apical extension of the junctional epithelium to the first bone-to-implant contact (aJE-fBIC);
6. Area analysis: calculating the percentage of bone in a defined square area around the implant. The area analysis was performed using 2 squares (2000  $\times$  2000  $\mu$ m), one placed coronally and one placed apically. The coronal square was placed with its upper border at the height of the first thread, and the apical square was placed with its lower border at the height of the third apical thread (bone density in %);
7. The best 3 consecutive threads regarding bone-to-implant contact.

**Statistical Analysis.** Because of the small number of animals (n = 3), the clinical evaluation was assessed solely quantitatively, and only descriptive statistical analysis (means and standard deviations)

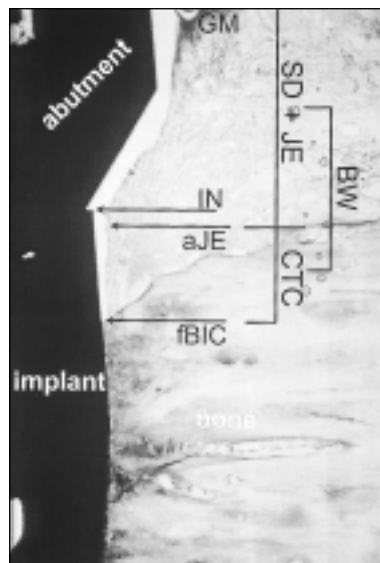


Fig 3 Illustration of the histometric evaluation with the following measurements performed: distance from the gingival margin (GM) to the apical extent of the junctional epithelium (aJE); GM-aJE = sulcus depth plus epithelial attachment (SD + JE). Distance from the aJE to the first bone to implant contact (fBIC); aJE-fBIC = connective tissue contact (CTC). SD + JE + CTC = biologic width (BW). Distance from the implant neck/implant-abutment junction (IN) to the fBIC (IN-fBIC). Distance from the IN to the aJE (positive value = aJE ends apical to the IN, negative value = aJE ends coronally to the IN).

tions) was performed. For the statistical evaluation of the histometric results, means, standard deviations, analysis of variance, F value, and Scheffe's test (SAS Statistical Software, Cary, NC) were applied to determine any differences between treatment modalities.

**Table 1** Gingival Index Values at Different Examination Time Points (Mean  $\pm$  Standard Deviation)

|                   | n | Month 1       | Month 3       | Month 6       |
|-------------------|---|---------------|---------------|---------------|
| Nonsubmerged      | 3 | 0.5 $\pm$ 0.4 | 0.1 $\pm$ 0.1 | 0.4 $\pm$ 0.1 |
| Submerged         | 3 | 0             | 0.5 $\pm$ 0.5 |               |
| Late nonsubmerged | 6 | 0.2 $\pm$ 0.2 | 0.4 $\pm$ 0.1 |               |

**Table 2** Plaque Index Values at Different Examination Time Points (Mean  $\pm$  Standard Deviation)

|                   | n | Month 1       | Month 3       | Month 6       |
|-------------------|---|---------------|---------------|---------------|
| Nonsubmerged      | 3 | 0.1 $\pm$ 0.1 | 0.2 $\pm$ 0.3 | 0.7 $\pm$ 0.3 |
| Submerged         | 3 | 0.1 $\pm$ 0.1 | 0.2 $\pm$ 0.3 |               |
| Late nonsubmerged | 6 | 0.1 $\pm$ 0.1 | 0.5 $\pm$ 0.1 |               |

**Table 3** Probing Depth Values (in mm) at Different Examination Time Points (Mean  $\pm$  Standard Deviation)

|                   | n | Month 1       | Month 3       | Month 6       |
|-------------------|---|---------------|---------------|---------------|
| Nonsubmerged      | 3 | 2.6 $\pm$ 0.3 | 1.9 $\pm$ 0.4 | 1.7 $\pm$ 0.1 |
| Submerged         | 3 | 2.8 $\pm$ 0.7 | 1.9 $\pm$ 0.3 |               |
| Late nonsubmerged | 6 | 2.5 $\pm$ 0.7 | 2.0 $\pm$ 0.3 |               |

**Table 4** Attachment Level Values (in mm) at Different Examination Time Points (Mean  $\pm$  Standard Deviation)

|                   | n | Month 1       | Month 3       | Month 6       |
|-------------------|---|---------------|---------------|---------------|
| Nonsubmerged      | 3 | 4.1 $\pm$ 0.1 | 4.3 $\pm$ 0.1 | 4.3 $\pm$ 0.3 |
| Submerged         | 3 | 4.1 $\pm$ 0.3 | 4.4 $\pm$ 0.1 |               |
| Late nonsubmerged | 6 | 4.5 $\pm$ 0.4 | 4.5 $\pm$ 0.2 |               |

## Results

**Clinical Findings.** The postoperative soft tissue wound healing around all implants (submerged, nonsubmerged, and late nonsubmerged) was without complication, except for 1 implant placed submerged in 1 animal (implant #2), which developed a fistula. This implant had to be removed after 3 months because osseointegration had not occurred, since it perforated the root of the adjacent canine during placement. All other implants were retained during the entire study period. After having identified in the histologic sections that implants #2 and #5 (implants placed in former 1P1 positions) perforated the adjacent canines, these implants were excluded from the clinical evaluation.

The Gingival/Mucosal Index values (Table 1) did not show comparable patterns between the 3 different groups. Whereas the 1-month evaluation for the nonsubmerged group presented the highest value (0.5), the other 2 groups showed a low inci-

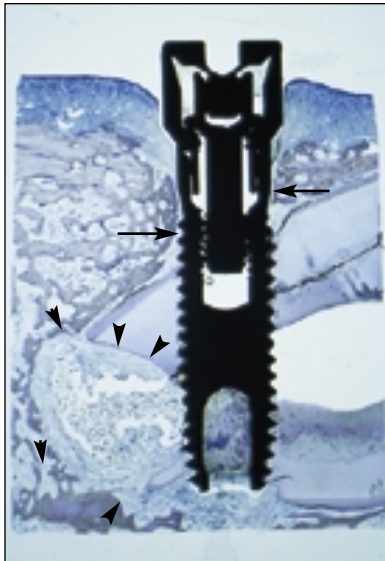
dence of peri-implant inflammation (submerged: 0, late nonsubmerged: 0.2). At the termination of the study, the Gingival Index values were in the range of 0.4 for nonsubmerged and late nonsubmerged implants and 0.5 for submerged implants.

Examination of Plaque Index (Table 2) demonstrated low scores for the different examination time points during the whole study period and in all treatment groups (means of 0.1 to 0.7). It is obvious that the index values increased in general to the highest scores at the last examination time point.

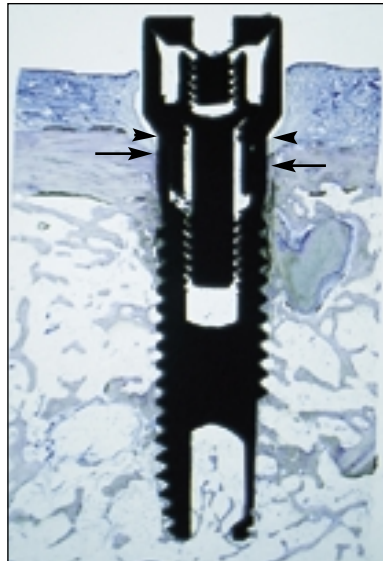
Probing depth and clinical attachment levels measured with a North Carolina periodontal probe are shown in Tables 3 and 4. A reduction in probing depth could be observed in the nonsubmerged and submerged treatment groups of about 1 mm (from 2.6 mm to 1.7 mm and from 2.8 mm to 1.9 mm, respectively). The attachment level did not demonstrate these alterations but remained constant. The differences over time for each group were rather small (from 0 mm to 0.3 mm).

**Table 5** Implant Mobility Values at Different Examination Time Points (Mean  $\pm$  Standard Deviation)

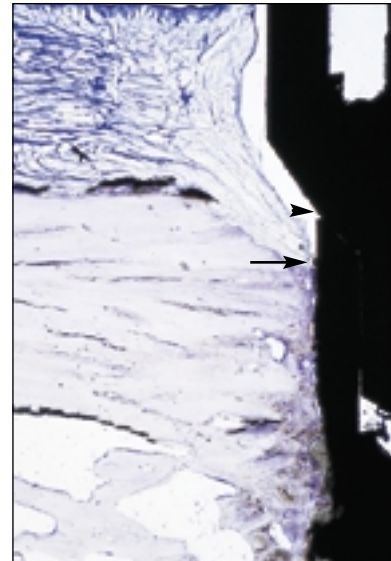
|                   | n | Month 1        | Month 3        | Month 6        |
|-------------------|---|----------------|----------------|----------------|
| Nonsubmerged      | 3 | -2.3 $\pm$ 1.5 | -2.3 $\pm$ 2.3 | -3.0 $\pm$ 1.0 |
| Submerged         | 3 | -4.7 $\pm$ 0.6 | -4.3 $\pm$ 0.6 |                |
| Late nonsubmerged | 6 | -4.8 $\pm$ 1.2 | -4.7 $\pm$ 0.0 |                |



**Fig 4** Implant perforating the natural canine. Apical granuloma and root resorption can be seen (*arrowheads*); soft tissue interposition between implant and alveolar bone also is evident (*arrows*) (original magnification  $\times 7$ ; toluidine blue stain).



**Fig 5a** Implant of the submerged group. (*Arrowheads* = implant neck; *arrows* = fBIC) (original magnification  $\times 9$ ; toluidine blue stain).



**Fig 5b** Higher magnification of Fig 5a. (*Arrowhead* = implant neck; *arrow* = fBIC) (original magnification  $\times 25$ ; toluidine blue stain).

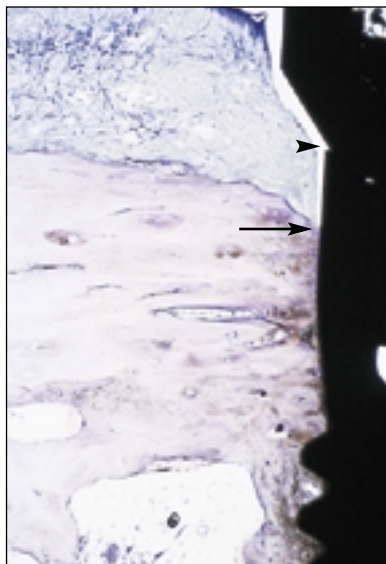
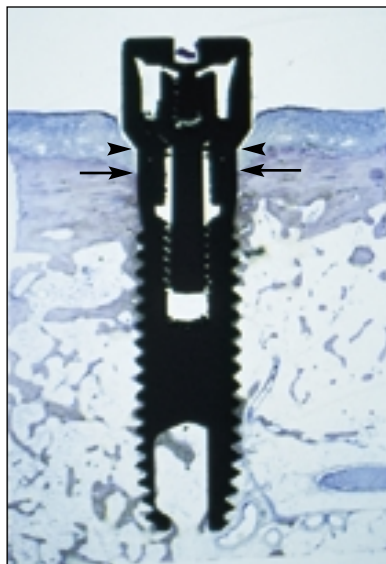
Implant mobility (Table 5) showed negative values for all implants. The mobility scores remained stable over time, with the submerged and late nonsubmerged implants showing higher negative values than the nonsubmerged group.

**Histologic Description.** The implants positioned in the mesial aspect (implants #2 and #5) perforated the natural canine. Therefore, these implants were excluded from further analysis. The mean percentages of the implant surface of these implants in contact with the tooth or tooth pulp (Fig 4) ranged from 50.9% to 85.1%. The percentage of bone-to-implant contact varied from 0% to 24.8%.

Histologic soft tissue evaluation of all other implants showed a junctional epithelium in a tapered configuration, with the cell layers being reduced in the apical direction. In all instances, the junctional epithelium was separated from bone by a layer of gingival connective tissue.

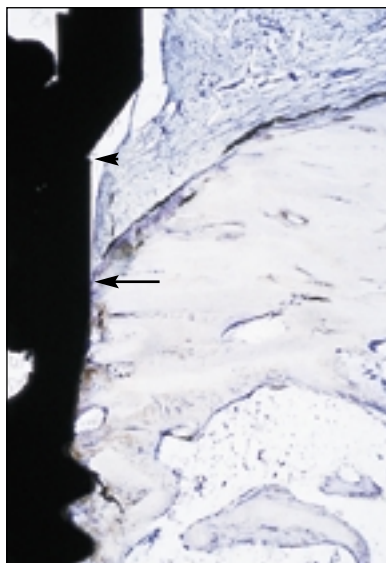
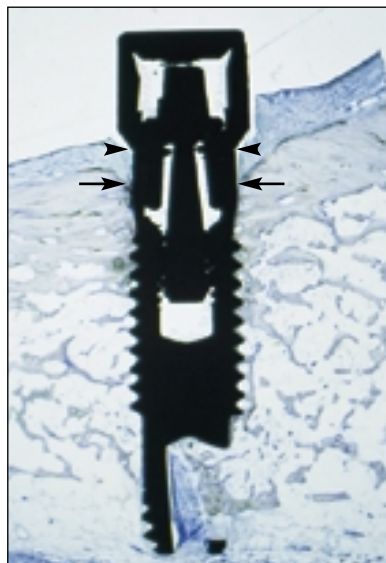
**Histometric Results.** Figures 5 to 7 show histologic sections of the different treatment groups. Figures 5a and 5b present an implant from the submerged group, Figs 6a and 6b an implant from the nonsubmerged group, and Figs 7a and 7b an implant from the late nonsubmerged group. The implant neck (*arrowheads*) and the first bone-to-implant contact (*arrows*) are outlined in the photographs. The cortical bone can be clearly distinguished from the cancellous.

The results of the bone-to-implant contact are shown in Table 6. The submerged implants showed a bone-to-implant contact of 63.4% (SD 15.9%), the nonsubmerged implants showed 70.3% contact (SD 2.9%), and the late nonsubmerged implants demonstrated a bone-to-implant contact of 58.7% (SD 12.2%). There were no statistically significant differences between the 3 treatment groups ( $P = .5134$ ).



**Fig 6a** (Left) Implant of the nonsubmerged group. (Arrowheads = implant neck; arrows = fBIC) (original magnification  $\times 9$ ; toluidine blue stain).

**Fig 6b** (Right) Higher magnification of Fig 6a. (Arrowhead = implant neck; arrow = fBIC) (original magnification  $\times 25$ ; toluidine blue stain).



**Fig 7a** (Left) Implant of the late nonsubmerged group. (Arrowheads = implant neck; arrows = fBIC) (original magnification  $\times 9$ ; toluidine blue stain).

**Fig 7b** (Right) Higher magnification of Fig 7a. (Arrowhead = implant neck; arrow = fBIC) (original magnification  $\times 25$ ; toluidine blue stain).

**Table 6 Bone-to-Implant Contact in Percentages for the 3 Treatment Groups**

|                   | n | Mean | SD   |
|-------------------|---|------|------|
| Nonsubmerged      | 3 | 70.3 | 2.9  |
| Submerged         | 3 | 63.4 | 15.9 |
| Late nonsubmerged | 6 | 58.7 | 12.2 |

$P = .5134$  (analysis of variance).

**Table 7 First Contact Between Bone and the Implant Surface Measured from the Implant Shoulder (in mm) for the 3 Treatment Groups**

|                   | n | Mean | SD                |
|-------------------|---|------|-------------------|
| Nonsubmerged      | 3 | 1.09 | 0.10 <sup>A</sup> |
| Submerged         | 3 | 0.58 | 0.37 <sup>B</sup> |
| Late nonsubmerged | 6 | 1.13 | 0.03 <sup>A</sup> |

$P = .0406$  (analysis of variance).

Same superscript letter indicates lack of statistically significant difference.

**Table 8 Results from the Histometric Measurements (Mean ± Standard Deviation) for the 3 Treatment Groups**

|                   | n | GM-aJE (mm) | IN-aJE (mm)  | aJE-fBIC (mm) | Area analysis (%) (coronal/apical) |
|-------------------|---|-------------|--------------|---------------|------------------------------------|
| Nonsubmerged      | 3 | 1.14 ± 0.37 | 0.02 ± 0.19  | 1.08 ± 0.27   | 53.1 ± 22.0/33.1 ± 2.6             |
| Submerged         | 3 | 1.23 ± 0.59 | -0.45 ± 0.69 | 1.00 ± 0.34   | 31.3 ± 8.2/28.6 ± 12.2             |
| Late nonsubmerged | 6 | 1.28 ± 0.51 | 0.05 ± 0.47  | 1.00 ± 0.38   | 35.9 ± 8.9/23.6 ± 4.1              |

GM-aJE:  $P = .9394$ ; IN-aJE:  $P = .4319$ ; aJE-fBIC:  $P = .9387$ ; area analysis: coronal  $P = .2320$ , apical  $P = .3714$ .

When the first contact between the bone and the implant surface measured from the implant shoulder was evaluated (in mm) (Table 7), the distance was 0.58 mm in the submerged implant group, 1.09 mm in the nonsubmerged group, and 1.13 mm in the late nonsubmerged group ( $P = .0406$ ). The vertical distance between the gingival margin and the apical extent of the junctional epithelium (GM = aJE) is presented in Table 8. The distances varied from 1.14 mm to 1.28 mm, with no statistically significant differences present ( $P = .9394$ ). Regarding the apical extent of the junctional epithelium from the implant-abutment junction (IN-aJE), the junctional epithelium in the submerged group ended on average slightly above the implant-abutment connection (0.45 mm). In the other 2 groups, the junctional epithelium extended slightly below the implant-abutment connection (nonsubmerged group: 0.02 mm; late nonsubmerged group: 0.05 mm). The differences were not statistically significant ( $P = .4319$ ). The distances from the apical extension of the junctional epithelium to the first bone-to-implant contact (aJE-fBIC) were 1.00 mm for the submerged group, 1.08 mm for the nonsubmerged group, and 1.00 mm for the late nonsubmerged group (Table 8;  $P = .9387$ ).

Regarding the area analysis (Table 8), mean coronal bone density was 31.3% in the submerged group, 53.1% in the nonsubmerged group, and 35.9% in the late nonsubmerged group ( $P = .2320$ ). Mean apical bone density was 28.6% for the submerged group, 33.1% for the nonsubmerged group, and 23.6% for the late nonsubmerged group ( $P = .3714$ ).

Table 9 demonstrates the results of the best bone-to-implant contact at 3 consecutive implant threads. The submerged group showed a mean of 98.9% of bone-to-implant contact at the best 3 consecutive threads. For the nonsubmerged group the value was 100%, and for the late nonsubmerged group it was 96.2%. The late nonsubmerged group was statistically significantly different from the nonsubmerged group ( $P = .0402$ ).

**Table 9 Best Bone-to-Implant Contact at 3 Consecutive Implant Threads (%) for the 3 Treatment Groups**

|                   | n | Mean | SD                 |
|-------------------|---|------|--------------------|
| Nonsubmerged      | 3 | 100  | 0 <sup>A</sup>     |
| Submerged         | 3 | 98.9 | 1.0 <sup>A,B</sup> |
| Late nonsubmerged | 6 | 96.2 | 2.2 <sup>B</sup>   |

$P = .0402$  (analysis of variance).

Same superscript letter indicates lack of statistically significant difference.

## Discussion

Brånemark et al<sup>14</sup> proposed the submerged placement of implants. The reasons for this approach were to protect the implant from possible bacterial invasion and to prevent apical proliferation of mucosal soft tissue, thus optimizing conditions for healing into the bony tissue. Mucosal coverage was also proposed as being protection for primary implant stabilization, which is a prerequisite for osseointegration. Schroeder et al<sup>3,15</sup> showed that the submerged placement of implants is not necessary to achieve osseointegration with middle and long-term success.<sup>11,19</sup> These results were achieved using the ITI Implant System (Straumann). Encouraged by these results, several investigators have used so-called 2-stage implant systems, intended for application in a submerged technique, in a transmucosal/nonsubmerged procedure.<sup>24,25,30</sup>

The implant system used in this investigation was advocated for application in a submerged as well as a nonsubmerged mode. In this investigation, the clinical and histologic behavior of the implants placed in submerged, nonsubmerged, and late nonsubmerged procedures was evaluated. The clinical parameters measured were not subjected to statistical analysis because of the small number of animals. However, with the material available, it can be shown that there were no major differences in the clinical behavior for the different treatment



groups and that with the oral hygiene regimen used, peri-implant soft tissue health could be established and maintained until the termination of the investigation.

Regarding short-term survival, Collaert and De Bruyn<sup>31</sup> showed in a recently published clinical investigation that in the mandible a 1-stage surgical approach using Brånemark System implants is as predictable as the conventional 2-stage procedure. The histologic results of the present investigation did not show significant differences between the different treatment groups, except for the first contact between bone and the implant surface and the bone-to-implant contact at the 3 best consecutive implant threads. The first bone-to-implant contact was located approximately 1 mm and 0.5 mm below the implant-abutment junction for the nonsubmerged groups and the submerged group, respectively. These distances are similar to those of the control group (0.78 mm) in the investigation by Abrahamsson et al,<sup>32</sup> but differ from the results of the test group from the same investigation<sup>32</sup> and from the results found by Hermann et al,<sup>33</sup> who radiographically evaluated crestal bone changes around nonsubmerged and submerged titanium implants. In the groups of the 2-part implants (which were comparable to the nonsubmerged and submerged groups in this investigation), they<sup>33</sup> could demonstrate radiographically that the most coronal bone-to-implant contact was approximately 2 mm below the microgap between the implant and the abutment. The differences are obviously the result of abutment dis- and reconnection<sup>32</sup> and of the use of different evaluation methods (radiographs<sup>33</sup> versus histometry).

Comparing the present investigation and the investigation by Cochran et al,<sup>34</sup> the biologic width in the latter study around 1-stage/1-piece implants was approximately 3 mm. There were variations within the extent of the different compartments of the biologic width over time. The sulcus depth decreased from 0.49 mm (3 months, unloaded) to 0.16 mm (12 months, loaded). In the same time frame, the extent of the junctional epithelium increased from 1.16 mm to 1.88 mm. The connective tissue contact around the implant changed from 1.36 mm in the 3-month unloaded group to 1.05 mm in the 12-month loaded group. In the present investigation, the differences in biologic width (GM to aJE plus aJE to fBIC) in the different groups were rather small: 2.22 mm for the nonsubmerged group, 2.23 mm for the submerged group, and 2.28 mm for the late nonsubmerged group. For the implant system used in this

investigation, the healing period (6 months for the nonsubmerged placement and 3 months for the late nonsubmerged placement) and the treatment method (nonsubmerged versus submerged) had no influence on the establishment of the biologic width. Also, the differences regarding the different compartments of the biologic width (GM to aJE and aJE to fBIC) showed only minor differences. There is a difference of approximately 0.8 mm between the biologic width in this investigation and the investigation of Cochran et al.<sup>34</sup>

The top of the nonsubmerged placed implants in the study by Cochran et al<sup>34</sup> was located 3 mm above the adjacent alveolar crest, so that the biologic width could be established over the length of the transmucosal implant part. Over time, little bone resorption occurred (0.05 mm from the 3-month unloaded group to the 12-month loaded group). In the present investigation, the implant shoulder was placed approximately at the level of the alveolar bone. In the nonsubmerged group (6 months of healing) bone loss was 1.1 mm; in the late nonsubmerged group (3 months of healing) bone loss was 1.1 mm; and in the submerged group (also 6 months of healing, where for 3 months the implants were submerged and 3 months nonsubmerged), the bone loss was approximately 0.5 mm. In these numbers, deviations of implant placement relative to the alveolar crest were not taken into account. Whether the biologic width of 3 mm would have been established with a longer healing period or with loaded implants through further bone loss could not be answered in this investigation. Since the biologic width might differ from patient to patient, small variations in the mean extension of the biologic width could certainly occur.

This conclusion is supported by the evaluation of Weber et al.<sup>35</sup> In their investigation, the healing of tissues adjacent to submerged and nonsubmerged unloaded titanium implants was compared. After 3.5 months, the mean distance between the mucosal border and the coronal alveolar bone-to-implant contact (ie, biologic width) in the submerged 2-piece treatment group, as well as in the nonsubmerged group, was 2.5 mm, with large intraindividual differences. In the same study,<sup>35</sup> the authors found that in all initially submerged implants, termination of peri-implant epithelium was found apical to the microgap between the implant and the transmucosal abutment cylinder. In the present investigation, this was true for the nonsubmerged and late nonsubmerged implants. In contrast, in the submerged implant group, the junctional epithelium ended 0.45 mm

coronal to the gap between the implant and the abutment. In the study by Abrahamsson et al<sup>32</sup> the junctional epithelium ended in the group where the abutments were dis- and reconnected approximately 0.7 mm below the implant-abutment microgap, and in the group in which the abutments were not removed, the junctional epithelium was 0.5 mm above the microgap.

The results found in the present pilot investigation are comparable to the results found by others regarding the biologic width and the location of the bone crest relative to the microgap created by the implant neck and the abutment. Furthermore, in this investigation it was observed coincidentally that penetrating a natural tooth while placing an implant will likely have a detrimental effect on its success.

### Conclusions

The authors are aware that because of the small sample size in this pilot investigation, the significance of these results is questionable. Therefore, the following conclusions are drawn with caution:

1. The utilized unloaded implant system showed similar clinical and histologic results when applied in a 1-stage or 2-stage approach where the abutments are not loosened or removed and when appropriate dental hygiene is performed.
2. Perforation of an adjacent tooth with an implant results in a poor prognosis for the implant.

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