
Implants Placed in Immediate Extraction Sites: A Report of Histologic and Histometric Analyses of Human Biopsies

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Five titanium plasma-sprayed implants were biopsied from a human volunteer 6 months after placement. Four test implants had been placed in immediate extraction sockets, while one implant was placed in a mature site and served as a control. The histologic analysis demonstrated that all five implants achieved osseointegration as demonstrated by light microscopy, whereas a varying degree of bone-implant contact was observed. The non-loaded control implant had the highest percentage of bone-implant contact, 72%, followed by the two implants placed in the canine sites presenting with a horizontal defect dimension of 1.5 mm or less. These implants were placed without a barrier membrane, but in a submerged fashion. The histometric analysis showed a mean bone-implant contact of 50% for these two implants. The lowest mean bone-implant contact (17%) was observed for the two molar implants, which had horizontal defect dimensions of 4 mm; these implants were placed in a non-submerged fashion with the implants perforating an expanded polytetrafluoroethylene membrane. The authors concluded that osseointegration may occur in immediate extraction sites in humans using titanium implants with a plasma-sprayed surface. The horizontal component of the peri-implant defect was apparently the most critical factor relating to the final amount of bone-implant contact.

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Key words: bone-implant contact, human biopsy, immediate extraction sites, osseointegration, titanium plasma-sprayed implants

Placing an implant during the same visit at which the tooth is extracted will reduce morbidity, treatment costs, and treatment time. This approach has been termed the "immediate implant"¹ and was first reported using osseointegrated implants by

Schulte et al in 1978.² Since that time, the clinical and radiographic success of this technique has been reported in a number of clinical reports using various approaches.³⁻¹¹ Numerous experimental studies¹²⁻²¹ confirmed that osseointegration can be achieved on a light microscopic level in animals following implant placement in immediate extraction sites.

The present report attempted to confirm the histologic observation in animal studies of osseointegration of immediate implants in implants placed in humans.

Materials and Methods

Specimens for this report were gathered from a 56-year-old man who first presented for periodontal therapy in 1976. During the ensuing 19 years, his inflammatory periodontal disease underwent several periods of exacerbation and remission, resulting in loss of clinical attachment and ultimately the loss of

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most of his dentition. For several years, he had attempted to wear a maxillary removable partial denture and a mandibular overdenture. The lower prosthesis was stabilized by four remaining mandibular teeth, two second molars and two canines. A work-up for dental implants was initiated after the patient indicated that his removable prostheses were unstable and caused considerable interference with mastication and speech, in spite of the fact that the restorations had been reworked several times.

A treatment plan, including implant-supported prostheses, was prepared and accepted by the patient. In addition, the patient, after thorough explanation and appropriate informed consent, volunteered to have additional implants placed, which would subsequently be removed in block sections.

Fifteen ITI titanium plasma-sprayed (TPS) implants (Straumann USA, Waltham, MA) were placed, six in the maxilla and nine in the mandible. All implants to be retained were placed with a conventional nonsubmerged approach.²²⁻²⁴ Those in the areas of the mandibular canines and second molars were placed immediately following the extraction of these teeth. The extractions were performed as atraumatically as possible, and the sockets were degranulated and rinsed with chlorhexidine and sterile saline. The ultimate goal of immediate implant placement in nonesthetic sites was to extract the tooth and place the implant immediately using a one-stage, nonsubmerged approach. Therefore, the immediate implants in the molar sites were placed with the coronal aspect of the implant uncovered by the soft tissue. In esthetic sites, the shape and contour of the healed soft tissues are more critical; consequently, both immediate implants in the canine sites were covered with mucosa using a submerged approach.

Control Implants. Two implants were placed in mature sites.¹ The implant placed in the maxillary right second molar was a 9-mm-long (the length of the TPS surface), 4.1-mm-diameter solid-screw implant. This implant was placed using standard protocol for nonsubmerged, one-stage implants. It served as a control, without functional load, and was scheduled for removal 6 months after placement, when the implants in the immediate sites were also to be harvested. A second control implant was placed in the area of the maxillary left second premolar. This implant was restored and will be removed after 1 year in function. The histologic findings of this implant will be presented in a second report.

Test Implants. Four implants were placed in immediate sites.¹ Following extraction of the mandibular left canine, an 11-mm-long, solid-screw implant (S 4.1) was placed. The diameter of the extraction socket was larger than the diameter of the

implant. The peri-implant bone defects had two dimensions, a horizontal defect dimension (HDD) and a vertical defect dimension (VDD) (Fig 1); the dimensions of these defects were measured with a caliper or a periodontal probe to the closest one-half millimeter. In this site, the VDD measured approximately 7 mm mesially and 5 mm distally, whereas the HDD was 1.5 mm at the coronal part of the implant mesially and distally and tapered to zero toward the apex. Primary closure of the soft tissues was obtained over the implant.

The mandibular right canine was extracted, and an 11-mm-long, solid-screw implant (S 4.1) was placed in the extraction site. The VDD of this site was 9 mm on the mesial and 6 mm on the distal aspect. The HDD was 1.5 mm at the widest on both aspects. Autogenous bone grafts harvested from other osteotomy sites were packed around the implant, and a connective tissue graft from the palate was draped over the head of the implant. This implant was not stable at the time of placement. Primary closure of the soft tissues over the implant and the grafted tissues was achieved.

An 8-mm-long, hollow-screw implant (HS 4.1) was placed in the distal socket immediately following removal of the mandibular right second molar. The bone core was intentionally removed prior to implant placement, leaving no bone inside the basket of the implant. The VDD was 6 mm on the mesial surface, and the HDD measured more than 4 mm at the same site. On the distal aspect, the implant was in direct contact with the socket wall. No grafting was performed, but a barrier membrane was used according to the principles of guided bone regeneration. A hole slightly smaller than the diameter of the implant body was made in an expanded polytetrafluoroethylene (e-PTFE) membrane (GT 9, W.L. Gore, Flagstaff, AZ) and pulled over the implant following the method described by Cochran and Douglas²⁵ (Fig 2). Subsequently, the soft tissues were adapted, leaving the head of the implant exposed but covering the membrane.

Immediately following the extraction of the mandibular left second molar, an 8-mm-long, hollow-screw implant (HS 4.1) was placed in the distal root socket. The VDD on the mesial aspect measured 5 mm. The bone core prepared by the trephine mill was also removed as previously described. The HDD measured more than 4 mm mesially. The implant and socket wall were in contact on the distal aspect. Autogenous bone grafts harvested from other osteotomy sites were packed around the implant to fill the peri-implant bone defect on the mesial aspect. The same membrane technique was applied as on the right side.

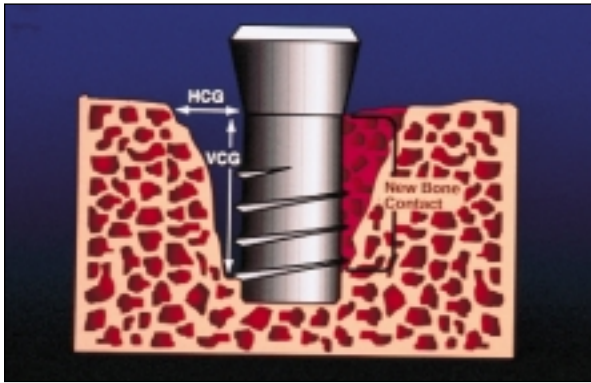


Fig 1 The horizontal defect dimension (HDD) was measured from the widest point of the socket wall to the implant surface, while the vertical defect dimension (VDD) was measured from the most coronal level of the titanium plasma-sprayed surface to the apex of the bony defect.

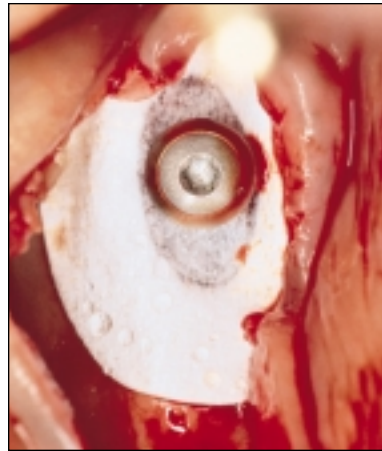


Fig 2 At both mandibular molar immediate extraction sites, an opening, slightly smaller than the diameter of the implant, was made in an e-PTFE membrane. The membrane was then placed around the implant, and the soft tissues were closed to cover the membrane but to leave the head of the implant exposed.

Follow-up Examinations and Harvesting of Specimens. The patient was seen frequently for follow-up visits. Chlorhexidine rinses were used daily in an attempt to keep the nonsubmerged implants free of clinical signs of inflammation. Six months after implant placement, the four test implants and one control implant were removed by block sections. The resulting defect sites were filled with demineralized freeze-dried bone allografts, covered with barrier membranes, and closed primarily. New prostheses, supported by the remaining implants, were later fabricated.

Histologic Preparation and Histometric Analysis. The harvested block specimens were placed in a mixture of 4% formalin and 1% calcium chloride fixative. A radiograph was made of each specimen to allow a precise cut along the long axis of each implant. The specimens were dehydrated and embedded in methylmethacrylate resin, then cut along the long axis in a mesiodistal direction. Three undecalcified sections of approximately 500- μ m thickness were obtained from each implant using a low-speed diamond saw with coolant. Subsequently, the sections were glued with acrylic cement to opaque Plexiglas, ground to a final thickness of approximately 80 μ m, and stained superficially with toluidine blue O com-

bined with basic fuchsin.²⁶ The central section of each implant was histometrically analyzed by evaluating the percentage of bone-implant contact at both the mesial and distal aspect of each implant. This analysis was done with intersection counts, using a grid with parallel sampling lines at a magnification of 100 \times . In addition, the distance between the most coronal point of the alveolar crest and the first bone-implant contact was measured in millimeters.

Results

Clinical Results. Small portions of the membranes around the mesial aspects of the two molar implants became exposed shortly after implant placement. No clinical signs of inflammation were observed during the 6-month healing period. At the day of harvesting, all five implant sites demonstrated healthy soft tissues. In addition, the nonsubmerged implants in the molar area yielded ankylotic stability and a clear ringing sound when struck with a metal instrument.

Histologic and Histometric Findings. All implants demonstrated osseointegration at the light microscopic level, with varying percentages of direct bone-implant contact. For the control implant placed in mature bone (the maxillary right second molar), the

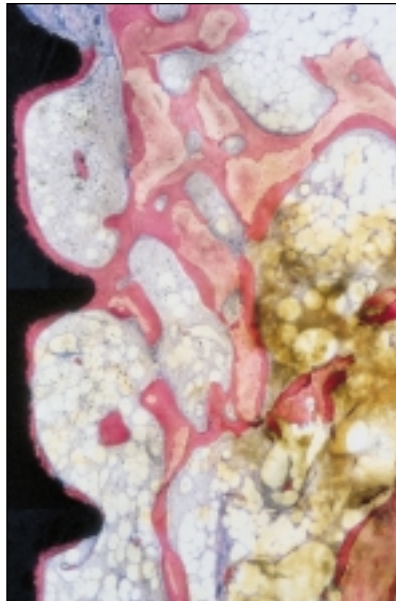


Fig 3 (Left) In this view of the mesial surface of the nonloaded control implant, new bone can be seen covering the surface of the implant (toluidine blue O/basic fuchsin stain; magnification $\times 12.5$).

Fig 4 (Below) The vertical distance from the most coronal bone to the first implant contact was measured; the data are shown in Table 2.

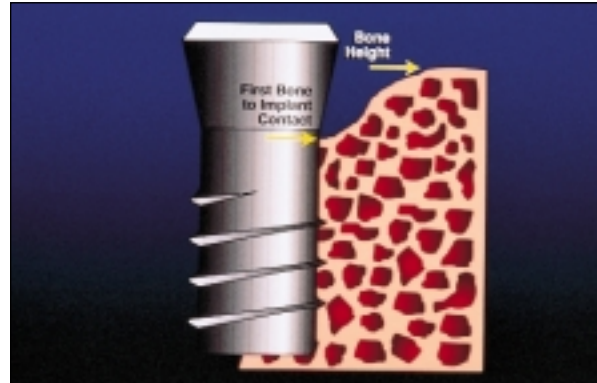


Table 1 Mean Vertical Distance From Most Coronal Bone to First Implant-Bone Contact

| Implant site | Vertical distance (mm) | |
|-------------------------|------------------------|--------|
| | Mesial | Distal |
| Test implants | | |
| Mandibular left canine | 1.73 | 1.83 |
| Mandibular right canine | 0.20 | 1.45 |
| Mandibular right molar | 2.18 | 2.50 |
| Mandibular left molar | 2.57 | 0.00 |
| Average | | 1.56 |
| Control implant | | |
| Maxillary molar | 0.52 | NA |

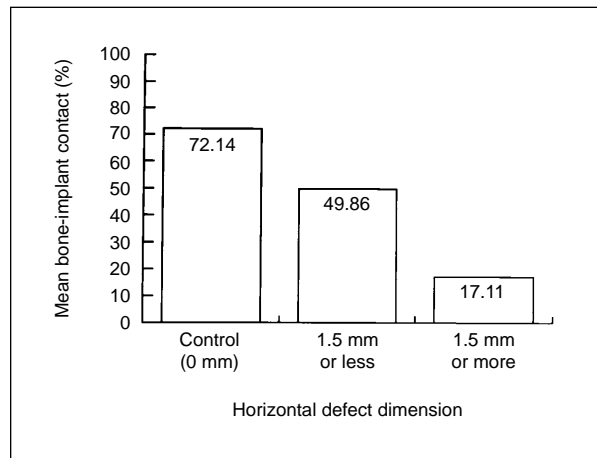


Fig 5 The mean percentage of bone-implant contact on the implant surface diminished as the horizontal defect dimension became wider.

Table 2 Mean Percentage of Bone-Implant Contact

| Implant site | Method | Mesial | Distal | Total |
|-------------------------|------------|--------|--------|-------|
| Test implants | | | | |
| Mandibular left canine | P | 60.19 | 59.31 | 59.75 |
| Mandibular right canine | P, AB, AST | 57.55 | 32.05 | 44.80 |
| Mandibular left molar | AB, M | 22.43 | 87.31 | 44.87 |
| Mandibular right molar | M | 11.79 | 2.75 | 7.27 |
| Control implant | | | | |
| Maxillary molar | | 72.14 | NA | 72.14 |

P = primary closure; AB = autogenous bone; AST = autogenous soft tissue; M = membrane.



Fig 6 New bone has bridged from the socket wall to contact along the length of the TPS surface of this implant, which was placed into an immediate extraction site. The defect dimensions were 1.5 mm horizontal (mesial and distal), and 7 mm (mesial) and 5 mm (distal) vertical at the time of placement (toluidine blue O/basic fuchsin stain; magnification $\times 3.2$).

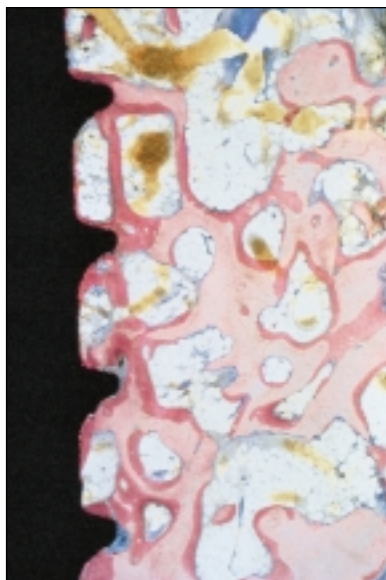


Fig 7 A higher magnification of the mesial implant surface shown in Fig 6 (toluidine blue O/basic fuchsin stain; magnification $\times 12.5$).



Fig 8 Horizontal defect dimensions of 1.5 mm (mesial and distal) and vertical defects of 9 mm (mesial) and 6 mm (distal) have been filled with new bone around this nonstable implant placed into a canine extraction site, grafted with autogenous bone, and covered with an autogenous soft tissue graft (toluidine blue O/basic fuchsin stain; magnification $\times 3.2$).

percentage of bone-implant contact was 72.14% (Fig 3). The distance from the alveolar crest to the first bone-implant contact was 0.52 mm (Fig 4). This distance around the four test implants ranged from 0 to 2.57 mm, with a mean of 1.56 mm (Table 1). Around the mandibular left canine, the percentage of bone-implant contact was 59% (Table 2 and Fig 5). The soft tissues were thinned over the head of the implant, and the horizontal defects, which were about 1.5 mm at their largest, were bridged with bone on both the mesial and distal surfaces and demonstrated an intimate contact between newly formed bone and the TPS surface (Figs 6 and 7). The implant in the mandibular right canine area also achieved osseointegration at the light microscopic level, even though this implant was not primarily stable at the time of placement (Fig 8). The horizontal and vertical defects were bridged by new osseous tissue, and the percentage of bone-implant contact was 44.80% for this implant (Table 2). The thick soft tissues covering this implant represented the connective tissue graft applied over the implant prior to soft tissue closure.

At the mandibular right second molar implant, where a membrane alone had been used, the previously empty basket of the implant was not completely filled with new bone (Fig 9). On the mesial aspect of the implant, the membrane and the bone were not in contact with the implant, and connective tissue could be seen adjacent to the TPS surface. The percentage of bone-implant contact was reduced (11.79%) on the mesial aspect of this implant (Table 2).

Autogenous bone grafts had been packed around the implant in the immediate extraction site of the mandibular left second molar. The hollow basket, which was empty at the time of implant placement, filled with new bone during the 6-month healing period. On the mesial implant surface, the percentage of bone-implant contact was 22.43%, since bone was in close proximity but not touching the TPS surface in coronal areas of the implant (Figs 10 and 11). This fact was not revealed by a radiograph taken just before biopsy (Fig 12). Mesially, the membrane was not well adapted to the implant surface, and the observed gap may have allowed the ingrowth of soft



Fig 9 An overview of the mandibular right second molar implant. Bone can be seen adjacent to but not in contact with the mesial (right side) of the implant surface. The horizontal defect dimension was greater than 4 mm and the vertical defect dimension was 6 mm (toluidine blue O/basic fuchsin stain; magnification $\times 2$).



Fig 10 Bone is in close proximity to but not touching the mesial (right) surface of the mandibular left second molar implant. Autogenous bone had been placed to fill the horizontal defect dimension of more than 4 mm and the vertical defect dimension of 5 mm (toluidine blue O/basic fuchsin stain; magnification $\times 3.2$).

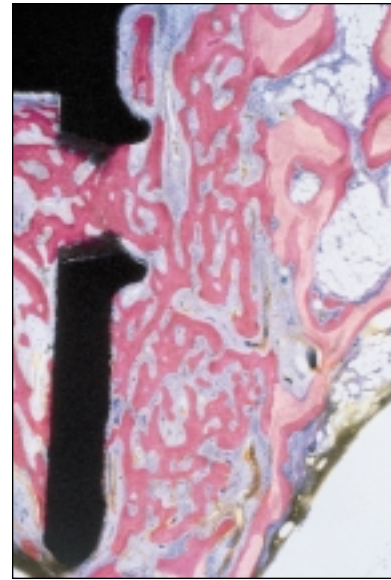


Fig 11 This higher magnification of the implant in Fig 10 shows the bone in close proximity to but not touching the mesial surface of the implant (toluidine blue O/basic fuchsin stain; magnification $\times 12.5$).

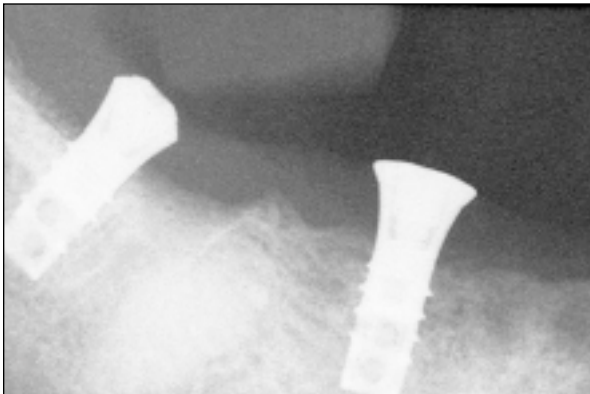


Fig 12 A radiograph taken just before biopsy of the mandibular right second molar implant appears normal despite the fact that bone is not in contact with the mesial (right) surface of the implant (see Figs 10 and 11).

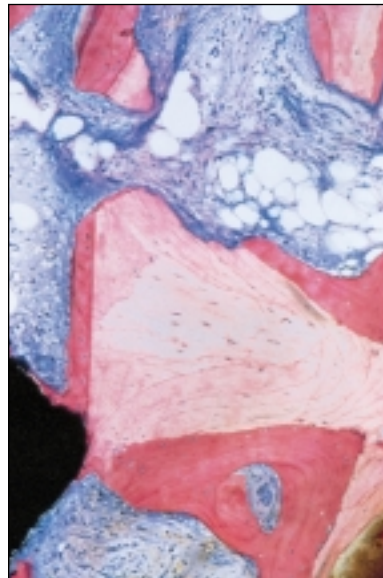


Fig 13 In this close-up view taken near the apex of the implant placed into the mandibular left second molar extraction site, new bone is closely associated with a graft fragment and with the implant surface (toluidine blue O/basic fuchsin stain; magnification $\times 50$).

tissues from the overlying mucosa (Fig 10). More apically, a bone graft fragment seen at higher magnification was associated with newly formed bone lining the surface of the implant and the graft (Fig 13). On the distal surface, where a close contact of the membrane and the implant surface was present, bone was in contact with 87.31% of the TPS surface.

Discussion

The present histologic and histometric report provides important information on human biopsies of implants placed in immediate extraction sockets of a 56-year-old male patient. The report appears to confirm numerous experimental studies¹²⁻²¹ on immediate implants in animals, since all four test implants demonstrated osseointegration with direct bone-implant contact, as determined by light microscopic analysis. The four test implants, however, demonstrated varying degrees of bone-implant contact. The highest percentage of bone-implant contact was seen at the control implant (72%), followed by the two canine implants, which had a mean bone-implant contact of approximately 50%, and in which small peri-implant bone defects (HDD = 1.5 mm) were present and no membranes were used. It seems that in small peri-implant defects, the use of barrier membranes is not necessary, as long as the socket walls are intact, a favorable defect morphology is present, and a titanium implant with an appropriate surface is placed. The implants used in the present report had a microporous titanium plasma-sprayed surface. Several animal studies have demonstrated that the surface characteristics of titanium implants have a significant influence on bone reaction during healing,²⁷⁻³⁰ since rough titanium surfaces show a significantly higher percentage of bone-implant contact when compared to smooth or fine-textured titanium surfaces. Two recent animal studies evaluating barrier membranes to regenerate peri-implant bone defects demonstrated only a poor bone apposition for smoothly machined titanium implants.^{31,32}

The smallest percentage of bone-implant contact was seen for the two molar implants in the mandible (mean bone-implant contact = 17%), where the HDD measured more than 4 mm, and where a barrier membrane was applied. In these two sites, a partial membrane exposure was observed during the initial stage of healing. This raises the following question: "Was the reduced bone-implant contact on these surfaces a function of the size of the horizontal defect, the method of membrane placement, or the early membrane exposure?" It could be argued that bridging did not occur in the larger horizontal

defects because the size of the defect exceeded the distance that bone bridging will occur. As of this writing, no studies have been found that test e-PTFE membranes for horizontal defects larger than 4 mm. Another possibility is that retraction of the membranes allowed soft tissues to migrate through the openings on the mesial aspects of the molar implants. This view could be supported by the fact that multiple studies have reported that less bone formation occurred in controls not covered with e-PTFE membranes. The third possible reason for the reduced bone-implant contact in these sites could have been an inflammatory process caused by early membrane exposure, as reported by several authors.³³⁻³⁵ Clinical signs of inflammation, however, were not seen at any of the patient's frequent follow-up visits, and very few inflammatory cells were seen on histologic sections. Hence, the most plausible explanation for the reduced bone-implant contact in these sites is that the membrane technique used, in which the implant neck penetrated the membrane and the mucosa, did not provide a sufficient barrier against the ingrowth of soft tissue cells from the overlying mucosa.

An interesting finding was that a test implant in a canine site achieved osseointegration, as determined by light microscopy, even though it was not clinically stable at the time of implant placement. It can be speculated that the applied autogenous bone grafts had a stabilizing effect on the placed implant. In addition, deep placement of the implant and primary closure of the soft tissues may have provided sufficient protection of the implant against destabilizing forces during healing. Thus, the secondary stability of the implant was provided by newly formed bone in the initial healing period establishing direct bone-implant contact.

Conclusions

Based on human biopsies involving four implants, this histologic and histometric report demonstrates that titanium implants with a plasma-sprayed surface can achieve osseointegration (determined at the light microscopic level) when placed immediately into extraction sockets. The histologic analysis showed a varying degree of bone-implant contact. These differences were most likely caused by the morphology of the peri-implant bone defects present at the time of implant placement. The horizontal component of the defects was most critical in dictating the final amount of bone-implant contact during a 6-month healing period. Within the limits of a study with a small sample size, a membrane was not necessary in sites with peri-implant bone defects not

exceeding 1.5 mm in horizontal dimension. The least amount of bone-implant contact was seen in two molar implants with large peri-implant bone defects despite the placement of barrier membranes. It seems that the technique used, involving a penetrating implant neck through the membrane and the mucosa, did not provide a favorable environment for optimal bone-implant contact. Therefore, other techniques seem warranted to optimize treatment outcomes in similar cases.

Acknowledgments

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