Bone Healing Following Immediate Versus Delayed Placement of Titanium Implants into Extraction Sockets: A Prospective Clinical Study

Lars Schropp, DDS[1]/Lambros Kostopoulos, MS, DDS, PhD[2]/Ann Wenzel, DDS, PhD, Dr Odont[3]

Purpose: *The aim of this study was to compare bone healing and crestal bone changes following immediate (Im) versus delayed (De) placement of titanium dental implants with acid-etched surfaces (Osseotite) in extraction sockets.* ***Materials and Methods:*** *Forty-six patients were randomly allocated to the Im or De group (n = 23 per group) and received 1 implant at the incisor, canine, or premolar region of the maxilla or the mandible. The implants were placed an average of 10 days following tooth extraction in the Im group and approximately 3 months after extraction in the De group. The widths (parallel and perpendicular to the implant) and the depth of marginal bone defects around the implants were measured clinically just after placement and 3 months later at the abutment surgery. The crestal bone changes mesially and distally to the implants were evaluated radiographically by linear measurements.* ***Results:*** *The survival rates were 91% in the Im group and 96% in the De group. In the Im group, the mean reductions in parallel width, perpendicular width, and depth of the largest defect of each implant amounted to 48% (from 4.4 to 2.3 mm), 59% (from 2.2 to 0.9 mm), and 48% (from 6.9 to 3.6 mm), respectively. The corresponding mean reductions in the De group amounted to 39% (from 3.1 to 1.9 mm), 77% (from 1.3 to 0.3 mm), and 34% (from 4.4 to 2.9 mm). The reduction over time was statistically significant in both groups ($P < .04$). For both groups, a higher degree of bone healing was achieved in the infrabony defects (> 60% for depth) than in dehiscence-type defects (approximately 25%). Furthermore, 70% of the 3-wall infrabony defects with a parallel width of up to 5 mm, a depth of maximum 4 mm, and a perpendicular width of maximum 2 mm had a capacity of spontaneous healing within a period of 3 months.* ***Discussion and Conclusion:*** *New bone formation occurs in infrabony defects associated with immediately placed implants in extraction sockets.* (Int J Oral Maxillofac Implants 2003;18:189–199)

Key words: *dental implants, immediate implant placement, osseointegration, tooth extraction, wound healing*

The introduction of endosseous implant–supported prostheses has contributed to a significant improvement in restoring the masticatory function of partially or completely edentulous patients. Several studies have demonstrated that treatment by means of titanium dental implants is a safe method for oral rehabilitation with high success rates.[1–3] The original treatment protocol[4] has been challenged within the last decade by reducing the time between tooth extraction and implant placement and by reducing the time between implant placement and implant loading.

Placement of an implant into a fresh alveolus will usually result in a gap between the occlusal part of the implant and the bone walls. To ensure osseointegration of the entire implant, synthetic bone substitutes, membranes, bone grafting, osteoinductive substances, or a combination of these have been used to achieve bone formation in such defects. Autogenous bone and a variety of xenogenic graft materials have been employed in conjunction with immediate implantation, with many of them showing successful results. Nevertheless, none of them have been shown

[1]PhD Student, Department of Oral Radiology, University of Aarhus, Århus, Denmark.
[2]Assistant Professor, Department of Oral and Maxillofacial Surgery, University of Aarhus, Århus, Denmark.
[3]Professor, Department of Oral Radiology, University of Aarhus, Århus, Denmark.

Reprint requests: Dr Lars Schropp, Department of Oral Radiology, University of Aarhus, Vennelyst Boulevard 9, 8000 Århus C, Denmark. Fax: +45-86-19-60-29. E-mail: lschropp@odont.au.dk

Presented at the 79th General Session of the International Association for Dental Research in Chiba, Japan, June 27–30, 2001.

to be superior to the others.[5,6] Immediate implant placement in extraction sockets in combination with barrier membranes also seems to be a predictable treatment modality. Lazzara[7] introduced the use of expanded polytetrafluoroethylene membranes after immediate implantation with a positive outcome. Since then, other case reports and studies have shown good results of immediately placed implants treated with this type of membrane.[8,9]

Later, bioresorbable barriers were developed, which offered the advantage that membrane removal was not needed; however, these possessed other drawbacks such as lack of stiffness (thus requiring a membrane-supporting material). In animal and human studies, it has been shown that resorbable barriers can be successfully used for bone augmentation purposes.[10,11] Furthermore, the combination of resorbable barriers and immediately placed implants seems to be comparable with the combination of nonresorbable barriers and immediately placed implants in terms of integration of the implants.[12] However, little information is available on this issue, and more controlled studies are needed.

Animal studies have indicated that osseointegration of immediately placed implants in extraction sockets can be achieved without bone augmentation procedures, and with a success rate comparable to that of delayed implant placement.[13,14] This was supported by a case series including 109 implants[15] and a prospective clinical study[16] in which high success rates of immediately placed implants were obtained without the use of membranes or grafts. In reviews of the literature,[5,6] it was concluded that there is no consensus whether the use of bone grafting, bone substitutes, osteogenesis-stimulating substances, and/or membranes in combination with implants immediately placed in extraction sockets yields better results than the use of immediately placed implants alone.

Since simplified surgical procedures and low treatment costs are preferable to the patient, it is desirable that the necessity for the various bone-reconstructive treatment strategies for achieving osseointegration of immediate implants be evaluated. Therefore, it is important to identify the type and size of peri-implant bone defects that heal spontaneously with bone.

The aim of the present study was to compare bone healing and crestal bone changes following the immediate versus delayed placement of submerged titanium dental implants in extraction sockets.

MATERIALS AND METHODS

Forty-seven patients (26 women, 21 men) referred to the Royal Dental College, University of Aarhus, Denmark, for tooth extractions, who needed single-tooth implant treatment at the incisor, canine, or premolar regions of the maxilla or the mandible, were consecutively included in this study. The mean age was 48 years (range, 20 to 74 years). The reasons for tooth extraction included root fractures, periodontally compromised teeth, endodontic failures, and advanced caries lesions. The patients were given oral and written information regarding the study, and their written informed consent was obtained. The investigation was approved by the Danish Committee for Clinical Research Ethics as being in accordance with the Helsinki Declaration II. The patients were randomly allocated to the immediate (Im) group (23 patients) or the delayed (De) group (24 patients). One implant per patient was placed. For experimental reasons (so as to be able to include in this sample patients with periapical lesions and to coordinate surgery with obtaining standardized radiographs), the implants in the immediate group were placed on average 10 days (range, 3 to 15 days) following tooth extraction; in the delayed group, implants were placed approximately 99 days following tooth extraction (range, 65 to 138 days).

Following local anesthesia, teeth were luxated with an elevator and extracted carefully with forceps (attempting to preserve the bone of the alveolus), and the sockets were debrided. In addition to clinical examination, intraoral, panoramic, and conventional cross-sectional tomographic radiographs were taken for the preoperative evaluation of the implant site.[17] A crestal incision connected with 2 vertical releasing incisions mesial and distal to the extraction site were performed, and a mucoperiosteal flap was elevated. The depth and buccolingual and mesiodistal dimensions of the alveolar socket (Im group) or of the remaining alveolar defect (De group) were measured, together with the height of possible dehiscences. After removal of granulation tissue from the socket, an implant with appropriate dimensions determined on the basis of the presurgical radiographs,[17] as well as the clinical evaluation of the recipient site at surgery, was placed. The implant was placed in such a way that the cover screw corresponded to the level of the adjacent bone. All implants were determined to be clinically stable. For ethical reasons, autogenous bone chips harvested from the adjacent bone were grafted to any exposed implant threads in cases of dehiscences present in the De group. Primary closure of the wound was achieved with a periosteal incision of the buccal flap and 5-0 silk sutures. In association with implant surgery, amoxicillin tablets (750 mg 3 times daily for 5 days) were systemically administered, and pain control was achieved by naproxen tablets (500 mg 2 times daily for 5 days). Medication

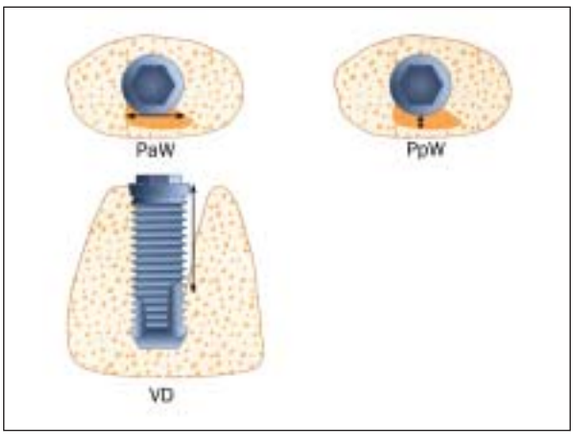

Fig 1a The dimensions of peri-implant 3-wall infrabony defects. Horizontal width of the defect parallel to the implant (PaW); horizontal width of the defect from the bone crest to the implant surface in a direction perpendicular to the long axis of the implant (PpW); defect depth measured from the implant-abutment joint and apically to the bone-to-implant contact (VD).

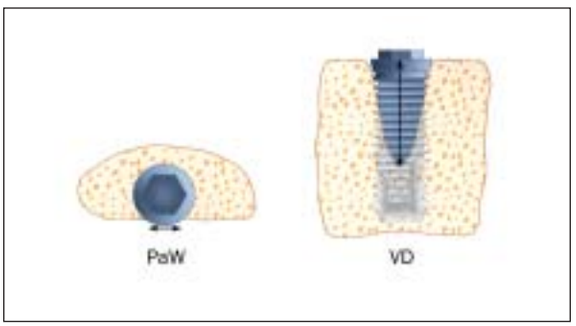

Fig 1b The dimensions of peri-implant dehiscence-type defects. Horizontal width of the defect parallel to the implant (PaW); defect depth measured from the implant-abutment joint and apically to the bone-to-implant contact (VD).

was started 1 hour before surgery. The patients rinsed their mouth with chlorhexidine digluconate 0.1% solution for 1 minute twice a day for 14 days following implant surgery. All implants were placed by the same clinician (LK).

A total of 46 Osseotite implants (Implant Innovations, Palm Beach Gardens, FL) were placed (37 in the maxilla and 9 in the mandible). Of the 37 maxillary implants, 22 were placed in the anterior region (12 Im, 10 De) and 15 were placed in the premolar region (8 Im, 7 De). Of the 9 mandibular implants, 2 were placed in the anterior region (1 Im, 1 De) and 7 were placed in the premolar region (2 Im, 5 De). In 1 patient, it was not possible to place an implant as planned in the central incisor region of the maxilla because of a substantial defect corresponding to insufficient healing of the extraction alveolus involving the anterior palatine foramen. This large bone defect was not recognized in the radiographs, including the tomograms, and treatment was postponed. Hence, 23 implants were placed in each of the 2 groups.

At 3 months following implant placement in the maxilla or mandible, the patients were subjected to a second operation. A crestal incision connected with 2 vertical releasing incisions mesial and distal to the extraction site was made, and a mucoperiosteal flap was elevated. The cover screw was replaced with a 1-piece or 2-piece EP healing abutment (Implant Innovations), and the flap was sutured with 5-0 silk sutures. In cases of dehiscences or fenestrations at this operation, autogenous bone chips were grafted to the defects. Grafting performed at implant placement was only repeated if a dehiscence or fenestration was still present. At 4 to 6 weeks following placement of the healing abutments, impressions were made for a fixed prosthetic restoration fabricated on STA abutments or UCLA abutments (Implant Innovations). Second-stage surgery and prosthetic treatment were performed by one of the authors (LS).

The dimensions of the marginal bone defects at the mesial, distal, buccal, and lingual sites of each implant were measured by means of a periodontal probe just after placement and 3 months later at the abutment connection surgery (Figs 1a and 1b). The following dimensions of the defects were measured in millimeters: *(1)* the horizontal width of the defect parallel to the implant at the bone crest (PaW), *(2)* the horizontal width of the defect from the bone crest to the implant surface in a direction perpendicular to the long axis of the implant (PpW), and *(3)* the vertical defect depth measured from the implant-abutment joint and apical to the bone-to-implant contact (VD). The sites were classified into 4 groups according to the size of the defects: 0 mm, 1 to 3 mm, 4 to 5 mm, and 6 or more mm. Furthermore, the peri-implant bone defects were divided into 2 types: 3-wall infrabony defects or dehiscences with exposure of the implant surface.

Standardized intraoral radiographs using the paralleling technique with an occlusal bite index[17] were obtained just after implant placement and 3 months later, at the abutment surgery. All radiographs were digitized with a resolution of 300 dpi by a flatbed scanner with a transparency module (Hewlett-Packard, Palo Alto, CA). The crestal bone levels

Table 1 Linear Radiographic Measurements (Median and 25th and 75th Percentiles)

Time of measurement	Median (25th/75th percentiles) (mm)		*P* value
	First recording	Second recording	
At implant surgery			
Mesially to implant	0.1 (0.1/0.2)	0.1 (0.0/0.7)	.33
Distally to implant	0.1 (0.1/0.3)	0.1 (0.1/0.8)	.43
Implant length	14.7(12.6/17.0)	14.9 (12.7/16.9)	.88
At abutment surgery			
Mesially to implant	0.1 (0.1/0.6)	0.1 (0.0/0.3)	.56
Distally to implant	0.1 (0.1/0.7)	0.1 (0.1/0.7)	.89
Implant length	14.1 (12.1/16.7)	14.2 (12.3/16.6)	.30

mesial and distal to the implants were evaluated in these radiographs. The distance from the shoulder of the implant (implant-abutment joint level) to the first visible bone-to-implant contact was determined by linear measurements. In addition, the length of the implant was measured to determine the image magnification. The measurements of bone levels were then adjusted according to the magnification. A computer program designed for measuring distances in digital images was applied (PorDiosW, Institute of Orthodontic Computer Sciences, Middelfart, Denmark), and the measurements were repeated to assess the reproducibility.

All data were analyzed by descriptive methods. Differences between the immediate and delayed groups regarding implant site and age distribution were tested by the chi-square test and the Student *t* test, respectively. The differences in clinical defect dimensions measured at implant placement surgery and abutment surgery were calculated and tested by means of Wilcoxon matched-pairs signed ranks test within both groups, using the largest defect at each implant as test parameter (the largest defect was determined by adding the measurements of parallel width, perpendicular width, and vertical depth for each defect). These differences in clinical defect dimensions were also tested following classification of the defects as 3-wall infrabony defects or dehiscences, and by means of the Mann-Whitney *U* test, differences in healing over time between the 2 types of defects were analyzed for the Im and De groups separately. By means of the latter test, differences in defect dimensions at the abutment operation between the Im and De groups were likewise tested. The changes in bone levels evaluated radiographically, as well as the agreement between the repeated measurements, were analyzed by Wilcoxon matched-pairs signed ranks test (Table 1). The level of statistical significance was set at $\alpha = .05$.

RESULTS

The age distribution was not significantly different ($P > .6$) between the Im group (49 years, range 25 to 70) and the De group (47 years, range 20 to 74). Furthermore, no significant difference between the groups existed in terms of distribution of the implants in the maxilla and the mandible ($P > .29$), or in the maxillary anterior and posterior regions ($P > .94$). The dimensions of the implants placed in the Im and De groups are shown in Fig 2.

Two implants in the Im group and one in the De group were lost at 3 months following surgery (survival rate of 91% and 96%, respectively). All 3 had been placed in the maxilla. In 1 of the immediate cases, an implant with a diameter of 3.25 mm was placed in the lateral incisor region. The bone quality was considered to be poor, and large dehiscences at 2 of the 4 measured sites occurred just after implant placement. In the other 2 cases, there was no obvious explanation for the implant loss. Apart from the 3 lost implants, none of the patients suffered severe postoperative complications in either group. Two patients in the Im group, who had received an implant in the mandibular second premolar region, had temporary sensibility disturbances but recovered within a month. Another patient experienced minor postoperative bleeding after implant placement in the maxillary premolar region.

Prior to placement of the Im implants, the mean depth and buccolingual and mesiodistal width of the alveolus amounted to 9.0 mm (range 5.0 to 15.0 mm), 7.3 mm (range 4.0 to 11.0 mm), and 6.6 mm (range 3.0 to 11.0 mm), respectively. Eleven of the 23 alveoli had a buccal dehiscence component with a mean height of 7.8 mm (range 5.0 to 14.0 mm), and 4 had a lingual dehiscence with a mean height of 6.0 mm (range 4.0 to 10.0 mm). In the De group,

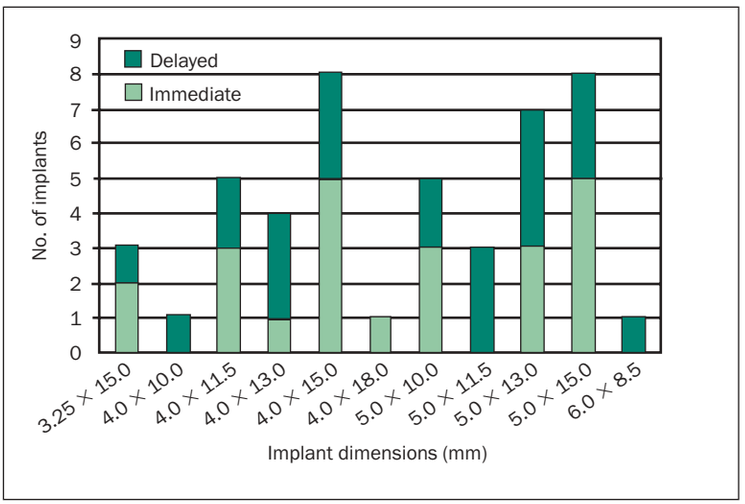

Fig 2 Dimensions (diameter × length) of placed implants.

the corresponding mean dimensions (depth and buccolingual and mesiodistal width) of the remaining alveolar defects were 3.9 mm (range 0.0 to 10.0 mm), 2.7 mm (range 0.0 to 8.0 mm), and 2.7 mm (range 0.0 to 9.0 mm), respectively. In this group, 4 of the remaining defects were associated with dehiscences, all of them localized buccally (mean height of 6.3 mm, range 3.0 to 8.0 mm).

Just after implant placement (Tables 2a to 2c), 60 of a total of 92 sites (65%) around the implants in the Im group were found to have defects (forty-eight 3-wall infrabony defects and 12 dehiscences), and 18 of 92 (20%) in the De group (eight 3-wall infrabony defects and 10 dehiscences). About one third in the former group and two thirds in the latter group were located buccally. The remaining defects were evenly distributed in the mesial, distal, and lingual sites. Three months later, at the abutment surgery, the total number of defects in the Im group was reduced to 35 (twenty 3-wall infrabony defects and 15 dehiscences), whereas in the De group, an increase to 25 was found (fourteen 3-wall infrabony defects and 11 dehiscences).

In both the Im and the De groups, the PpW ranged from 1 to 3 mm for all infrabony defects except 2 sites in the Im group. In the Im group, 44 of the 59 defects (75%) (notice in Table 2c that 1 measurement of the depth at implant placement is missing) were 4 mm or deeper, and two thirds (n = 40) had a PaW of 4 mm or wider. The number of defects with a depth ≥ 6 mm amounted to 27 at implant placement, but after 3 months, only 6 defects remained in this category. All 6 were located buccally, and 5 of them were dehiscences. Two of the lost implants were among these. In the De group, 5 defects had a depth larger than 5 mm at implant placement; 3 of these remained in this category at abutment connection (2 dehiscences).

Tables 3a to 3c depict the mean dimensions of the largest defect of each implant at implant placement and abutment connection and their reduction over time. The reduction of the PaW, the PpW, and the VD in the Im group amounted to 48% (from 4.4 to 2.3 mm), 59% (from 2.2 to 0.9 mm), and 48% (from 6.9 to 3.6 mm), respectively. The corresponding values in the De group amounted to 39% (from 3.1 to 1.9 mm), 77% (from 1.3 to 0.3 mm), and 34% (from 4.4 to 2.9 mm). This reduction over time was statistically significant ($P < .04$) in both groups. No significant difference in the defect dimensions at abutment operation existed between the Im and De groups ($P > .27$). At sites with no defects at implant placement, it was found at abutment connection that greater bone resorption had occurred in the De group than in the Im group.

Since the results indicated that the type of defect had an influence on healing capacity, the reductions in the 3-wall infrabony defects and the dehiscences were analyzed separately. In the Im group, the VD was reduced by 63% related to the infrabony defects (from 6.3 to 2.3 mm) (Figs 3a to 3f), whereas a reduction of 24% was achieved for the dehiscences (from 8.2 to 6.2 mm) (Figs 4a to 4f). In the De group the reductions amounted to 61% (from 3.8 to 1.5 mm) and 23% (from 4.8 to 3.7 mm), respectively. The PaW of the infrabony defects was reduced by 54% (4.1 to 1.9 mm) for both groups, while the reduction of PaW was less for the dehiscences (32%;

Table 2a No. of Peri-implant Defects in Parallel Width (PaW) at Each Examination

Group	PaW (mm)	No. of sites: At implant placement	No. of sites: At abutment connection
Immediate	0	32	57
	1–3	20 (17)	21 (13)
	4–5	34 (26)	14 (7)
	≥ 6	6 (5)	0 (0)
	All ≥ 1	60 (48)	35 (20)
Delayed	0	74	67
	1–3	10 (3)	8 (3)
	4–5	8 (5)	17 (11)
	≥ 6	0 (0)	0 (0)
	All ≥ 1	18 (8)	25 (14)

Numbers represent 3-wall infrabony defects and dehiscences, while numbers in parentheses represent 3-wall infrabony defects only.

Table 2b No. of Peri-implant Defects in Perpendicular Width (PpW) at Each Examination

Group	PpW (mm)	No. of sites: At implant placement	No. of sites: At abutment connection
Immediate	0	44	72
	1–3	(46)	(20)
	4–5	(1)	(0)
	≥ 6	(1)	(0)
	All ≥ 1	(48)	(20)
Delayed	0	84	78
	1–3	(8)	(14)
	4–5	(0)	(0)
	≥ 6	(0)	(0)
	All ≥ 1	(8)	(14)

Numbers represent 3-wall infrabony defects and dehiscences, while numbers in parentheses represent 3-wall infrabony defects only.

Table 2c No. of Peri-implant Defects in Vertical Depth (VD) at Each Examination

Group	VD (mm)	No. of sites: At implant placement	No. of sites: At abutment connection
Immediate	0	32	57
	1–3	15 (15)	20 (15)
	4–5	17 (15)	9 (4)
	≥ 6	27 (17)	6 (1)
	All ≥ 1	59 (47)	35 (20)
Delayed	0	74	67
	1–3	8 (4)	18 (12)
	4–5	5 (3)	4 (1)
	≥ 6	5 (1)	3 (1)
	All ≥ 1	18 (8)	25 (14)

Numbers represent 3-wall infrabony defects and dehiscences, while numbers in parentheses represent 3-wall infrabony defects only.

Table 3a Dimensions of Largest Parallel-Width (PaW) Defects at Each Examination, and Percent Reduction Over Time

Group/ defect type	Mean PaW ± SD (median): Implant placement	Mean PaW ± SD (median): Abutment connection	% reduction
Immediate			
All	4.4 ± 1.5 (4.0)	2.3 ± 1.6 (3.0)	48*
3-wall infrabony	4.3 ± 1.7 (4.0)	2.1 ± 1.7 (2.0)	51*
Dehiscences	4.6 ± 0.8 (5.0)	2.9 ± 1.2 (3.0)	37*
Delayed			
All	3.1 ± 1.4 (3.0)	1.9 ± 1.9 (2.0)	39*
3-wall infrabony	3.3 ± 1.5 (4.0)	1.2 ± 1.8 (0.0)	64
Dehiscences	3.0 ± 1.4 (3.0)	2.3 ± 1.8 (3.0)	23

*$P < .05$.

Table 3b Dimensions of Largest Perpendicular-Width (PpW) Defects at Each Examination, and Percent Reduction Over Time

Group/ defect type	Mean PpW ± SD (median): Implant placement	Mean PpW ± SD (median): Abutment connection	% reduction
Immediate			
All	—	—	—
3-wall infrabony	2.2 ± 1.4 (2.0)	0.9 ± 0.8 (1.0)	59*
Dehiscences	—	—	—
Delayed			
All	—	—	—
3-wall infrabony	1.3 ± 0.5 (1.0)	0.3 ± 0.5 (0.0)	77*
Dehiscences	—	—	—

*$P < .05$.

Table 3c Dimensions of Largest Vertical-Depth (VD) Defects at Each Examination, and Percent Reduction Over Time

Group/ defect type	Mean VD ± SD (median): Implant placement	Mean VD ± SD (median): Abutment connection	% reduction
Immediate			
All	6.9 ± 2.7 (7.0)	3.6 ± 3.0 (3.0)	48*
3-wall infrabony	6.3 ± 2.5 (6.0)	2.3 ± 2.0 (3.0)	63*
Dehiscences	8.2 ± 2.8 (8.0)	6.2 ± 3.1 (6.5)	24
Delayed			
All	4.4 ± 3.0 (4.0)	2.9 ± 3.6 (1.5)	34*
3-wall infrabony	3.8 ± 2.5 (3.5)	1.5 ± 3.2 (0.0)	61*
Dehiscences	4.8 ± 3.4 (4.5)	3.7 ± 3.8 (3.0)	23

*$P < .05$.

Figs 3a to 3f *Healing of a 3-wall infrabony defect following immediate placement of the implant.*

Fig 3a Before implant placement.

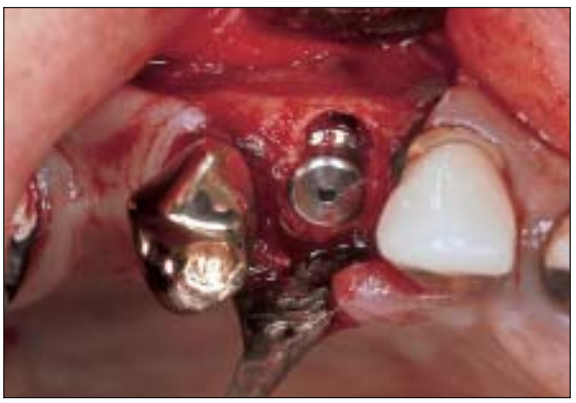

Fig 3b Immediately after implant placement.

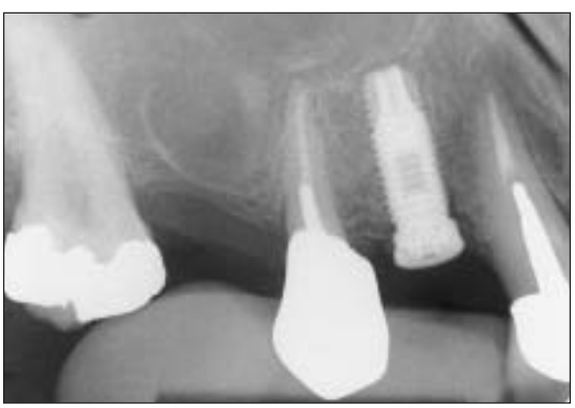

Fig 3c Radiograph taken 1 week after implant placement.

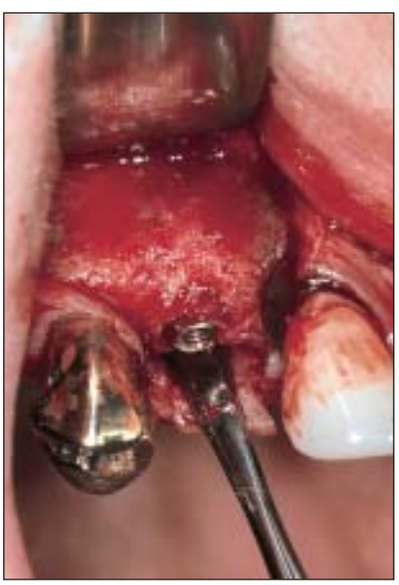

Fig 3d *(Right)* At abutment operation.

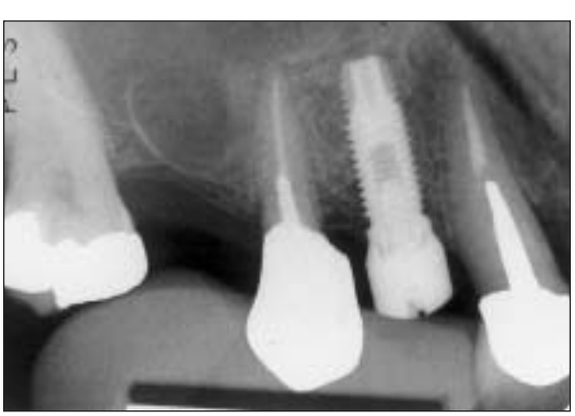

Fig 3e Radiograph taken immediately after abutment connection.

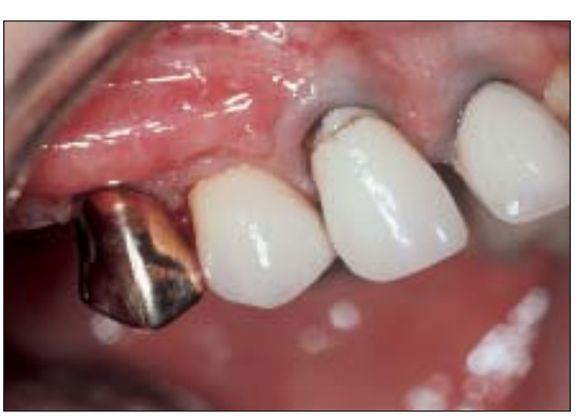

Fig 3f Definitive restoration.

Figs 4a to 4f *Dehiscence-type defect that did not heal following immediate placement of the implant.*

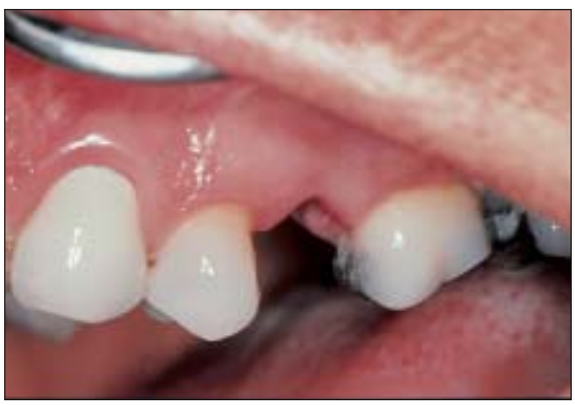

Fig 4a Before implant placement.

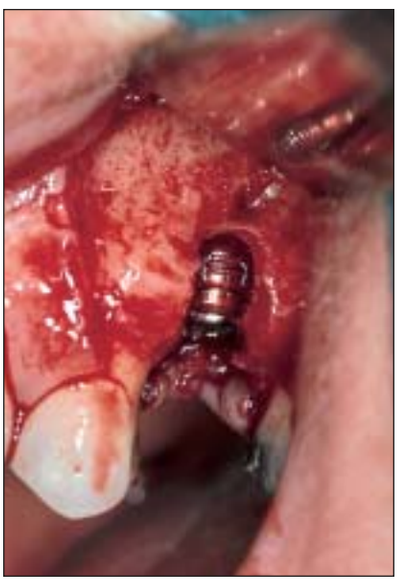

Fig 4b *(Right)* Immediately after implant placement.

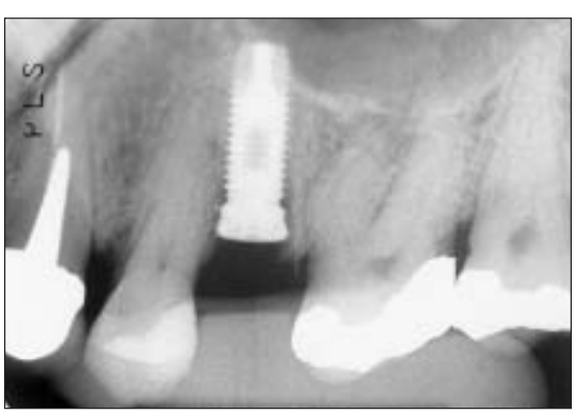

Fig 4c Radiograph taken 1 week after implant placement.

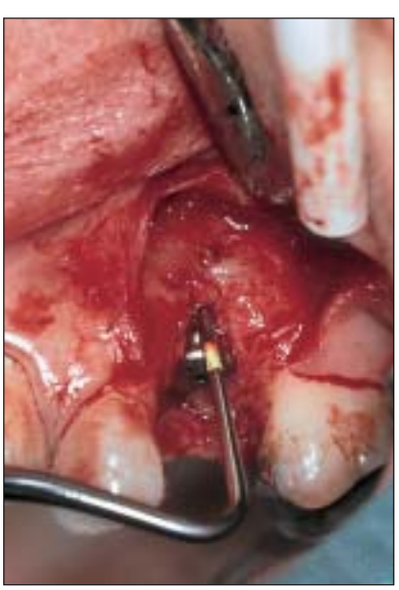

Fig 4d *(Right)* At abutment operation.

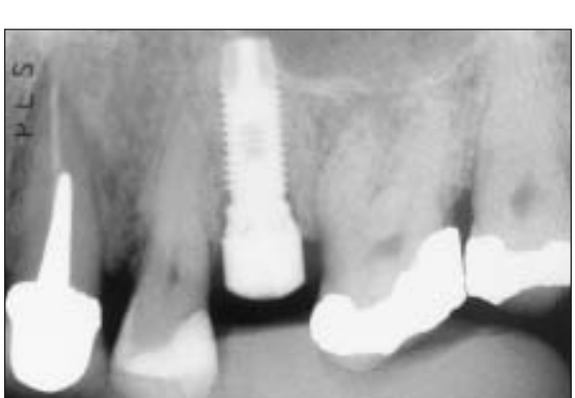

Fig 4e Radiograph taken 1 week after abutment operation.

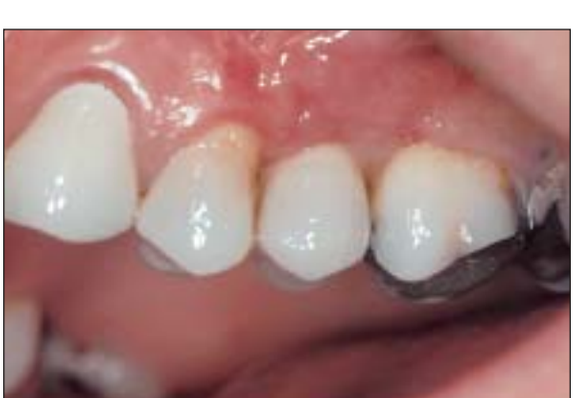

Fig 4f Definitive restoration.

3.8 to 2.6 mm). The reduction was not significantly different between the 3-wall infrabony defects and dehiscences in any of the groups ($P > .10$). Furthermore, no significant differences were found between the Im and De groups for the 3-wall infrabony defects at abutment operation ($P > .14$) or for the dehiscences ($P > .14$).

When 3-wall infrabony defects with a PaW of 1 to 3 mm in both the Im and De group were analyzed, it was revealed that 65% healed completely. The mean VD and PpW of these amounted to 2.2 mm and 1.0 mm, respectively, at baseline. The mean depth of the remaining 35% was 4.6 mm at baseline and was reduced to 2.9 mm. The PpW at baseline amounted to 2.0 mm and ended with a width of 1.3 mm. Fifty-two percent of infrabony defects with a PaW of 4 to 5 mm healed completely. The mean depth and PpW were 4.1 mm and 1.4 mm, respectively. Of the remaining 48% of infrabony defects, a 25% reduction of the PaW was found. VD at baseline amounted to 5.9 mm and PpW amounted to 2.2 mm. These dimensions were reduced to 3.3 mm and 1.0 mm, respectively, after 3 months. Seventy percent of the defects with a PaW of 4 to 5 mm, a PpW of 1 to 2 mm, and a depth of maximum 4 mm healed totally.

High reproducibility of linear measurements of the bone levels in the radiographs was found by comparing the repeated measurements (Wilcoxon matched pairs signed-ranks tests, $P > .3$) (Table 1). However, the clinical and radiographic measurements of the depth of the mesial and distal defects immediately after implant placement were not in agreement. In the Im group, 26 clinical defects with a mean depth of 4.8 mm were found mesially and distally to the implants at implant placement. Seventeen of these were 4 mm or deeper. Only 12 defects, with a mean depth of 1.7 mm, were recognized in the intraoral radiographs. Conversely, there was good agreement between the radiographic and the clinical measurements of the defect depth at abutment operation (mean of 1.2 mm versus 0.9 mm). Because of the discrepancy between the clinical and radiographic findings at implant operation, the reduction of the defects over time detected radiographically (29%; from 1.7 to 1.2 mm) corresponded poorly with the clinical determination (81%; from 4.8 to 0.9 mm). In the De group, more defects were found at implant operation on the radiographs (n = 13) than clinically (n = 5).

DISCUSSION

The results of this investigation demonstrated significant bone formation in 3-wall infrabony defects associated with immediately placed implants with a double acid-etched surface following tooth extraction. Less, but still considerable, bone generation was found in defects around the delayed implants. Without the use of any bone-reconstructive techniques such as graft materials or barrier membranes, the number of 3-wall infrabony defects in the Im group was halved after 3 months, whereas an increase was found in the De group. Interestingly, it was shown that the relative reduction of the defects in the Im group was almost independent of the size, whereas in the De group, the relative reduction decreased with larger defects. However, the dimensions of the defects in the De group after 3 months of healing were not significantly different from those in the Im group. At sites without defects at implant placement, a small amount of bone loss had occurred during the observation period, solely in the De group. A possible explanation for the difference in bone healing between defects related to Im implants versus De implants may be that the waiting period of at least 3 days between tooth extraction and implant placement meant that the Im implants were placed into sites where the inflammatory response of the organism, as well as wound healing, was in its active stage.

Approximately the same number of dehiscences at the implant surfaces were found in the Im and De groups (12 and 10, respectively) just after placement of the implants. Most of the dehiscences in the Im group were related to the extraction of the teeth, whereas in the De group, most of the dehiscences arose as a result of preparation of the implant site because the alveolar ridge was narrow.

Since measurements made at multiple sites within the same patient are statistically correlated, it was decided to choose the largest defect at each implant for the data analyses. This defect was considered to be the one having the greatest impact on the prognosis for implant survival. Analysis of the largest 3-wall infrabony and dehiscence defect of each implant separately revealed an appreciable difference in the reduction of the dimensions of these 2 defect types. In the Im group, a 63% reduction in depth had occurred for the infrabony defects (Figs 3a to 3f), versus a reduction of 24% for the dehiscences (Figs 4a to 4f). A similar difference was observed in the De group (61% versus 23%). However, it appeared that the reduction in depth or parallel width in both the Im and the De groups was not significantly different between the 3-wall infrabony and dehiscence defects. This might be explained partly by the small number of defects available for statistical analyses.

Likewise, Dahlin and coworkers showed that peri-implant dehiscences associated with implant

placement at healed extraction sites and covered with a mucoperiosteal flap alone did not heal with bone.[18] In the De group, grafting was carried out for ethical reasons just after implant placement in cases of dehiscence defects. The finding that this additional treatment did not have any substantial effect on bone generation strongly suggests that complete bone formation in peri-implant dehiscence-type defects likely will not be achieved by the mere transplantation of autogenous bone particles.

An interesting finding in the present material was that 70% of the 3-wall infrabony defects with a parallel width of up to 5 mm, a depth of up to 4 mm, and a perpendicular width of up to 2 mm had the capacity of spontaneous healing during a period of 3 months. This finding suggests that the effect of peri-implant bone-reconstructive procedures (such as GTR, grafting materials, bone-inductive substances) on bone formation should be evaluated in 3-wall infrabony defects with larger dimensions than those mentioned above. However, it is likely that bone formation continues after abutment connection surgery, thereby resulting in further reduction of the defect dimensions.

The present study did not disclose the quality of the interface between the implant surface and the generated bone in the peri-implant defects. However, experimental animal studies have demonstrated histologically that osseointegration occurs after the placement of implants into fresh extraction sockets.[19–21] The present study did not disclose whether the quality of the bone generated following immediate implant placement was comparable to the quality of bone surrounding the implant following delayed placement. Therefore, long-term, controlled clinical and radiographic studies are needed to evaluate this aspect of implant dentistry. However, in an animal study,[13] histologic observations indicated that there was no difference in the stability of newly formed bone around immediately placed implants and bone surrounding conventionally placed implants.

The overall survival rate of 91%, though evaluated in only a short-term follow-up, was comparable with that for conventional implant placement in the anterior and premolar regions.[1–3] This supports the results of previous studies and case reports, which have demonstrated high success rates in conjunction with immediate implants.[22–26]

The rationale for immediate implant placement is that one utilizes the potential of new bone formation in the extraction socket to obtain osseointegration. Advantages of the immediate procedure include preservation of the alveolar bone height and width[27,28]; furthermore, treatment time and costs are reduced. Various guidelines for this technique have been suggested,[7,16,23] but there is no consensus regarding which protocol to follow. Among the issues that have been discussed is whether the presence of chronic infection is a contraindication for implant placement. In an animal study,[29] it was found that experimentally induced periapical lesions had no influence on osseointegration of immediately placed implants. Other investigators have reported successful treatment outcomes related to immediate implantation at chronically infected sites.[15,30,31] Nevertheless, it was concluded in a review of the literature[6] that infection associated with an extracted tooth contraindicates immediate implant placement. To reduce the risk of complications caused by infection, the immediate technique was modified in the present study by deferring the time of implant placement for at least 3 days following extraction.

In the present material, potential for spontaneous bone healing was found in 3-wall infrabony defects associated with titanium dental implants with a double acid-etched surface placed into extraction sockets, while dehiscences failed to heal completely with bone. More controlled, prospective clinical studies are needed to define the potential for spontaneous healing, for instance, in 1-wall and 2-wall infrabony peri-implant defects, as well as the long-term prognosis of immediate implant placement into fresh extraction sockets.

ACKNOWLEDGMENTS

This project was supported by Implant Innovations, Palm Beach Gardens, Florida. The authors wish to thank the staff at the Department of Oral and Maxillofacial Surgery, the Department of Oral Radiology, and the Department of Periodontology and Oral Gerodontology, Royal Dental College, University of Aarhus, Denmark, for their assistance.

REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
2. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11–25.
3. Jemt T, Lekholm U, Adell R. Osseointegrated implants in the treatment of partially edentulous patients: A preliminary study on 876 consecutively placed fixtures. Int J Oral Maxillofac Implants 1989;4:211–217.

4. Brånemark P-I. Introduction to osseointegration. In: Brånemark P-I, Zarb G, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:1–76.
5. Schwartz-Arad D, Chaushu G. The ways and wherefores of immediate placement of implants into fresh extraction sites: A literature review. J Periodontol 1997;68:915–923.
6. Mayfield L. Immediate, delayed and late submerged and transmucosal implants. In: Lang NP, Karring T, Lindhe J (eds). Proceedings of the 3rd European Workshop on Periodontology: Implant Dentistry. Berlin: Quintessence, 1999: 520–534.
7. Lazzara RJ. Immediate implant placement into extraction sites: Surgical and restorative advantages. Int J Periodontics Restorative Dent 1989;9:332–343.
8. Becker W, Becker BE. Guided tissue regeneration for implants placed into extraction sockets and for implant dehiscences: Surgical techniques and case report. Int J Periodontics Restorative Dent 1990;10:376–391.
9. Becker W, Dahlin C, Becker BE, et al. The use of e-PTFE barrier membranes for bone promotion around titanium implants placed into extraction sockets: A prospective multicenter study. Int J Oral Maxillofac Implants 1994;9:31–40.
10. Kostopoulos L, Karring T. Augmentation of the rat mandible using guided tissue regeneration. Clin Oral Implants Res 1994;5:75–82.
11. Simion M, Misitano U, Gionso L, Salvato A. Treatment of dehiscences and fenestrations around dental implants using resorbable and nonresorbable membranes associated with bone autografts: A comparative clinical study. Int J Oral Maxillofac Implants 1997;12:159–167.
12. Zitzmann NU, Naef R, Schärer P. Resorbable versus nonresorbable membranes in combination with Bio-Oss for guided bone regeneration. Int J Oral Maxillofac Implants 1997;12:844–852.
13. Barzilay I, Graser GN, Iranpour B, Natiella JR, Proskin HM. Immediate implantation of pure titanium implants into extraction sockets of *Macaca fascicularis.* Part II: Histologic observations. Int J Oral Maxillofac Implants 1996;11:489–497.
14. Barzilay I, Graser GN, Iranpour B, Proskin HM. Immediate implantation of pure titanium implants into extraction sockets of *Macaca fascicularis.* Part I: Clinical and radiographic assessment. Int J Oral Maxillofac Implants 1996;11:299–310.
15. Rosenquist B, Grenthe B. Immediate placement of implants into extraction sockets: Implant survival. Int J Oral Maxillofac Implants 1996;11:205–209.
16. Becker BE, Becker W, Ricci A, Geurs N. A prospective clinical trial of endosseous screw-shaped implants placed at the time of tooth extraction without augmentation. J Periodontol 1998;69:920–926.
17. Schropp L, Wenzel A, Kostopoulos L. Impact of conventional tomography on prediction of the appropriate implant size. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92:458–463.
18. Dahlin C, Andersson L, Linde A. Bone augmentation at fenestrated implants by an osteopromotive membrane technique. A controlled clinical study. Clin Oral Implants Res 1991;2:159–165.
19. Barzilay I, Graser GN, Iranpour B, Natiella JR. Immediate implantation of a pure titanium implant into an extraction socket: Report of a pilot procedure. Int J Oral Maxillofac Implants 1991;6:277–284.
20. Knox R, Caudill R, Meffert R. Histologic evaluation of dental endosseous implants placed in surgically created extraction defects. Int J Periodontics Restorative Dent 1991;11: 364–375.
21. Warrer K, Gotfredsen K, Hjørting-Hansen E, Karring T. Guided tissue regeneration ensures osseointegration of dental implants placed into extraction sockets. An experimental study in monkeys. Clin Oral Implants Res 1991;2:166–171.
22. Gelb DA. Immediate implant surgery: Three-year retrospective evaluation of 50 consecutive cases. Int J Oral Maxillofac Implants 1993;8:388–399.
23. Block MS, Kent JN. Placement of endosseous implants into tooth extraction sites. J Oral Maxillofac Surg 1991;49: 1269–1276.
24. Tolman DE, Keller EE. Endosseous implant placement immediately following dental extraction and alveoloplasty: Preliminary report with 6-year follow-up. Int J Oral Maxillofac Implants 1991;6:24–28.
25. Lang NP, Brägger U, Hämmerle CH, Sutter F. Immediate transmucosal implants using the principle of guided tissue regeneration. I. Rationale, clinical procedures and 30-month results. Clin Oral Implants Res 1994;5:154–163.
26. Brägger U, Hammerle CH, Lang NP. Immediate transmucosal implants using the principle of guided tissue regeneration (II). A cross-sectional study comparing the clinical outcome 1 year after immediate to standard implant placement. Clin Oral Implants Res 1996;7:268–276.
27. Denissen HW, Kalk W. Preventive implantations. Int Dent J 1991;41:17–24.
28. Wheeler SL, Vogel RE, Casellini R. Tissue preservation and maintenance of optimum esthetics: A clinical report. Int J Oral Maxillofac Implants 2000;15:265–271.
29. Novaes AB Jr, Vidigal GM Jr, Novaes AB, Grisi MF, Polloni S, Rosa A. Immediate implants placed into infected sites: A histomorphometric study in dogs. Int J Oral Maxillofac Implants 1998;13:422–427.
30. Novaes AB Jr, Novaes AB. Immediate implants placed into infected sites: A clinical report. Int J Oral Maxillofac Implants 1995;10:609–613.
31. Pecora G, Andreana S, Covani U, De Leonardis D, Schifferle RE. New directions in surgical endodontics; Immediate implantation into an extraction site. J Endod 1996;22: 135–139.