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Clinical and radiographic performance of delayed-immediate single-tooth implant placement associated with peri-implant bone defects. A 2-year prospective, controlled, randomized follow-up report

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***Abstract*:**

Objectives: The aim of the present study was to compare the delayed-immediate (Im) and the delayed (De) protocols for placement of single-tooth implants.

Material and methods: After allocation to the Im and De groups by random, 46 patients were treated with a single-tooth implant with acid etched surfaces (Osseotite®) in the anterior or pre-molar region of the maxilla or the mandible on average 10 days (Im) or 3 months (De) following tooth extraction, respectively. Forty-one patients attended a follow-up visit 2 years after implant placement corresponding to $1\frac{1}{2}$ years of loading of the implant restorations. Peri-implant and prosthetic parameters were evaluated clinically and marginal bone levels measured on radiographs.

Results: Three implants were lost, all before mounting of the crown. None of the implant restorations had failed after $1\frac{1}{2}$ years of function. Probing pocket depths were reduced by up to 1.4 mm on average from the time of loading to the 2-year follow-up and at that time, no significant difference between the Im and De groups was found (4.2 *versus* 4.1 mm). A statistically significant radiographic marginal bone loss had occurred in the Im group (mean = 0.8 mm) as well as in the De group (mean = 0.7 mm) in the follow-up period. However, a mean marginal bone level of approx. 1.5 mm in both groups measured from the implant–abutment junction was found to be acceptable. It was demonstrated that probing pocket depths and marginal bone levels after $1\frac{1}{2}$ years of loading of the implant-retained crowns were not influenced by the presence of peri-implant bone defects immediately after implant placement. Furthermore, no severe prosthodontic complications, such as screw loosening or porcelain fractures, arose in this study material.

Conclusion: High success rates of single-tooth implants after $1\frac{1}{2}$ years of function were achieved using the delayed-immediate and delayed implant placement techniques.

Key words: 2-year follow-up study; delayed-immediate implant placement; dental implants; single-tooth

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The original protocol for treatment with dental implants introduced by Brånemark (1985) has been challenged within the last decades. One matter of interest has been to investigate whether it is possible to shorten the time period between tooth extraction and placement of the implant, alternatively to insert the implant at the same visit as the removal of the tooth (immediate implantation). In addition to the obvious benefits for the patient in terms of fewer surgical sessions and a more expeditious delivery of the final implant restoration, the immediate or delayed-immediate concepts may be advantageous from a biologic viewpoint. Previous studies have shown that early implant placement may lead to preservation of alveolar bone height and width (Denissen & Kalk 1991, Schropp et al. 2003b, Wheeler et al. 2000), and furthermore, it may enhance osseointegration by taking advantage of the natural bone healing process around the implant.

Several clinical investigations have demonstrated that multiple-tooth as well as single-tooth implants can be placed immediately in extraction sockets with success (Missika et al. 1997, Touati & Guez 2002, Schwartz-Arad & Chaushu 1997). High survival rates have been achieved with an observation period of up to 7 years (Douglass & Merin 2002). Big resources have been spent on improving the outcome after immediate implantation by modifying the surgical technique. Likewise, form, surface structure and topography of the implant components have been modified in order to comply with the specific demands related to implant placement into a fresh extraction socket, thereby, increasing primary implant stability and enhancing bone formation on the implant surface. However, immediate implant placement in extraction sockets is often associated with the presence of peri-implant defects at the time of surgery. These defects have varying form and dimensions. It has been suggested to apply bone-reconstructive methods (GTR, grafting materials) in conjunction with immediate implant placement in order to ensure bone formation in peri-implant bone defects (Lazzara 1989, Todescan, Jr. et al. 1987). However, data is available showing good results also in cases without the use of membranes or grafts (Becker et al. 1998, Schropp et al. 2003a). Obviously, it is advantageous to both the patient and the dentist, as well as from a socio-economic point of view to simplify treatment with implants by restricting the application of complicated, peri-implant, bone reconstructive procedures to situations where this is necessary. It is therefore imperative to identify the type and size of bone defects around immediately placed implants that heal spontaneously in humans. Schropp et al. (2003a) demonstrated that a higher degree of bone healing was achieved in peri-implant infrabony defects than in dehiscence-type defects with or without grafting with autogenous bone particles (a depth reduction of 60% *versus* 25%). Furthermore, it was shown that 70% of three-wall infrabony defects with a parallel width of up to 5 mm, a maximum depth of 4 mm, and a perpendicular width of maximum 2 mm had a capacity of spontaneous healing. It is also important to investigate whether peri-implant bone defects present at implant placement surgery or at abutment surgery have an impact on implant survival, clinical peri-implant conditions, and marginal bone level on a long-term basis.

It must be emphasized that conclusions drawn on the immediate implant placement approach are primarily based on case studies. Moreover, clinical trials have most often focused on the success rates of implants. To the best of our knowledge, no randomized, controlled clinical studies on immediate implant placement have been conducted previously. Furthermore, long-term data on the peri-implant conditions do still not exist.

The purpose of this prospective clinical study was to compare the peri-implant and prosthetic conditions for single-tooth implants placed according to the delayed-immediate (Im) and the delayed (De) protocols at a 2-year follow-up examination.

Materials and Methods

A total of 46 patients (25 women and 21 men) were treated with an Osseotite® implant (3i Implant Innovations Inc., Palm Beach Gardens, FL, USA) in the anterior or pre-molar region of the maxilla or the mandible (Fig. 1). Two implant placement techniques were used and the patients were allocated to either a delayed-immediate (Im) group or a delayed (De) group by random:

Delayed-immediate: The implants were placed on average 10 days (range 3–15 days) following tooth extraction. No membranes or grafting were used at implant placement. Autogenous bone particles were grafted to exposed implant threads in cases of dehiscences or fenestrations at abutment surgery.

Delayed: The implants were placed on average 3 months (range 65–138 days) following tooth extraction. No membranes were used, while autogenous bone particles were grafted to any exposed implant threads in cases of dehiscences or fenestrations at implant placement. Grafting of these types of defects was also performed if defects were present at abutment connection surgery.

The teeth were removed by careful extraction technique. The extraction sockets were not covered by soft tissue before placement of the implants (Fig. 2a and 3a). However, in two cases in the Im group crown fracture during tooth extraction necessitated a flap elevation and subsequent closure of the wound. In both the Im and the De group, a crestal incision connected with two buccal vertical releasing incisions involving the crevices of the teeth mesial and distal to the extraction site preceded the implant insertion. Following elevation of a mucoperiosteal flap, the implants were placed with the cover screws situated at the same level as the surrounding bone (Fig. 2b and 3c). The bucco-lingual implant position was partly determined by the morphology of the alveolus. It was aimed at achieving the smallest bone defect around the implant, but at the same time, a favourable location with regard to the aesthetics and loading conditions of the future prosthetic restoration was taken into consideration. Primary closure of the wound was achieved by means of a periosteal incision at the base of the buccal flap followed by a coronal positioning and stabilization of the flap with 5-0 silk sutures.

After a 3-month healing period in both groups, a second stage surgery was performed at which a one- or two-piece EP® Healing Abutment (3i Implant Innovations Inc.) was mounted to the implants in order to condition the peri-implant soft tissues for 4–6 weeks. An incision technique corresponding to the one performed at the implant placement operation was used and a mucoperiosteal flap was elevated. The position of the crestal incision was carefully determined in order to provide the establishment of attached mucosa at the buccal aspect of the implant. Since three implants did not osseointegrate only 43 of 46 patients were treated with an implant-supported restoration. Single-tooth metal-ceramic crowns were made on STA abutments or UCLA abutments (3i Implant Innovations Inc.) in all cases, except for one, for whom a three-unit fixed partial denture was fabricated. Abutment connection was achieved by Gold-Tite™ square uni-screws (3i Implant Innovations Inc.) torqued to 32 Ncm by the use of a torque indicator. Forty-one restorations were cemented, while two were screw-retained.

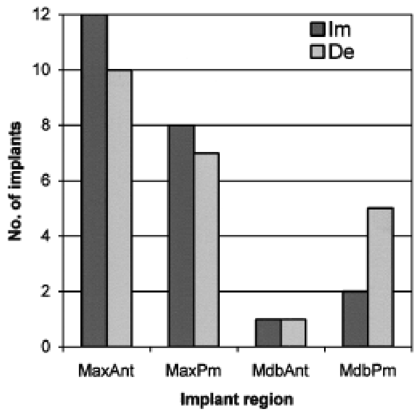

Fig. 1. Frequency distribution of implant regions. MaxAnt, maxillary anterior region; MaxPm, maxillary premolar region; MdbAnt, mandibular anterior region; MdbPm, Mandibular premolar region.

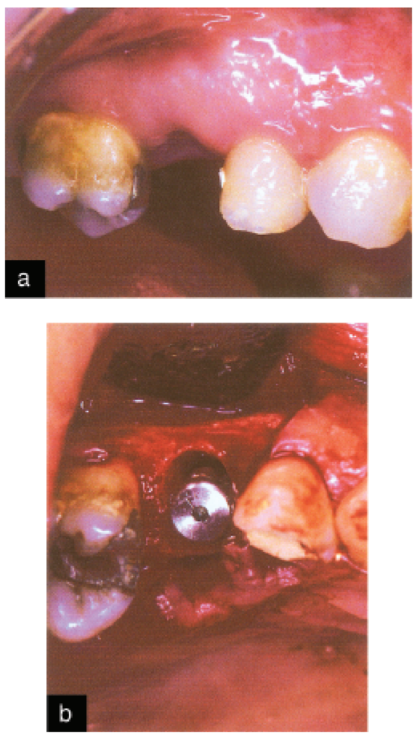

Fig. 2. (a) The extraction site at the day of implant placement. An upper right second premolar was extracted 13 days before. (b) Three-wall infrabony defects buccally and lingually to the implant were present following placement.

A follow-up evaluation was carried out 9 months (Control 1) and 2 years (Control 2) after implant placement corresponding to a functional loading time of the suprastructure of approximately 4 months and $1\frac{1}{2}$ years, respectively. Forty patients attended the first control visit and 41 patients the second. They were asked for possible complaints and a check of implant mobility, screw loosening, porcelain fractures, exposure of the implant or metal margins of the crown or abutment was performed. Probing pocket depths were measured at the buccal, mesial, distal and lingual aspects of the implants approximately one week after delivery of the restoration (Baseline) and at Control 1 and 2 visits. The primary outcome variable in the present study was marginal bone level changes assessed radiographically. On digitized intra-oral radiographs, marginal bone levels (distance from implant–abutment junction to the first visible bone-to-implant contact) were determined mesial and distal to the implants by the use of a computer program (PorDiosW, Institute of Orthodontic Computer Sciences, Middelfart, Denmark) designed for measuring distances on digital images. The measurements of bone levels were adjusted according to the magnification by measuring the length of the implants (for detailed information on radiographic evaluation, see Schropp et al. (2003a)). Recordings on the radiographs were performed at second stage surgery (Baseline) and again at the two control examinations. The radiographic examinations were blinded.

Data treatment

Mean values, standard deviations and medians were calculated for probing pocket depths and marginal bone levels measured on radiographs. Changes in probing pocket depths and bone levels from Baseline to Control 2 were analysed by means of Wilcoxon matched-pairs Signed Ranks Test within the Im and the De groups, while differences between the two groups at Baseline, Control 1, Control 2 and in change over time were tested by Mann–Whitney *U*-test. Additionally, probing pocket depths as well as marginal bone levels measured at Control 2 for implant sites associated with a peri-implant bone defect (an extension of at least 1 mm in two or three dimensions) at implant placement or at abutment surgery were compared with those for implant sites not associated with a defect. Furthermore, it was tested whether a difference in probing pocket depth existed when comparing peri-implant three-wall infrabony defects and dehiscences. Figure 2b illustrates three-wall infrabony defects surrounding an implant inserted 13 days after tooth extraction. An example of a dehiscence-type defect associated with an implant placed 9 days post-extraction is shown in Fig. 3c. For statistical reasons, the data for the Im and De groups were pooled because of the small number of sites, when

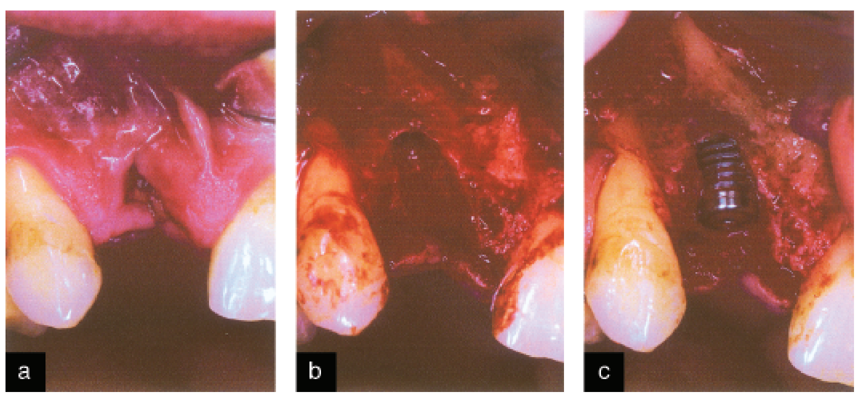

Fig. 3. (a) The extraction site at the day of implant placement. An upper right central incisor was extracted 9 days before. (b) The extraction alveolus. The coronal part of the buccal bone plate is lacking. (c) A dehiscence is present at the buccal aspect of the implant just after placement.

categorizing these according to their type of bone defect. p-values below 5% were considered statistically significant. However, the Bonferroni procedure was applied for probing pocket depths and radiographic measurements in cases where multiple comparisons were performed. This resulted in a reduction of the level of significance to 0.2% (Table 1a) and 0.4% (Table 2a), respectively.

Results

Three maxillary implants, two in the pre-molar region and one in the anterior region, were lost at second stage surgery corresponding to a survival rate of 91% in the Im group and 96% in the De group. No further implants were lost within the 2-year observation period. At the 9-month follow-up (Control 1), two patients had withdrawn from the study and of the remaining patients one did not attend the Control 1 visit.

Probing pocket depths were reduced during the observation period in both groups (Table 1a). From baseline to 2 years after implant placement (Control 2), a mean probing pocket depth reduction at the buccal, mesial, distal and lingual aspects of the implant from 0.3 to 1.4 mm was found in the Im group, while the reduction in the De group was smaller, namely between 0.2 and 0.6 mm. The reduction over time was statistically significant for the lingual sites in the Im group ($p = 0.001$). However, no significant difference in mean probing pocket depth (average of the four sites per implant) was observed at Control 2 examination between the Im and De groups (4.2 and 4.1 mm, respectively). Likewise, the mean probing pocket depth at implant sites associated with a peri-implant bone defect at implant placement or at abutment surgery did not differ significantly from the probing pocket depth at sites without a defect (Table 1b, c). Furthermore, buccal sites harbouring a dehiscence-type of defect at abutment surgery did not exhibit deeper probing pocket depths at Control 2 than sites harbouring a three-wall infrabony defect (3.9 mm *versus* 3.8 mm).

Marginal bone loss assessed on radiographs was observed mesial and distal to the implants in the Im and De groups during the time from abutment connection to Control 2 (Table 2a). The mean marginal bone loss at the mesial aspect was 0.5 mm in the Im group and 0.8 mm in the De group. The corresponding findings for the distal sites were 1.0 and 0.6 mm. These changes were statistically significant ($p < 0.004$), except at the mesial aspect in the Im group. Sixty to eighty percent of the bone loss took place in the period from Baseline to Control 1 in the Im group and 83–88% in the De group. The marginal bone level (an average of the mesial and distal sites) at Control 2 was located 1.4 mm apically to the implant–abutment junction level in the Im group, which did not differ significantly from the bone level of 1.6 mm recorded in the De group ($p > 0.06$). Neither were the marginal bone levels after $1\frac{1}{2}$ years of loading significantly different for implant sites with or without a defect at the time of implant placement (Table 2b). Comparing the marginal bone level mesially and distally to the implants at Control 2 for sites exhibiting a bone defect at abutment surgery *versus* sites without a defect, statistically significant differences were found (Table 2c).

In the observation period from delivery of the implant-supported restoration to the 2-year follow-up examination, all of the implants remained immobile and

Table 1a. Probing pocket depths in mm at implant sites in the delayed-immediate and the delayed groups at Baseline as well as 9 months (Control 1) and 2 years (Control 2) after implant placement

	Del-immediate	Delayed	Del-immediate vs. Delayed (p)
Buccally			
Baseline*	4.3 ± 1.3 (4.0)	4.1 ± 1.3 (4.0)	0.73
Control 1	4.1 ± 1.3 (4.0)	3.9 ± 1.3 (3.0)	0.59
Control 2	3.8 ± 1.5 (3.0)	3.9 ± 1.3 (3.0)	0.80
Baseline vs. Control 2 (p)	0.04	0.55	0.16
Mesially			
Baseline*	5.4 ± 1.5 (5.0)	4.5 ± 1.3 (4.0)	0.04
Control 1	5.2 ± 1.5 (5.0)	4.1 ± 0.9 (4.0)	0.01
Control 2	4.8 ± 1.6 (5.0)	4.3 ± 1.0 (4.0)	0.38
Baseline vs. Control 2 (p)	0.10	0.95	0.24
Distally			
Baseline*	4.7 ± 1.6 (5.0)	4.5 ± 1.1 (5.0)	0.94
Control 1	5.0 ± 1.4 (5.0)	4.2 ± 1.2 (4.0)	0.09
Control 2	4.4 ± 1.1 (4.0)	4.3 ± 1.1 (4.5)	0.89
Baseline vs. Control 2 (p)	0.20	0.62	0.66
Lingually			
Baseline*	5.1 ± 1.6 (5.0)	4.3 ± 1.2 (4.0)	0.11
Control 1	4.5 ± 1.4 (5.0)	3.7 ± 0.9 (4.0)	0.07
Control 2	3.7 ± 1.3 (3.0)	3.7 ± 0.9 (3.0)	0.76
Baseline vs. Control 2 (p)	0.001	0.06	0.06

*One week after mounting of the implant restoration
Mean ± std. dev. (median).

Table 1b. Probing pocket depths at implant sites with and without peri-implant bone defects at implant placement recorded 2 years after implant placement

	No defects		Defects		Significance (p)
Buccally	3.5 ± 1.0 (3.0)	$N = 13$	3.9 ± 1.5 (3.5)	$N = 28$	0.43
Mesially	4.2 ± 1.3 (4.0)	$N = 26$	5.0 ± 1.3 (5.0)	$N = 15$	0.06
Distally	4.4 ± 1.1 (4.0)	$N = 31$	4.4 ± 1.2 (4.5)	$N = 10$	0.90
Lingually	3.8 ± 1.2 (3.0)	$N = 29$	3.4 ± 1.0 (3.0)	$N = 12$	0.40

Both groups (Im and De) are included. Mean ± std. dev. (median).

Table 1c. Probing pocket depths at implant sites with and without peri-implant bone defects at abutment surgery recorded 2 years after implant placement

	No defects		Defects		Significance (p)
Buccally	3.7 ± 1.2 (3.0)	$N = 15$	3.8 ± 1.5 (3.0)	$N = 26$	0.81
Mesially	4.4 ± 1.4 (5.0)	$N = 32$	4.8 ± 1.3 (4.0)	$N = 9$	0.69
Distally	4.3 ± 1.1 (4.0)	$N = 32$	4.4 ± 1.0 (5.0)	$N = 9$	0.76
Lingually	3.7 ± 1.1 (3.0)	$N = 31$	3.5 ± 1.2 (3.0)	$N = 10$	0.58

Both groups (Im and De) are included. Mean ± std.dev. (median).

Table 2a. Radiographic measurements of marginal bone levels (mm) in the delayed-immediate and the delayed groups at Baseline as well as 9 months (Control 1) and 2 years (Control 2) after implant placement

	Del-immediate	Delayed	Del-immediate vs. Delayed (*p*)
Mesially			
Baseline*	0.8 ± 0.8 (0.8)	0.8 ± 1.1 (0.0)	0.56
Control 1	1.2 ± 0.7 (1.3)	1.5 ± 0.8 (1.5)	0.39
Control 2	1.3 ± 0.8 (1.2)	1.6 ± 0.6 (1.4)	0.07
Baseline vs. Control 2 (*p*)	0.08	0.003	0.19
Distally			
Baseline*	0.4 ± 0.6 (0.0)	0.9 ± 0.9 (0.9)	0.04
Control 1	1.0 ± 0.6 (1.1)	1.4 ± 0.7 (1.4)	0.08
Control 2	1.4 ± 0.7 (1.2)	1.5 ± 0.6 (1.6)	0.24
Baseline vs. Control 2 (*p*)	0.0001	0.001	0.12

*At healing abutment connection
Mean ± std.dev. (median).

Table 2b. Marginal bone levels (mm) for both groups (Im and De) at implant sites with and without peri-implant bone defects at implant placement recorded 2 years after implant placement

	No defects		Defects		Significance (*p*)
Mesially	1.5 ± 0.6 (1.3)	$N = 26$	1.4 ± 0.9 (1.5)	$N = 15$	0.89
Distally	1.4 ± 0.7 (1.5)	$N = 31$	1.4 ± 0.7 (1.2)	$N = 10$	0.67

Mean ± std.dev. (median).

Table 2c. Marginal bone levels (mm) for both groups (Im and De) at implant sites with and without peri-implant bone defects at abutment surgery recorded 2 years after implant placement

	No defects		Defects		Significance (*p*)
Mesially	1.3 ± 0.6 (1.3)	$N = 32$	2.0 ± 0.7 (1.9)	$N = 9$	0.02
Distally	1.3 ± 0.6 (1.3)	$N = 32$	1.9 ± 0.6 (1.8)	$N = 9$	0.03

Mean ± std. dev. (median).

none of the suprastructures were associated with screw loosening or porcelain fractures. In five cases, it was necessary to recement the crown because of loosening. All of these were initially cemented with a temporary cement, but after recementation with a zinc phosphate cement, no loss of retention recurred. Exposure of metal margins of the crown or abutment was found in four patients (two delayed-immediate cases and two delayed cases). In one case (Im), the metal margin of the crown was visible one week after delivery and remained visible at Control 2. In two cases (1 Im, 1 De), the metal margin of the crown or the abutment became exposed during the observation period. In one case (De), however, an exposed abutment margin was present just after mounting of the crown, but during the $1\frac{1}{2}$ years of function the visible metal became covered with peri-implant soft tissue.

Peri-implant complications arose in one case. A fistula formation was seen in relation to an implant replacing a maxillary central incisor. This implant had been placed very deeply (the implant shoulder was situated approximately 10 mm more apically than the cemento-enamel junction of the adjacent teeth) because of extreme atrophy of the alveolar process in this area. Furthermore, an intra-oral radiograph disclosed remnants of cement at the implant–abutment joint. After meticulous scaling, the acute symptoms and the fistula disappeared, and the peri-implant bone level corresponded to the first implant thread. However, probing pocket depths of 6–8 mm were present at the time of Control 2.

None of the patients reported complaints about their implant restoration, except the patient with peri-implant fistula, who suffered from a bad taste in the mouth originating from the peri-implant mucosa.

Discussion

The results of this prospective study demonstrated that a successful prosthetic reconstruction can predictably be achieved and function for an observation period of 2 years after delayed-immediate placement of implants with acid-etched surfaces into extraction sockets. Only two of the delayed-immediate implants in the maxilla failed prior to occlusal loading. The rest of the implants remained in function during the following $1\frac{1}{2}$ years. It was not possible to trace the fate of the implants placed in two patients not having attended the recall visits. However, even if assuming that these implants were lost, survival rates exceeding 95% have been obtained in the present material. These results corroborate previous investigations, which have evaluated the immediate, the delayed and the late protocols for single-tooth implant placement (Gibbard & Zarb 2002, Schmitt & Zarb 1993, Kan et al. 2003, Groisman et al. 2003).

An interesting finding was that a reduction in probing pocket depth occurred from the time of delivery of the implant-supported crown to the 2-year follow-up examination both in the Im and the De group. Probing pocket depth reduction amounting up to 1.5 mm in the Im group was observed, and it was statistically significant at the lingual aspect of the implant. For the implants placed according to the delayed approach, probing pocket depths were reduced to a smaller extent, namely by up to 0.5 mm. In both groups, a mean probing pocket depth of approximately 4 mm was found at the 2-year follow-up, which may be considered to be acceptable. An investigation of Chang et al. (1999) indicated that probing depths are generally greater at implants than at contralateral teeth. Even though it is the prevalent opinion that increased pocket depth at natural teeth is a sign of periodontal disease and must be reduced in order to prevent further progression, there is no evidence showing a correlation between probing pocket depth and the presence or absence of active disease (Wennström et al. 1997). Likewise, it has not been demonstrated that increased pocket depth at implants deteriorates the prognosis. However, it is reasonable to assume that probing pocket depths not exceeding 4.0 mm are preferable to facilitate the patient's ability for self-performed plaque control as well as accessibility for proper professional peri-implant cleaning.

Peri-implant probing has been accepted as a good technique for assessing the peri-implant health status (Lang et al. 1994). In addition to be a simple alternative to radiographic examination, pocket probing has the advantage that the clinical probing attachment level can be evaluated also at the buccal and lingual aspects of the implant. However, peri-implant probing is indeed also associated with several shortcomings, which should be considered. First, one should be aware of the differences in tissue composition of gingiva and peri-implant tissue that exist (Berglundh et al. 1991). Similarly, differences have been found when comparing the attachment between root surface and gingiva and the attachment between peri-implant mucosa and the implant surface. Ericsson and Lindhe (1993) showed that these histological differences had an impact on probing depth measurements, since probe penetration becomes more advanced at implants than at teeth. Furthermore, the location of the probing tip in relation to the crestal bone is influenced by the peri-implant mucosal health (Schou et al. 2002). An animal study, which has compared clinical probing and radiographic assessment with the histological bone level at implants, revealed that only the radiographic bone level correlated significantly with the histological assessment (Isidor 1997). Second, the reproducibility of probe measurements is influenced by factors such as: implant design, insertion angle of the probe and the force applied. In order to enhance the reproducibility, different types of pressure-sensitive probes have been developed (Atassi 2002). A weakness of the present study may be that a probing technique with non-standardized probing force was used. However, an argument of employing a manual probing instrument could be that a better tactile perception can be provided compared with for example electronic probes, which in turn allows for the detection of obstructions such as implant threads and crown contours. In an effort to improve the reproducibility in this material, the same examiner performed all probing measurements.

Analysis of the marginal bone levels assessed on intra-oral radiographs showed that bone resorption occurred at the proximal surfaces of the implants within the observation period of the present study and regardless whether the delayed-immediate or the delayed implant insertion concept was applied. When calculating an average for the mesial and distal surfaces, a mean bone loss of 0.8 mm in the Im group and 0.7 mm in the De group was recorded, resulting in a marginal bone level from the implant shoulder of approximately 1.5 mm at the 2-year follow-up examination for both groups. Most of this bone resorption occurred within the first 9 months of loading. These figures correspond to findings from a previous study, which have evaluated immediate and delayed-immediate placement of implants after 1 year of loading (Grunder et al. 1999). The present results also meet the success criteria for implant treatment proposed in the consensus report of the 1st European Workshop on Periodontology: ''The criteria of success demand an average bone loss of less than 1.5 mm during the first year after insertion of the prostheses'' (Albrektsson & Isidor 1994), as well as the criteria defined by Albrektsson et al. (1986), who proposed that an annual marginal bone loss of less than 0.2 mm after the first year is ''acceptable''.

Despite the marginal bone resorption, no severe peri-implant complications arose in the present study material. A peri-implant fistula formation was seen in one case, which most likely was caused by a very deeply positioned implant in combination with remnants of cement submarginal of the peri-implant mucosa.

Apart from the necessity of recementing five implant-retained crowns, there were no prosthodontic complications during the study period. Neither screw loosening nor porcelain fractures were seen. Screw loosening has been reported to be a common prosthetic complication in relation to implant-supported restorations (Ekfeldt et al. 1994, Henry et al. 1996, Laney et al. 1994). In the present study, gold-alloy-coated screws were used for the retention of the abutment component, which might be one explanation for not observing this type of prosthodontic complication. This is in agreement with the results of a clinical study that had demonstrated the efficacy of Gold-Tite™ square uniscrews (3i Implant Innovations Inc.) in cement-retained implant restorations (Drago 2003). Furthermore, 41 of 43 crowns were cemented on screw-retained abutments, which also may be an advantage in relation to screw loosening. Singer and Serfaty (1996) suggested that cementation of implant-supported single crowns and bridges may lower technical complications.

The results of the present study should be seen in the light of the high percentage of implant sites harbouring a peri-implant bone defect just after implant placement (65% in the Im group and 20% in the De group). At abutment surgery, 16% of the implants sites in the Im group and 12% in the De group were associated with a dehiscence-type defect. Sixty-seven percent and 45%, respectively, of these had a vertical extension of 4 mm or larger (Schropp et al. 2003a). It is noteworthy that none of these defects were treated with membranes, but solely filled with autogenous bone chips harvested from the surroundings. It is striking that the peri-implant conditions after $1\frac{1}{2}$ years of loading of the implant-supported restorations were not influenced by the presence of peri-implant bone defects immediately after implant placement. Neither were the probing pocket depths influenced by the presence of bone defects at abutment surgery. Likewise, it was not decisive for the probing pocket depths whether the defects were three-wall infrabony defects or dehiscences. The comparison between infrabony defects and dehiscences was made solely for sites buccally to the implants since only few of the other three sites were associated with dehiscences in this material. These findings indicate that peri-implant bone defects, including dehiscences, present at implant placement or three months later at the abutment connection, should not give rise to major concern regarding development of deep pockets. In contrast, the marginal bone level recorded at the 2-year follow-up was located significantly more apically at proximal implant sites, which were associated with peri-implant bone defects at the time of the abutment surgery than at those sites not associated with a bone defect. However, a marginal bone level situated 2 mm below the implant–abutment joint may be considered to be acceptable. It will be of great interest in future follow-up examinations to evaluate whether this increased loss of peri-implant marginal bone may have a clinical importance and thereby have an impact on the long-term prognosis of the implants.

An important difference between the Im and De implant placement procedures was that the delayed implants were augmented with bone chips twice in cases of dehiscences or fenestrations (at implant surgery and at abutment surgery), whereas the delayed-immediate implants were augmented only once (at abutment surgery). The rationale of performing grafting just after implant placement in the non-experimental (De) group was for ethical reasons. It is reasonable though to assume that this significant difference in treatment between the two groups may have an impact on the peri-implant conditions. However, the clinical examinations at the operations revealed that the additional augmentation treatment had no substantial effect on bone formation from implant placement to abutment surgery in the present material, since no difference in depth reduction of the dehiscences was found when comparing the Im and De groups (24% *versus* 23%) (Schropp et al. 2003a).

It can be discussed how acceptable peri-implant conditions can be achieved around implants, which were associated with infrabony defects or dehiscences of an appreciable size immediately after insertion of the implants. The present study cannot disclose the quality of the peri-implant tissues forming on the surface of such implants. A possible explanation might be that bone formation continues following abutment surgery until the defects are completely filled with bone. A second explanation could be that the exposed part of the implant becomes integrated into fibrous connective tissue. A third explanation could be that apical proliferation of junctional epithelium occurs along the exposed implant surface, thereby establishing a soft tissue seal and healthy peri-implant conditions. Eventually, probing pocket depth reduction might simply be a result of peri-implant mucosa recession. However, only few implants in the present study were associated with a visible metal margin of crown or abutment, and no implant threads were exposed, which indicates that the reduction of probing pocket depths rather was caused by integration of the initially exposed implant surfaces into peri-implant soft tissues or newly generated bone. Several investigations have been carried out regarding the biological aspects of the soft tissue seal around dental implants (Vogel 1999). However, more animal studies should be conducted to clarify healing dynamics around immediately placed implants associated with peri-implant bone defects that do not heal spontaneously.

The current study demonstrated that acid-etched, titanium, single-tooth implants placed according to a delayed-immediate or delayed surgical protocol following tooth extraction in the anterior or pre-molar regions can be predictably successful over a period of 2 years. High survival rates were achieved without severe peri-implant or prosthetic complications.

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