Immediate Loading with Complete Implant-Supported Restorations in an Edentulous Heavy Smoker: Histologic and Histomorphometric Analyses

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The clinical case presented is that of an edentulous female patient, a heavy smoker, who received implant-supported complete restorations in the maxilla and mandible using the immediate loading concept according to the Ankylos implant system. The patient received 12 commercially pure titanium (grade 2) Ankylos implants, 6 in the maxilla and 6 in the mandible. The implants were loaded immediately after surgery with temporary acrylic resin prostheses fabricated chairside using a prefabricated customized splint. The definitive ceramometal restorations were seated 4 months after surgery. Clinical and radiologic evaluation at 7 months after implant placement indicated functional bone anchorage of all implants, despite the patient being a smoker and having poor bone quality. The patient died 7 months after implant placement because of lung cancer; however, there was no known disease at the time of implant placement. After her death, the implants with the surrounding tissues were removed en bloc and examined histologically and histomorphometrically using undecalcified cut and ground sections. All implants were osseointegrated to some extent and surrounded by lamellar bone. However, around the upper, nonthreaded parts of the implants, much of the bone had been resorbed. In this region, fibrous connective tissue was in close contact with the titanium surface. Epithelial proliferation with pocket formation could not be observed in any of the implants. The histomorphometric evaluation of bone-implant contact in threads demonstrated a mean of approximately 51% of the available surface and a mean bone volume of approximately 52%, with a tendency toward greater contact and volume around the implants in the maxilla. If the nonthreaded cylindric portions of the implants were included, mean bone-implant contact was 46% and mean bone volume was 47%. INT J ORAL MAXILLOFAC IMPLANTS 2005;20:282–290

Key words: *edentulous jaws, immediate loading, primary stability*

The use of immediately loaded implants to restore edentulous jaws has been proposed by various authors.[1,2] However, such implants have failed in areas with soft bone (eg, the posterior part of the mandible), and the treatment protocol for these implants includes other limitations as well. Patients with wound healing problems, such as those with diabetes or habits of smoking or bruxing, need to be screened and probably excluded from immediate loading protocols.[1] In addition, limited data are available from human specimens regarding the osseointegration of immediately loaded implants after several years of functional loading. The data available show direct bone-implant contact of more than 46%.[3–6] The present study is unique in that it presents clinical and radiologic data on implants from different regions of the same patient, a patient who was treated according to a well-defined immediate loading protocol (ie, prostheses received on the day of implant placement). Moreover, there is a paucity of information about wound healing at the bone-implant interface in heavy smokers with immediately loaded implants.

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CLINICAL PATIENT REPORT

The patient, a 50-year-old woman, consulted the Department of Oral Surgery and Implantology, Dental School, Johann Wolfgang Goethe University, Frankfurt, Germany, for a new prosthetic restoration after extraction of the maxillary and mandibular teeth precipitated by advanced periodontal disease. The patient expressed interest in a fixed, implant-supported prosthesis. She was a heavy smoker (more than 10 cigarettes per day for a period longer than 10 years) but seemed generally healthy. She was examined clinically and radiographically and was advised to smoke less or stop smoking before receiving implant therapy. Because her job as a stewardess required her to travel overseas frequently, immediate loading using the Ankylos implant system (Friadent, Mannheim, Germany) was recommended.[7]

Impressions of the maxilla and mandible were made with alginate and the maxillomandibular jaw relationships were recorded to enable the fabrication of 2 complete dentures. Customized surgical guides were fabricated in acrylic resin after duplication of the complete dentures. In addition, a splint was designed using elastic foil for the fabrication of temporary fixed restorations to be placed after implant surgery.

After a midcrestal incision under local anesthesia, mucoperiosteal flaps were elevated in the maxilla and mandible and 12 Ankylos implants 11 mm long and 3.5 mm in diameter were placed at the sites of teeth 5(14) to 7(12), 10(22) to 12(24), 21(34) to 23(32), and 26(42) to 28(44). The bone quality was very poor (class 3 or 4 according to Lekholm and Zarb).[8] Parallelism of the placed abutments was examined using primary resin abutments placed on the implants during surgery and immediately after removal of the cover screws. The temporary abutments were replaced with standard abutments for the Ankylos implant system and fixed in place with controlled torque (15 Ncm for angulated abutments and 25 Ncm for straight abutments, in keeping with the protocol for this system). Periotest values were recorded to evaluate implant stability immediately after placement, 4 months after placement, and 7 months after placement. The flaps were sutured, and temporary fixed restorations were fabricated chairside using a customized splint and Protemp resin material (Espe, Seefeld, Germany). The temporary restorations had symmetrical contacts in centric occlusion, maintaining the predetermined vertical dimension of occlusion (Figs 1 and 2).

A soft diet was advised for the first 6 to 8 weeks of healing. The definitive ceramometal implant-supported fixed restorations were placed and temporarily cemented 4 months after loading. Because of functional, esthetic, and phonetic considerations, a cantilever of 2 teeth was used in the mandible and of 1 molar at each side in the maxilla (Fig 3). Seven months after implant placement and loading, the patient was re-examined because the prosthesis was loose. The peri-implant tissues were examined clinically and radiographically at this visit, and clinical measurements were performed. All implants were clinically stable, the soft tissues appeared healthy, and no bone loss could be observed radiographically in comparison to the baseline measurements (Fig 4).

At this time the patient was hospitalized because of severe lung cancer ($T_4N_3M_1$, stage 4 bronchial carcinoma). After discussions with the patient concerning the severity of her disease, as well as consultation with her oncologist, chemotherapy without surgical intervention was suggested. The patient decided to donate her implants with surrounding tissues en bloc for postmortem histologic examination. The prostheses were luted with Temp-bond cement material (Kerr, Karlsruhe, Germany), and the patient was transferred to the hospital.

During hospitalization in the Clinic for Internal Medicine for the scheduled chemotherapeutic treatment, a septic fever with significant increase in inflammatory blood indices was diagnosed. To control the bacteremia, antibiotics were administered systemically. Further chemotherapeutic treatment was postponed for 1 week, when an additional high fever attack was seen. The patient was not able to accept any further chemotherapeutic agents, and only acute symptomatic interventions were performed. Computerized tomography did not show any significant reduction of the tumor in the right lung. The patient died 2 weeks later (3 months after diagnosis).

SAMPLE PREPARATION

Several hours postmortem the implants were removed with their surrounding tissues using a surgical handpiece and a Lindemann bur under cooling with sterile saline. Four blocks (1 from each quadrant) containing 3 implants each were prepared (Fig 5) and examined radiographically. Cut and ground sections were then prepared for histologic and histomorphometric examinations.

The 4 block samples were immersed in 4% buffered formaldehyde solution for about 72 hours before transportation to the laboratory. Specimen handling and preparation followed the internal guidelines at the Biomaterials/Handicap Research Laboratories regarding processing samples with

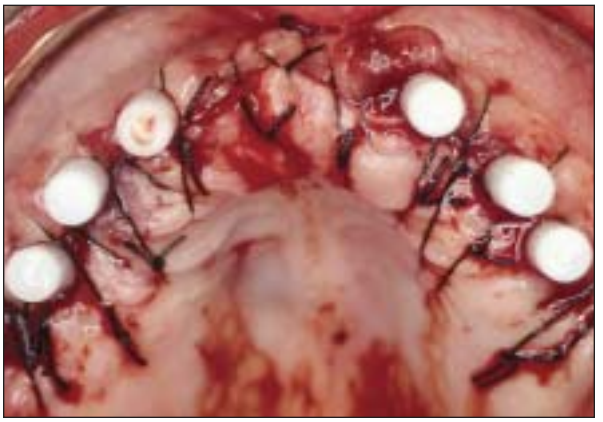


Fig 1a Implant placement in the maxilla according to a surgical guide.

Fig 1b Implant placement and abutment connection in the mandible.

Fig 2a The provisional prosthesis in occlusion.

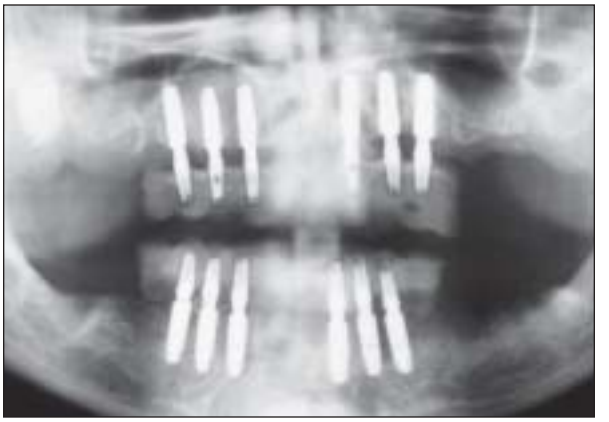


Fig 2b A radiograph obtained immediately after surgery.

implants in situ to create undecalcified cut and ground sections. For this purpose, the laboratories are equipped with the Exakt cutting and grinding system with necessary utilities (Exakt Apparatebau, Norderstedt, Germany).

Upon the arrival of the specimens at the laboratory, they were immersed in new 4% neutral buffered formaldehyde solution for 2 days. They were then dehydrated in a graded series of ethanols, infiltrated in a combination of diluted and pure resin, embedded in pure resin (Technovit; Kulzer, Wehrheim, Germany), and polymerized in a light polymerization unit. Each implant, still surrounded by bone tissue, was divided along its long axis using a band saw. The sample surfaces were ground parallel, mounted, and fixed on an acrylic plastic sheet. All 3 implants from each quadrant were mounted in a row that resembled the in vivo placement. Two ground sections were prepared from each quadrant. The initial thickness of the sections was about 200 µm. These sections were ground to 100 µm and observed using microradiography. The sections were then ground to approximately 10 µm according to the techniques described by Donath and Breuner,[9] Donath,[10] and Johansson and Morberg.[11]

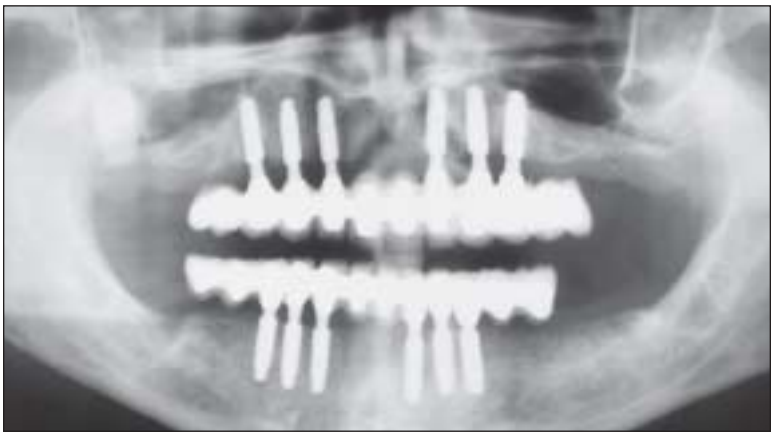
Finally, the sections were stained with 1% toluidine blue mixed with pyronin G and with a modified basic fuchsin staining (Levai-Laczko). The sections were then covered with slip covers and examined using light microscopy.

HISTOMORPHOMETRIC ANALYSIS

The histomorphometric investigation was conducted using a Leitz Aristoplan light microscope (Leitz, Wetzlar, Germany) equipped with a Microvid System (Leitz), which enabled computer-based morphometric measurements directly in the eyepiece of the microscope. All measurements were performed with lenses of 10× magnification and a zoom of up to 2.5× magnification. Bone-implant contact, bone area


Fig 3 The definitive restoration in occlusion (dental technique: M. Funk, CDT).


Fig 4 Excellent peri-implant tissue conditions in both *(above left)* the maxilla and *(above right)* the mandible 7 months postloading. *(Right)* A radiograph showing the definitive restoration in place; no bone loss can be seen around the implants.



inside the threads, and bone area immediately outside the inner threads (mirror image) were calculated for each implant.[12] The results had the potential to reflect the remodeling stage of the tissue; eg, a 1:1 ratio of bone in the inner area to bone in the outer area could reflect a balanced healing situation; a ratio of 1:2 (ie, less bone inside than outside) could reflect ongoing remodeling and incomplete bone turnover. Mean values, standard deviations, and ranges were calculated and presented for each individual implant. Means were also calculated for maxillary and mandibular implants as groups.

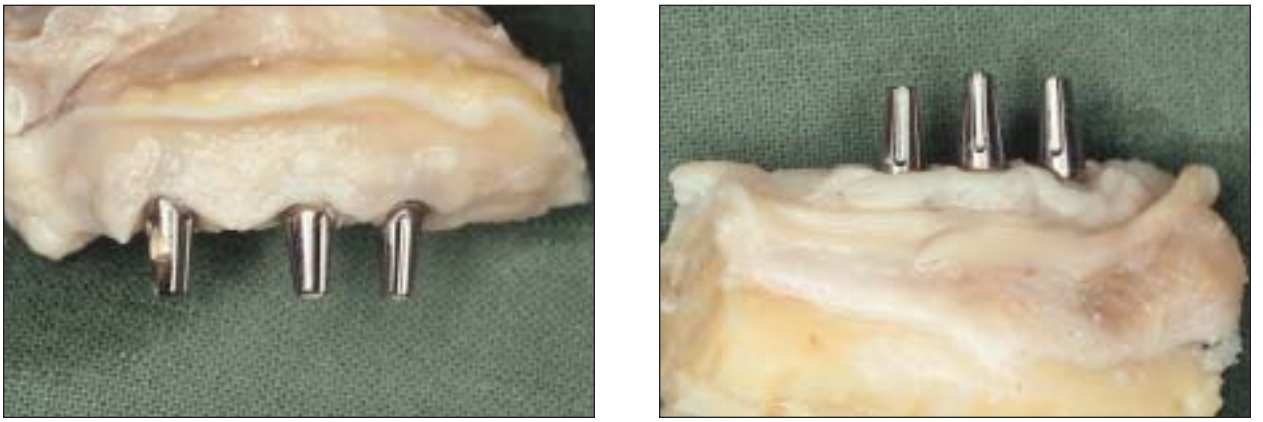


Fig 5 Postmortem preparation of *(left)* the left quadrant of the maxilla and *(right)* the right quadrant of the mandible.

Table 1 Periodontal Indices

	Implant placement	Prosthesis placement	Follow-up (7 mo)
PI	0.9 ± 0.79	0 ± 0	0 ± 0
SBI	1.33 ± 0.65	0 ± 0	0.08 ± 0.28
PPD(b) (mm)	1.41 ± 0.51	2 ± 0	2.75 ± 0.45
PPD(m) (mm)	2 ± 0.85	1.58 ± 0.51	1.91 ± 0.28
KM (mm)	5.08 ± 0.99	4.66 ± 1.07	3.5 ± 0.52

PI = modified Plaque Index[13]; SBI = Sulcus Bleeding Index; PPD(b) = probing pocket depth at the buccal side of the implant; PPD(m) = probing pocket depth at the mesial side of the implant; KM = keratinized mucosa.

Table 2 Periotest Values from Baseline to 7 mo Postloading

Area no.	PV0	PV1	PV2
Maxilla			
5 (14)	7	5	2
6 (13)	5	4	2
7 (12)	6	4	1
10 (22)	5	3	1
11 (23)	3	5	3
12 (24)	3	3	0
Mean ± SD	4.83 ± 1.22	4.0 ± 0.66	1.5 ± 0.83
Mandible			
21 (34)	−3	−2	−3
22 (33)	−2	−3	−4
23 (32)	−2	−1	−3
26 (42)	−4	−4	−4
27 (43)	−3	−3	−4
28 (44)	−1	−4	−4
Mean ± SD	−2.50 ± 0.83	−2.83 ± 0.86	−3.66 ± 0.44
Total	1.16 ± 3.66	0.58 ± 3.41	−1.08 ± 2.58

PV0 = Periotest value at the time of implant placement and loading (baseline); PV1 = Periotest value at the time of the placement of the definitive restorations (4 mo postloading); PV2 = Periotest value at the final examination (7 mo postloading).

RESULTS

The peri-implant clinical indices showed a periodontally healthy condition, as demonstrated in Table 1. The Periotest results are summarized in Table 2. The radiographic examinations revealed bone defects between the implants in the maxilla as well as in the mandible, as can be seen in Fig 4c. The histomorphometric results are summarized in Table 3. Irrespective of parameters evaluated (bony contact, bone area, and mirror image), the mean values were similar in the maxilla and the mandible. The mean percentage of within-thread bony contact for the maxillary samples was 53%, compared to 48% for the mandibular samples. The mean percentages of bony contact around the entire implant (including the crestal nonthreaded portion of the implant) were 48% for maxillary samples and 44% for mandibular samples. The mean bone area inside the threads was 53% for the maxillary samples and 50% for mandibular samples. With respect to the mirror images, more bone could be seen outside the implants placed in the maxilla (58% vs 50% in the mandible), while there was no difference between within-thread and outside-the-thread areas (ie, mirror-image areas) in the mandible (50% for both).

Qualitative Analysis

Figures 6 to 10 demonstrate light microscopic pictures of the cut and ground sections being microradiographed (Figs 6a and 7a) and later stained with toluidine blue for light microscopy. In general, the implants placed in both the maxilla and the mandible demonstrated bone pockets (soft tissue areas around the unthreaded part of the implant) of different degrees. These bony pockets were clearly visible on microradiographs (Figs 6a and 7a) as well as on histologically stained sections (Figs 6b and 7b).

Table 3 Percentage of Bony Contact Determined by Histomorphometric Examination

	BIC—threads only		BIC—threads + upper cylinder		Inner area		Mirror image	
Quadrant	Mean (%)	Range	Mean (%)	Range	Mean (%)	Range	Mean (%)	Range
Maxillary right (n = 3)	44 ± 9	34–51	40 ± 8	31–46	52 ± 6	45–57	60 ± 8	57–67
Maxillary left (n = 3)	62 ± 4	58–65	55 ± 4	52–59	54 ± 9	43–59	57 ± 3	54–60
Mandibular left (n = 3)	46 ± 7	39–53	42 ± 7	35–48	48 ± 9	40–57	48 ± 22	26–70
Mandibular righ (n = 3)	51 ± 9	42–59	47 ± 8	38–53	52 ± 7	44–57	52 ± 10	40–58
Maxilla (n = 6)	53 ± 11	34–65	48 ± 10	31–59	53 ± 7	43–59	58 ± 5	52–67
Mandible (n = 6)	48 ± 8	39–59	44 ± 7	35–53	50 ± 7	40–57	50 ± 15	26–70

BIC = bone-implant contact.

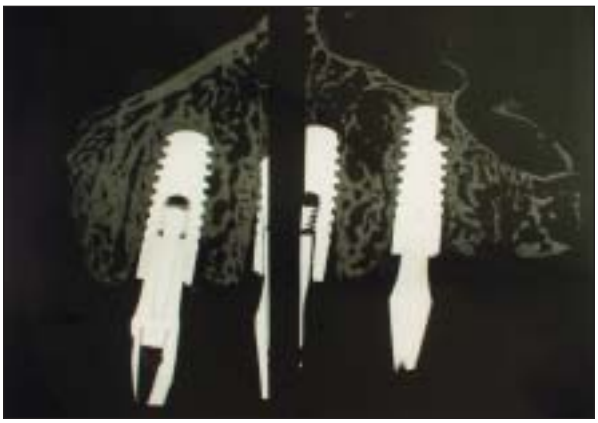


Fig 6a Microradiographic examination of the maxillary implants demonstrated osseointegration 7 months after immediate loading. Small bony pockets were seen at the crestal aspect of some implants (original magnification ×1.3).

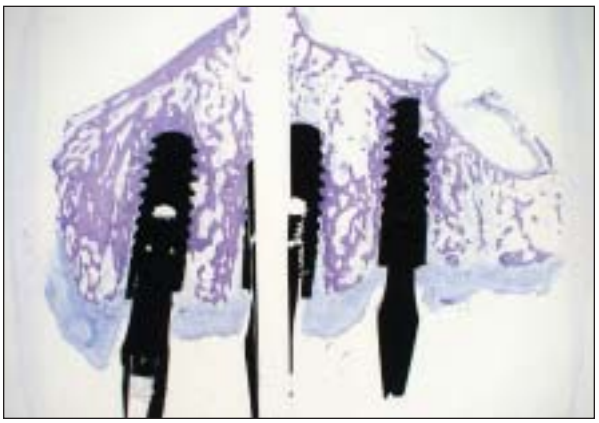


Fig 6b An undecalcified cut and ground section of the implants shown in Fig 6a (toluidine blue; original magnification ×1.3).

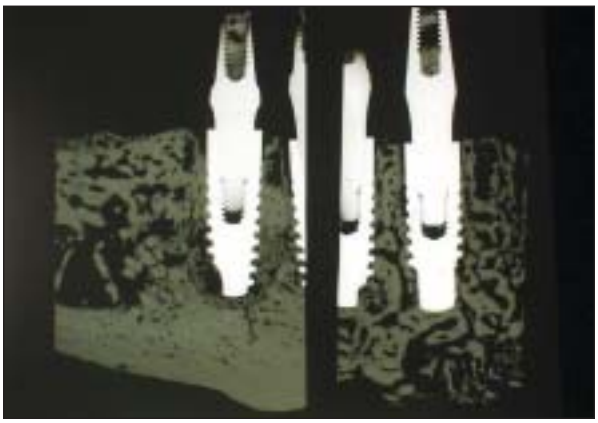


Fig 7a Microradiographic examination of the mandibular implants showed integration with the alveolar bone without soft tissue formation at the interface 7 months after loading. Small bony pockets can be seen at the crestal aspect of the implants (original magnification ×1.3).

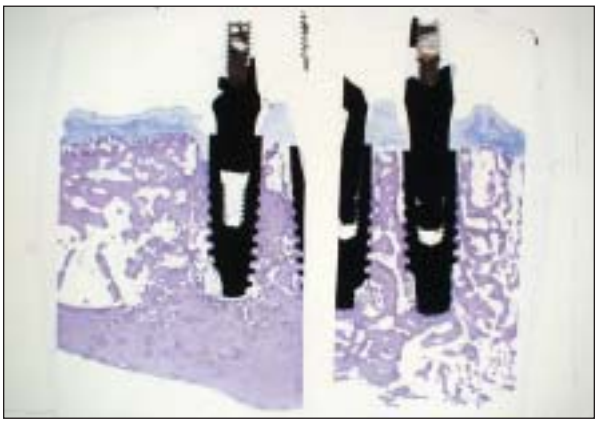


Fig 7b Undecalcified cut and ground section of the implants shown in Fig 7a (toluidine blue; original magnification ×1.3).

The alveolar crest was characteristically filled by bone marrow, and no crestal cortical bone plate could be observed, which allowed these spaces to be open for supracrestal soft tissue. The implants were osseointegrated to some extent and were surrounded by mostly lamellar-type bone. However, much of the bone was not remodeled, especially around the upper, nonthreaded part of the implants (hence the presence of bony pockets). In this region, fibrous connective tissue was in close contact with the titanium surface, but no epithelial migration was found (ie, there was no deep pocket formation).

Maxillary Implants. All implants in the maxilla were osseointegrated to some extent. Incomplete mineralized bone filled some of the implant threads. In some areas, soft connective tissue surrounded the crestal part of the implant without any epithelial proliferation and with only very small pocket formation. Only small single blood vessels and single macrophages were found. Fibrous connective tissue and fat tissue covered the apical portions of some implants. Some areas with deeper bony pocket formation, ie, areas where there had been much bone resorption, also showed epithelial proliferation. In the crestal peri-implant bony defects, fibrous connective tissue with remnants of vital bone was found; the collagen fibers were oriented parallel to the implant surface. Cell debris and leukocytes could be observed in these areas. Single lymphocytes infiltrated the lamina propria. The vascularization was higher in the bone marrow spaces. One implant was placed in direct contact with the sinus mucosal membrane. In this case, the titanium surface in contact with the sinus membrane was covered by collagen fibers.

Mandibular Implants. All implants had some direct bone contact. The peri-implant bone presented numerous osteocytes and was lamellar in organization. Large areas consisting of bone particles (especially in apical areas) were observed around some implants. These bone particles were probably remnants from the bone-bed preparation. The bone was less mineralized or even not remodeled. Peri-implant bony pockets completely filled by soft connective tissue were found without epithelial proliferation. The soft tissue contained blood vessels coming from the bone marrow, lymphocytes, macrophages, and bone particles.

The connective tissue adjacent to the implant surface was collagen rich. Parallel-oriented fibers and bundles as well as blood vessels were found. Single macrophages filled the bone-free areas of the implants. The peri-implant soft tissue was not inflamed. The epithelium was proliferated only on the abutment surface and did not reach the implant top. The adjacent connective tissue (lamina propria) was infiltrated by lymphocytes and macrophages.

DISCUSSION

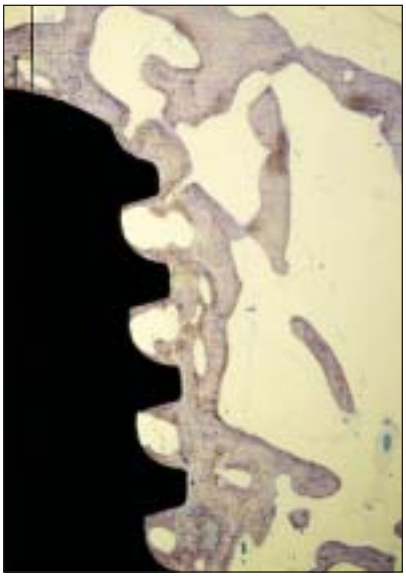
Clinical, histologic, and histomorphometric data were presented from 12 implants placed in poor-quality bone in the maxilla as well as in the mandibular symphysis of the same patient. These implants were immediately loaded with temporary prostheses fabricated chairside to connect and immobilize the implants immediately after surgery. The placed implants were primarily stable and revealed low Periotest values immediately after surgery. However, the mobility values decreased with increased loading time, indicating better implant integration as time passed. The patient was advised to adhere to a soft diet for the initial healing period to avoid excessive loading. Cantilevers were not used in the transitional fixed prostheses but only in the definitive fixed restorations.

Survey examinations of the cut and ground sections revealed mostly spongy-type bone with large marrow spaces around the lower two thirds of the implants. Soft tissue areas were frequently observed around the upper nonthreaded parts of the implants. The bone surfaces at this level were undergoing some resorption.

The histomorphometric data, which was in agreement with the qualitative evaluation, demonstrated that bony contact in maxillary and mandibular implants was similar (48% for maxillary implants vs 44% for mandibular implants). Whether these values indicate "good" or "poor" integration of the implants is unknown. There is no consensus about the amount of bone contact needed for a clinically stable implant. However, it has been demonstrated that bone tissue encapsulation of implants will increase with time.[14]

Bone area formed inside the implant threads was about 52% for both the maxilla and the mandible. Generally, more bone had formed in the outer mirror-image areas than inside the threads in maxillary implants but not in mandibular implants. The fact that less bone was found inside the threads than in the mirror-image areas may indicate that the bone area inside the threads was not fully remodeled. One can only speculate as to whether this is related to the short healing time or to host tissue factors, ie, smoking, the impact of immediate loading in a poor bone bed, the chemotherapy, or a combination of these parameters.

Further clinical studies should be performed using this treatment concept in edentulous jaws with poor bone quality as well as in patients who are heavy smokers so as to establish the efficacy of this loading protocol under similar conditions in daily practice.



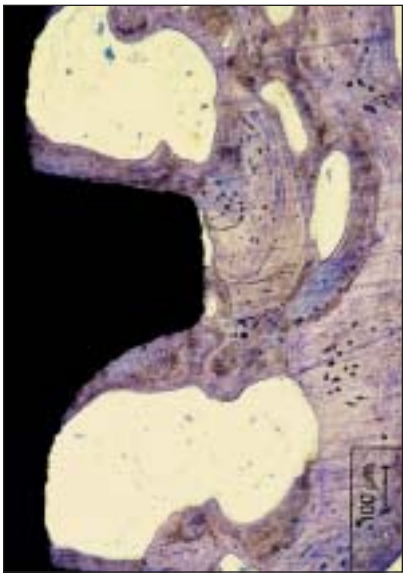
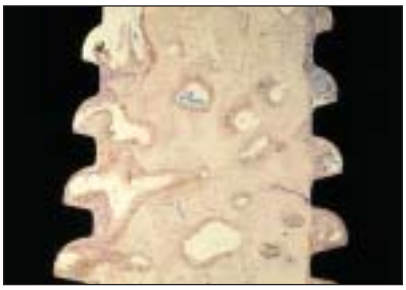
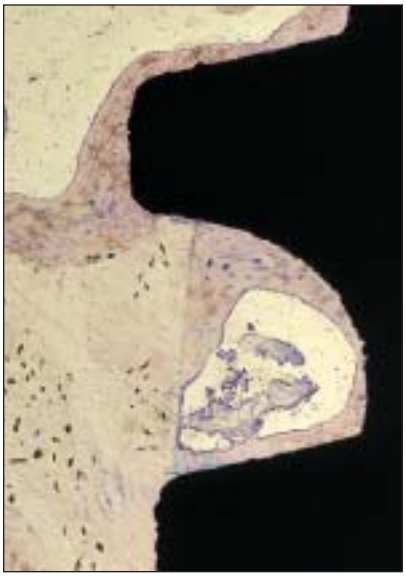


Fig 8 Histologic examination of a maxillary implant. *(Left)* Direct bone contact with the titanium surface was found, and there was new formation of high-vitality bone at the thread top *(dark staining)*. *(Right)* Less mineralized bone was found in the valleys of the threads. Bar = 100 µm (toluidine blue; original magnification ×5.6 and ×20).





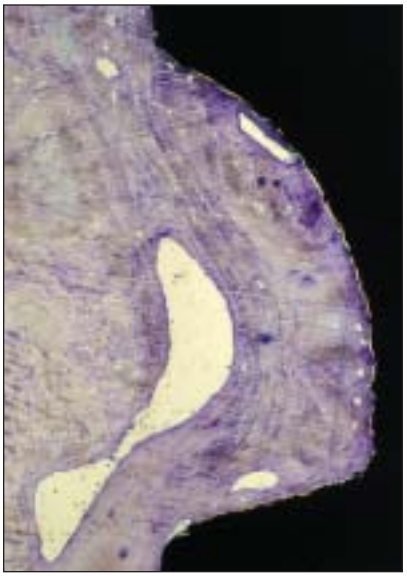
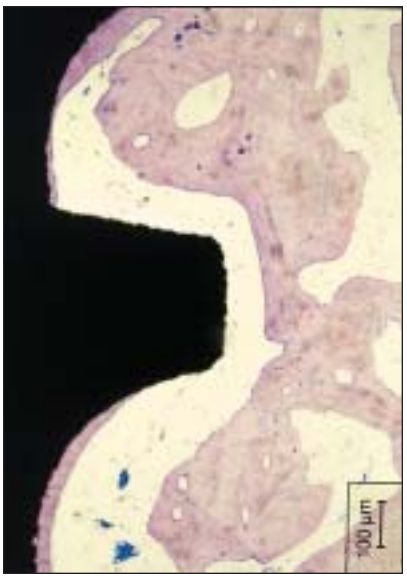


Fig 9a *(Above left)* An interimplant area demonstrating implant integration in the alveolar bone of the mandible. The implants had direct bone contact. In the lower (apical) part of the implants, more compact bone can be seen, whereas in the middle, the bone is more cancellous (toluidine blue; original magnification ×2.3).

Fig 9b *(Above center)* Higher magnification of the implant shown in Fig 9a. The layer of bone in direct contact with the implant had a wallpaperlike or carpetlike appearance and contained a high number of osteocytes. Stainable material (new bone formation) was found between the implant and bone (toluidine blue; original magnification ×20).

Fig 9c *(Above right)* Higher magnification of a mandibular implant. New bone formation *(dark staining)* can be seen in the valley between the threads. The new bone was lamellar in organization (toluidine blue; original magnification ×25).

Fig 10 *(Right)* Bone lining the surface of a mandibular implant. The surrounding tissue was covered by fibrous connective tissue and fat tissue. Bar = 100 µm (toluidine blue; original magnification ×20).



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