Immediate Loading of Tapered Implants Placed in Postextraction Sockets and Healed Sites

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Objective: The aim of the present study was to compare the survival, stability, and complications of immediately loaded implants placed in postextraction sockets and healed sites.

Methods: Over a 2-year period, all patients presenting with partial or complete edentulism of the maxilla and/or mandible (healed site group, at least 4 months of healing after tooth extraction) or in need of replacement of nonrecoverable failing teeth (postextraction group) were considered for inclusion in this study. Tapered implants featuring a nanostructured calcium-incorporated surface were placed and loaded immediately. The prosthetic restorations comprised single crowns, fixed partial dentures, and fixed full arches. Primary outcomes were implant survival, stability, and complications. Implant stability was assessed at placement and at each follow-up evaluation (1 week, 3 months, and 1 year after placement): implants with an insertion torque (IT) <45 N·cm and/or with an implant stability quotient (ISQ) <70 were considered failed for immediate loading. A statistical analysis was performed.

Results: Thirty implants were placed in postextraction sockets of 17 patients, and 32 implants were placed in healed sites of 22 patients. There were no statistically significant differences in ISQ values between the 2 groups, at each assessment. In total, 60 implants (96.8%) had an IT $\geq$45 and an ISQ $\geq$70 at placement and at each follow-up control: all these implants were successfully loaded. Only 2 implants (1 in a postextraction socket and 1 in a healed site, 3.2%) could not achieve an IT $\geq$45 N·cm and/or an ISQ $\geq$70 at placement or over time: accordingly, these were considered failed for stability, as they could not be subjected to immediate loading. One of these 2 implants, in a healed site of a posterior maxilla, had to be removed, yielding an overall 1-year implant survival rate of 98.4%. No complications were reported. No significant differences were reported between the 2 groups with respect to implant failures and complications.

Conclusion: Immediately loaded implants placed in postextraction sockets and healed sites had similar high survival and stability, with no reported complications. Further long-term studies on larger samples of patients are needed to confirm these results.

Key Words: Complications, healed sites, immediate loading, postextraction sockets, stability, survival

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Dental implants have proven to be a predictable modality for replacing missing or failing teeth with various types of fixed dental prostheses, and more than 30 years of evidence on the clinical use of endosseous implants has revealed satisfactory long-term results.[1,2] Traditionally, dental implants have been placed in a 2-stage protocol, with a submerged healing period of 4 to 6 months.[3] This load-free healing period was considered necessary to obtain mineralized bone at the bone–implant interface, before second-stage surgery, and prosthesis placement.[3] In fact, it was originally believed that applying force to the implant during the critical healing period might cause micromotion at the bone–implant interface, which could result in fibrous encapsulation and implant failure.[3]

Though associated with highly successful outcomes,[4,5] these traditional protocols led to long treatment times, multiple surgeries, and the discomfort and embarrassment of wearing removable prostheses during transition.[6] As a consequence, patients asked for fewer surgical interventions and shorter healing periods prior to loading, and the traditional protocols for placing and loading oral implants were revised to meet these demands.[6] Moreover, the need to wait before loading an implant was not scientifically based, but rather clinically based;[6] it was therefore justifiable to question whether this extended healing period is an absolute prerequisite to obtain osseointegration or if, in certain circumstances, this period could be shortened without jeopardizing the success of the implant.[6] For these reasons, the first clinical and experimental investigations were initiated to evaluate whether healing and osseointegration could be achieved under functional loading,[7,8] and the concept of immediate loading was introduced.[6–8]

Several definitions of immediate loading have been offered by many research teams, as have different opinions regarding the indications and procedures for clinical success;[6,9,10] however, implants are generally defined as "immediately loaded" if they are restored by a functional, fixed interim prosthesis that is placed into occlusion with opposing teeth or implants at the time of implant placement or within 48 to 72 hours after insertion.[6,9,10] Immediate loading reduces the overall treatment time, avoids a second-stage surgery, and offers immediate comfort for patients, as there is no need for a removable prosthesis during the healing phase.[6,9,10]

To date, the concept of loading implants immediately after placement has gained popularity among patients and clinicians.[9,10] Several studies have reported that, under optimal conditions, satisfactory predictable outcomes can be achieved with immediate loading of different types of fixed implant-supported restorations.[11–13]

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More recently, surgical protocols that include immediate implant placement and loading have been introduced.[14,15] The rationale for the immediate placement is that it avoids an interim healing phase with removable prosthesis, further reduces the number of clinical interventions, and decreases treatment time.[14–16] On the other hand, the risk of complications and failure may be higher, because after this surgical protocol it can be difficult to achieve adequate primary implant stability.[17–21] Primary implant stability, defined as the biometric stability achieved immediately after implant insertion, is a fundamental requirement for successful implant osseointegration and function.[18–21] If substantial primary stability is not achieved at implant placement, immediate loading might induce micromotion, resulting in fibrous encapsulation of the implant and failure to osseointegrate.[18–21] Although primary implant stability is a prerequisite for success when implants are immediately loaded in healed sites,[11–13] it may be even more important when implants are loaded in postextraction sockets, particularly in the posterior regions, which involve challenges related to anatomic, occlusal, and biomechanical factors.[20–24]

Until now, few studies have investigated the possibility of immediately loading implants in fresh extraction sockets,[22,23] and even fewer have compared the outcomes of immediately loaded implants placed in postextraction sockets and healed sites.[16,24–30] Therefore, the aim of the present prospective, single-center clinical study was to compare the survival, stability, and complication rates of immediately loaded implants placed in postextraction sockets and healed sites.

METHODS

Patient Selection

Over a 2-year period (June 2012–June 2014), all patients referred to a single private dental clinic (EasyPlant Dental Clinic, Gwangju, South Korea) for treatment with oral implants were considered for inclusion in this study on the basis of the following criteria:

- Partial or complete edentulism of the maxilla and/or mandible (with a period of edentulism of at least 4 months) or need for replacement of nonrecoverable failing teeth at the time of recruitment
- Age at least 18 years
- Good systemic and oral health
- Sufficient residual bone volume to allow placement of an implant at least 7 mm long and 3.5 mm in diameter
- Dentition in the opposing jaw to obtain occlusal contacts
- Ability to sign an informed consent form.

Patients were excluded from this study in the presence of any of the following:

- Severe systemic diseases that would not allow a surgical intervention
- Uncontrolled diabetes mellitus
- Immunocompromised status
- Radiotherapy in the maxillofacial region
- Chemotherapy
- Treatment with oral and/or intravenous amino-bisphosphonates
- Heavy smoking habit ($\geq$10 cigarettes/day)
- Bruxism or parafunctional habits
- Alcohol abuse
- Psychological disorders
- Pregnancy or lactation.

Patients were advised that smoking is associated with an increased risk of implant failure.[31] Bruxers were patients with repetitive jaw muscle activity characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible.[32] Bruxism was diagnosed on the basis of patients' questionnaires, clinical examination, and electromyography.[32] Information was given to each patient regarding alternative treatment options, such us more traditional therapies (including fixed partial dentures on natural teeth or implants with a delayed loading protocol). All participants received a thorough explanation of the planned treatment and its potential risks and complications, and signed a written informed consent form prior to being enrolled in the study. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki on clinical research involving human subjects, 1975, as revised in 2008, and was approved by the local ethics committee.

Preoperative Assessment

Prior to implant placement, each patient was investigated clinically and radiographically. Panoramic and periapical radiographs formed the basis of the primary investigation; cone beam computed tomography scans were used as the final investigation, when necessary, to assess more accurately the bone volume available for implant placement. Cone beam computed tomography data sets were acquired and subsequently transferred to specific implant navigation software (R2Gate; MegaGen Implant, Gyeongbuk, South Korea) to perform a three-dimensional reconstruction of the edentulous ridges. With this navigation software, it was possible to correctly assess the width of each implant site and the thickness and density of the cortical plates and cancellous bone, as well as the ridge angulations. The preoperative workup also included an assessment of the ridge anatomy using casts and diagnostic wax-up to provide the clinician with a better understanding of the patient's prosthetic needs.

Implant Design and Surface Characterization

The implants used in this study (AnyRidge; MegaGen Implants) were characterized by a tapered design with strong self-cutting threads (Knifethread) to ensure high initial stability in the immediate loading protocol.[13] These implants had an internal hexagon combined with a 5-mm-deep conical connection (10°), providing a tight seal and high mechanical strength, with built-in platform switching designed to maintain crestal bone and increase soft tissue volume. The implants featured a nanostructured calcium-incorporated surface (Xpeed).[33] The implants for the study were available in lengths of 7, 8.5, 10, and 11.5 mm; the available diameters were 3.5, 4, 4.5, 5, 6, and 7 mm.

Surgical Procedures

All patients underwent professional oral hygiene treatment prior to implant insertion and were instructed to rinse with a 0.12% chlorhexidine mouthwash for 1 minute, twice a day, starting 2 days before the intervention. Patients were administered prophylactic antibiotics (amoxicillin 2 g, 1 hour before surgery). All surgical procedures were carried out by a single, experienced operator (C-HH), according to a 1-stage (nonsubmerged) surgical protocol.

Local anesthesia was achieved using 4% articaine hydrochloride with epinephrine 1:100,000 (Septanest; Septodont, Saint-Maur-des-Fossés Cedex, France).

For extraction sockets, a flapless approach was used. The failing teeth were extracted as atraumatically as possible, to preserve the buccal alveolar bone. Sockets were debrided of any remaining granulation tissue with an excavator and irrigated with sterile saline. Subsequently, implant sites were prepared according to

the manufacturer's instructions. Selection of the final drill size was based on bone quality, evaluated by radiographic assessment, according to the criteria of the Lekholm and Zarb index[34] and, at drilling, according to the clinician's judgment.[5] Profuse saline irrigation was used throughout the drilling procedure. As a general role, implants were placed in underprepared osteotomies, and socket preparation was deepened beyond the alveolar apex, to engage the apical bone; remaining gaps between the implant and the surrounding bone >2 mm were filled with autogenous bone or freeze-dried bone allograft (FDBA; Megaoss, MegaGen Implant).

For healed ridges, a minimal crestal incision was performed to access the sites. After reflection of a full-thickness flap, osteotomy was initiated with a 2.0-mm drill to the desired depth under profuse saline irrigation; the implant site was then prepared as suggested by the implant manufacturer. Selection of the final drill size was based on the aforementioned criteria,

For both extraction sockets and healed ridges, surgeons were free to choose implant lengths (7, 8.5, 10, and 11.5 mm) and diameters (3.5, 4.0, 4.5, 5, 6, and 7 mm), according to clinical indications. A torque of 50 N·cm was set for insertion of the implants; if the machine-driven insertion was discontinued because of high insertion torque, then the last threads were placed with a manual wrench. On the other hand, in patient of a final insertion torque <45 N·cm, the implant could not be immediately loaded and was therefore considered failed for immediate loading. All implants were inserted slightly below the crestal bone level, and their stability was checked clinically as the absolute absence of axial or rotational movement on removal of the implant driver without use of the stabilizing wrench. Finally, implant stability was measured by resonance frequency analysis (RFA) with a dedicated instrument (MegaISQ; Integration Diagnostics, Goteborg, Sweden).[35] This portable instrument emits magnetic pulses to a small magnet (Smartpeg) screwed directly on the implant with 5 N·cm; the magnet starts to vibrate, and the probe listens to the tone and translates it to an implant stability quotient (ISQ) value.[35] Implant stability quotient values range from 1 (minimum stability) to 100 (maximum stability).[35] For each implant, 2 measurements were made (buccal and palatal sites); the mean of all measurements was rounded to a whole number and regarded as the final ISQ of the implant. For ISQs <70, implants were not considered stable enough to be loaded and were considered failed for immediate loading.

Postoperative medications included antibiotics (amoxicillin plus clavulanic acid 500 mg every 8 hours for 5 days) and analgesics (ibuprofen up to 600 mg every 8 hours). After surgery, patients were given detailed instructions to rinse their mouth with 0.12% chlorhexidine mouth rinse, 3 times daily. Patients were advised to eat a soft diet during the first weeks to reduce excessive loading forces at the bone–implant interface.

Prosthetic Procedures

Pickup impressions were taken immediately after surgery or the following day. Temporary fixed restorations (single crowns [SCs], fixed partial dentures, and fixed full arches) were fabricated in acrylic resin and delivered within 72 hours of implant placement. All temporary restorations were screw-retained, with a hole created in the direction of the long axis of the implant to fit the abutment and the prosthetic screw. The occlusion was checked with articulating papers (Bausch Articulating Papers; Bausch, Nashua, NH). As previously described,[13] the provisional restorations were carefully contoured and polished to provide correct emergence profiles (slightly flat or concave on interproximal and palatal sides and slightly convex on the buccal aspect to support the soft tissues), adaptation to the gingival tissues, scalloped gingival architecture, and appropriate support to the interdental papillae. In particular, in the extraction socket group, the contours of the temporary restorations were designed to mimic the original tooth form, sealing the socket and maintaining clot formation subgingivally. This kind of morphology provided support for the labial gingiva. Finally, the provisional restorations were screwed to the implants, and the occlusal holes were closed with Teflon flowable resin composite. Where possible, temporary restorations were adjusted with light occlusal marks so that the occlusal surfaces were in slight static contact with the opposite dentition, but were not in contact in lateral movements. Temporary restorations were replaced with definitive restorations 3 months after surgery. Definitive restorations were metal–ceramic or full ceramic, depending on the clinical indication. All definitive restorations were carefully evaluated for proper occlusion, and protrusion and laterotrusion were assessed on the articulator and intraorally. Maintenance care was provided every 6 months. All patients were enrolled in a recall program.

Outcome Measures

Follow-up evaluations were conducted 1 week, 3 months (at the time of delivery of the final restoration), and 1 year after implant placement. During each follow-up visit, a clinical assessment of the implant, peri-implant tissues, and prosthesis was carried out by the same experienced operator (C-HH) who placed the implants. The following outcome measures were recorded.

Implant Survival

All implant losses were categorized as failures. Failure to osseointegrate with implant mobility in the absence of clinical signs of infection; persistent/recurrent peri-implant infection (with pain, suppuration, bone loss); progressive severe marginal bone loss in the absence of infection; and implant body fracture were the conditions for which implant removal could be indicated. A distinction was made between "early" (before the abutment connection) and "late" (after the abutment connection) implant failures.

Implant Stability

Insertion torque (IT) and RFA were used as methods for measuring implant stability. An IT of 50 N·cm was set at placement of the implants; if the machine-driven insertion was discontinued because of high IT, then the last threads were placed with a manual wrench. However, if the final IT was <45 N·cm, the implant could not be immediately loaded and was considered failed for immediate loading. As previously described, RFA was used to measure the stability of each implant, immediately after implant placement, 1 week later, 3 months later (at delivery of the final restoration), and at the 1-year follow-up examination.[35] After that, abutments were repositioned and screwed on the implants so that the prostheses could be reinserted. In general, the acceptable stability range is 55 to 85 ISQ; however, in the present study, in the case of ISQ values <70, implants could not be immediately loaded and were considered failed for immediate loading.

Biological Complications

Biological complications included pain or swelling after surgery; soft tissue inflammation, pain, or swelling, with no peri-implant bone loss (peri-implant mucositis); peri-implant infection with fistula formation, pain, suppuration or exudation, discomfort on occlusion, and advanced peri-implant bone loss (peri-implantitis) and peri-implant bone loss >1.5 mm after the first year of function, or >0.2 mm each following year, without any clinical sign of infection. Peri-implant mucositis was indicated by the presence of bleeding on probing and/or suppuration, associated with a probing depth ≥4 mm but with no evidence of radiographic bone loss beyond bone remodelling; the threshold for diagnosis

of peri-implantitis was a probing depth ≥4 mm, bleeding on probing, and/or pus secretion associated with evidence of radiographic bone loss (>2.5 mm).[36] The assessment of biological complications included identification of any complications that had affected the implant-supported restorations over the 1-year follow-up period.

Prosthetic Complications

Prosthetic complications were divided into mechanical complications (failures or complications of prefabricated implant components, such as abutment loosening and abutment fracture) and technical complications (superstructure-related failures or complications, such as decementation/loss of retention, ceramic fracture/chipping, and fracture of the metallic framework of restoration).[5] Prosthetic complications were also divided into minor complications (no treatment needed or <20 minutes chair time, eg, repositioning of a loosened abutment, recementation, polishing chipped off porcelain) and major complications (>60 minutes chair time and additional laboratory costs, eg, removal of a fractured abutment and fabrication of new restorations). Assessment of prosthetic complications included the identification of any occurrence of mechanical or technical complications over the 1-year follow-up period.

Statistical Analysis

All collected data were inserted on a sheet for statistical analysis (Excel 2003; Microsoft, Redmond, WA). Descriptive statistics were used for patient demographics, distribution of implants, types of restorations, implant survival, stability, and biologic and prosthetic complications. Absolute and relative frequency distributions were calculated for qualitative variables (implant location and position, implant length and diameter, types of prosthetic restorations), whereas means, standard deviations, medians, and confidence intervals (95% CIs) were calculated for quantitative variables (such as patient age and ISQ). The 1-year implant survival rate was calculated at the implant level. The influence of surgical protocol on implant survival and complications, as well as differences in the distribution of implants between the 2 groups (postextraction sockets versus healed sites), was investigated using Fisher exact test. The Mann–Whitney test for independent variables was used to investigate differences in ISQ values between the 2 groups (postextraction sockets versus healed sites) at different times (at placement and 1 week, 3 months, and 1 year after placement). The level of significance was set at 0.05. All computations were carried out with statistical analysis software (SAS 9.2 release; SAS Institute, Cary, NC).

RESULTS

From June 2012 to June 2014, 62 commercially pure titanium implants with a specially designed deepened thread and a nanostructured calcium-incorporated surface were placed in 39 patients (26 men, 13 women) aged 17 to 75 years (mean age, 46.4 ± 14.5 years; median, 44 years; 95% CI, 41.9–51.0 years). Only 11 implants were placed in the maxilla (17.7%); 51 implants (82.3%) were placed in the mandible. Most of the implants were placed in posterior regions: 4 were incisors (6.5%), 5 were cuspids (8.0%), 13 were premolars (21.0%), and 40 were molars (64.5%). In detail, 2 incisors, 2 premolars, and 7 molars were placed in the maxilla, and 2 incisors, 5 cuspids, 11 premolars, and 33 molars were placed in the mandible. The most frequently inserted implants were 10 mm long (38 implants, 61.3%), 11.5 mm long (17 implants, 27.4%), and 8.5 mm long (6 implants, 9.7%); the 7-mm-long implants (only 1 implant placed, 1.6%) were the least frequently used. The most frequently used implant diameter was 6 mm (23 implants, 37.1%), followed by 5 mm (15 implants, 24.2%), 4.5 mm (10 implants, 16.2%), and 4 mm (8 implants, 12.9%); the 3.5- and 7-mm-diameter implants were the least frequently used (only 3 implants placed per each diameter, 4.8%). The most frequent indication was the restoration of partially edentulous patients (24 implants, 38.7%), whereas the least frequent indication was the treatment of fully edentulous patients (16 implants, 25.8%). A total of 22 implants (35.5%) were inserted to restore single-tooth gaps. The final prosthetic restorations comprised 9 fixed partial dentures , 22 SCs, and 2 fixed full arches, each one supported by 8 implants.

Thirty implants were placed in the postextraction sockets (4 in the maxilla, 26 in the mandible) of 17 patients (13 men, 4 women; aged 17–75 years; mean: 47.5 ± 17.5 years; median: 46 years; 95% CI: 39.4–55.6 years), and 32 implants were placed in the healed sites (7 in the maxilla, 25 in the mandible) of 22 patients (13 men, 9 women; aged 26–67 years; mean: 45.6 ± 11.8 years; median: 39 years; 95% CI: 40.5–50.6). The 2 study groups were basically homogeneous with respect to sex, age, implant location, implant length, and types of prosthetic restorations (P values ≥0.05); however, the groups did differ with respect to implant position and implant diameter (P values <0.05). In fact, in healed sites, only premolars and molars were placed, so that wider implant diameters were used.

At the end of the study, 60 implants (60/62: 96.8%) had an IT ≥45 and an ISQ ≥70 at placement and at different follow-up controls: all these implants were successfully loaded. Only 2 implants (2/62, 3.2%) could not achieve an IT of at least 45 N·cm cm and/or an ISQ value of at least 70 at placement or over time: accordingly, these implants were considered failed for stability, as they could not be subjected to immediate loading. In detail, the first implant that failed for immediate loading was placed immediately after tooth extraction in the mandibular first molar area. The IT was 50 N·cm, and the ISQ value 84. The pickup impression was made immediately after the surgery. The provisional SC was delivered 72 hours after the surgery, and the ISQ value was 83 at that time. Two weeks later, however, the patient complained of discomfort in this area during function, and an ISQ value of 66 was recorded; accordingly, the crown was removed and the implant was left unloaded for 7 weeks. After this undisturbed healing time, the provisional crown was delivered and the ISQ value increased to 81. This implant survived, but it was considered failed for immediate loading. The second implant that failed for immediate loading could not survive and had to be removed. This implant was placed in a healed site of the posterior maxilla. It was a second molar that achieved an IT of 50 N·cm and an ISQ value of 77 at placement, so the pickup impression was made, and the provisional SC was delivered 72 hours after surgery. One week later, an ISQ value of 78 was recorded for this implant; however, after 9 months of functional loading, the patient complained of pain on the crown during function. The implant showed mobility and loss of integration, in the absence of peri-implant infection, with a marked drop in ISQ value: it was consequently removed and replaced with another implant with a wider diameter.

Overall, at the end of the present study, 61 implants (61/62, 98.4%) survived. Only 1 implant (1/62: 1.6%) failed and had to be removed from a healed site of the posterior maxilla. No biological or prosthetic complications were reported during the entire follow-up period (Fig. 1). The distribution of implants by location and position, length and diameter, types of prosthetic restorations, as well as numbers of failures and complications encountered during this study, in the 2 groups (postextraction sockets versus healed sites) is outlined in Table 1. No statistically significant differences were reported between the 2 groups with respect to implant failures (P values ≥0.05) and complications. Mean standard deviations, median, and 95% CI values for ISQ in postextraction and healed sites at different times are summarized in Table 2. A slight increase

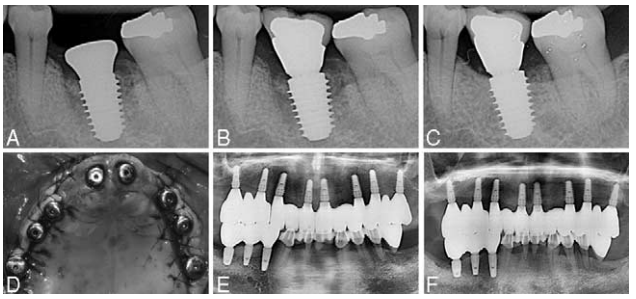

FIGURE 1. Single implant placed in the mandible and multiple implants placed in the maxilla: (A) a wide-diameter single implant was placed immediately after extraction of a mandibular molar. Insertion torque was 50 N·cm and ISQ value was 77. (B) delivery of the crown 72 h after surgery. ISQ value was 80 at that time. (C) periapical radiograph of the final crown after 1 yr of loading. ISQ was 82 at that time. (D) Intraoperative clinical photograph of 8 implants placed in the maxilla. ISQ values were measured immediately after placement, and 1 week later, (E) panoramic radiograph at the delivery of the final fixed full-arch. (F) panoramic radiograph of the final fixed full arch after 1 year of functional loading. All implants showed stable crestal bone level without clinical symptoms or biological complications. ISQ, implant stability quotient.

in ISQ values was observed in both postextraction sockets and healed sites over time. No statistically significant differences in the ISQ values were reported between the 2 groups at the different times.

DISCUSSION

The high level of predictability in implant therapy has encouraged the reevaluation of several aspects of the traditional Brånemark implant protocol, most notably the requirement that implant sites heal prior to loading.[6,8–10] Several clinical studies on the immediate loading of different implant-supported fixed restorations have reported high survival and success rates.[11–13] These positive outcomes have been confirmed in a series of systematic reviews[8,37–39] on the immediate loading of dental implants supporting different types of prosthetic restorations. In fact, implant survival rates for immediate loading are similar to those for early or conventional loading for partially edentulous patients with extended edentulous sites in the posterior zone, as long as strict inclusion and exclusion criteria are followed.[37] Immediately and conventionally loaded single-implant crowns seem to be equally successful with respect to implant survival and marginal bone loss, at least for implants inserted with torques $\geq$20 to 45 N·cm or ISQ values $\geq$60 to 65 and with no need for simultaneous bone augmentation.[38] Finally, when selecting patients carefully and using dental implants with a rough surface, immediate loading of fixed prostheses in fully edentulous patients results in implant survival and failure rates similar to those for early and conventional loading.[39]

More recently, immediate implant placement and loading was introduced in the aim of further reducing treatment time and costs and number of surgeries.[14–16,40,41]

TABLE 1. Implant Distribution and Number of Failures and Complications by Surgical Protocol (Implants Placed in Postextraction Sockets Versus Healed Sites)

		Surgical Protocol		
	All Implants	Postextraction Sockets	Healed Sites	*P* Value*
N	62	30	32	—
Implant location, n				
Maxilla	11	4 (13.3%)	7 (21.9%)	0.3
Mandible	51	26 (86.7%)	25 (78.1%)	
Implant position, n				
Incisors	4	4 (13.3%)	0 (0.0%)	0.0008
Cuspids	5	5 (16.7%)	0 (0.0%)	
Premolars	13	8 (26.7%)	5 (15.6%)	
Molars	40	13 (43.3%)	27 (84.4%)	
Implant length, n				
7 mm	1	1 (3.3%)	0 (0.0%)	0.05
8.5 mm	6	1 (3.3%)	5 (15.6%)	
10 mm	38	16 (53.4%)	22 (68.8%)	
11.5 mm	17	12 (40.0%)	5 (15.6%)	
Implant diameter, n				
3.5 mm	3	3 (10.0%)	0 (0.0%)	0.002
4 mm	8	8 (26.7%)	0 (0.0%)	
4.5 mm	10	3 (10.0%)	7 (21.9%)	
5 mm	15	5 (16.7%)	10 (31.2%)	
6 mm	23	11 (36.6%)	12 (37.5%)	
7 mm	3	0 (0.0%)	3 (9.4%)	
Prosthesis, n				
Single crowns	22	8 (26.7%)	12 (37.5%)	0.73
Fixed partial dentures	24	14 (46.6%)	12 (37.5%)	
Fixed full arches	16	8 (26.7%)	8 (25.0%)	
Failures for survival, n	1	0	1	0.5
Failures for loading, n	2	1	1	0.9
Biological Complications, n	0	0	0	n.a.
Prosthetic complications, n	0	0	0	n.a.

n.a., not applicable.
*Fisher exact test.

TABLE 2. Mean (Standard Deviation), Median, Confidence Interval 95% for Implant Stability Quotient at Different Times, by Surgical Protocol (Implants Placed in Postextraction Sockets Versus Healed Sites)

		Surgical Protocol		
	All Implants	Postextraction Sockets	Healed Sites	*P* Value*
At placement	78.8 (3.7); 79; 77.8–79.7 (n = 62)	78.5 (3.8); 78.5 77.1–79.8 (n = 30)	79.1 (3.7); 80; 77.8–80.3 (n = 32)	0.420
1 wk after placement	79.6 (3.5); 80; 78.7–80.4 (n = 62)	79.3 (3.4); 79.5; 78–80.5 (n = 30)	79.8 (3.6); 80; 78.5–81.0 (n = 32)	0.528
3 mo after placement	80 (3.4); 80; 79.1–80.8 (n = 61)	79.6 (3.5); 80; 78.3–80.8 (n = 29)	80.3 (3.3); 80; 79.1–81.4 (n = 32)	0.467
1 yr after placement	80.3 (3.3); 80; 79.4–81.1 (n = 60)	80.1 (3.3); 80; 78.9–81.3 (n = 29)	80.5 (3.4); 80; 79.3–81.6 (n = 31)	0.687

*Mann–Whitney test for independent variables.

Although recent systematic reviews have pointed out that immediate implantation is only successful if the primary stability of the implant can be provided by the residual bone in the socket after tooth extraction[18] and, consequently, the insertion of implants in fresh extraction sockets may affect the failure rates,[17] recent clinical studies have reported similar positive outcomes comparing the survival and success rates of immediately loaded implants placed in postextraction sockets and healed sites.[16,24–30] Malchiodi et al[25] evaluated the difference in success rates in the maxilla between postextraction implants and implants placed in healed sites, both of which were immediately loaded, after 6 years of follow-up. In total, they inserted and immediately loaded 239 implants in 81 patients: 138 implants were placed in fresh postextraction sites (57.7%), and 101 implants in healed sites (42.3%).[25] At the end, only 8 of the 239 implants failed, for an overall success rate of 96.6%. Six of the failed implants had been inserted in postextraction sites, whereas 2 had been placed in healed sites: the success rates were 95.7% and 98.0%, respectively.[25] Statistical analysis revealed no significant differences between postextraction and healed sites.[25] In a clinical study by Gillot et al,[26] 113 consecutive patients about to have their maxillae rendered fully edentulous received 4 to 8 implants each (total number = 675), which were immediately placed in healed sites (323 implants, 47.9%) or fresh sockets (352 implants, 52.1%). Immediate loading of provisional prostheses was performed and all patients were followed up for 6 months.[26] The overall implant survival rate after 6 months was 99.1%. Six implants in 6 patients (5.3%) were lost.[26] Five of them were inserted in fresh extraction sockets (1.4%) and 1 in a healed site (0.3%). Again, immediate implant placement and loading resulted in high implant and prosthetic survival rates, and there were no significant differences between implants placed in healed sites and those placed in fresh extraction sites.[26] In another study by Degidi et al,[28] 416 fixtures were placed immediately after extraction, and 658 fixtures were placed in healed sites. All fixtures were immediately loaded. After 3 years, postextraction immediately loaded implants had high survival and success rates, similar to those reported in previous studies of 2-stage procedures or immediately loaded implants inserted in healed bone.[28] These results were confirmed by other studies, in which placement in healed or fresh extraction bone sites did not influence the survival and success of immediately loaded fixtures.[16,24–30]

Our present prospective 1-year follow-up study seems to confirm these results. In our study, 30 implants were placed in postextraction sockets (4 in the maxilla, 26 in the mandible) of 17 patients, whereas 32 implants were placed in healed sites (7 in the maxilla, 25 in the mandible) of 22 patients. Our 2 study groups were homogeneous with respect to sex, age, implant location, implant length, and types of prosthetic restorations, but differed in implant position and implant diameter. In fact, in healed sites, only premolars and molars were placed, so that wider implant diameters were used. At the end of the study, only 1 implant failed and had to be removed, for an overall implant survival rate of 98.4%. This implant failed in a healed site in the posterior maxilla; however, no statistically significant differences in implant survival were reported between the 2 groups (postextraction sockets and healed sites). No biological or prosthetic complications were reported. Finally, with respect to implant stability, 60 implants (96.8%) had an IT $\geq$45 and an ISQ $\geq$70 at placement and at different follow-up controls: these implants were successfully loaded. Only 2 implants (3.2%) could not achieve an IT of at least 45 N·cm and/or an ISQ value of at least 70 at placement or over time: accordingly, these implants were considered failed for stability, as they could not be subjected to immediate loading.

Primary implant stability refers to the stability of a dental implant immediately after placement: it mostly derives from mechanical engagement of the implant threads (macroretentions) with cortical bone.[6,9,10,18–21] Bone quantity and quality, surgical technique (including operator's skills), and implant macrotopographical design are the main factors influencing primary implant stability.[6,9,10,18–21] During healing, primary stability is replaced by a biological bonding between newly formed bone and implant surface: this is called secondary stability.[6,9,10,18–21] The main factors influencing secondary stability are primary stability, bone remodeling, and implant surface characteristics.[19,20]

The assessment of implant stability is important for the prognosis of implant treatment, especially with immediate loading.[9,10,18–21,42,43] Therefore, it is important to correctly assess the degree of implant stability at placement, as well as its changes over time. Several techniques have been suggested for the assessment of implant stability.[42,43] The percussion test was the first method proposed to assess primary stability and to estimate the level of osseointegration.[43,44] This test relies heavily on the clinician's level of experience and subjective beliefs, is rather inaccurate, and cannot be used experimentally as a standardized testing method.[43,44] The Periotest (Seimens, Bensheim, Germany) has been proposed as a more objective method for assessment of implant stability.[45] Although it was better than the percussion test, the Periotest has been criticized for its lack of resolution, poor sensitivity/specificity, and susceptibility to operator variability.[42,43,45] Insertion torque has been recognized as a useful method for documentation of primary implant stability.[46–48] Insertion torque can be measured either with highly sensitive instruments like electronic probes inserted in the low-speed insertion device or with the not so accurate manual wrench ratchet.[47] There is consensus that

for a successful immediate loading, the IT should be between 30 and 40 N·cm,[46,47] even with implants placed in postextraction sockets.[48,49] Although IT can be a useful tool, it is a one-time method for evaluating implant stability, and repeated measurements over time are not possible.[18,19] However, continuous quantitative and objective monitoring is important in determining implant stability over time: this can be a valuable tool for making decisions pertaining to treatment protocols. Resonance frequency analysis is a diagnostic tool for detecting implant stability as a function of stiffness of the bone–implant interface, not only at placement but also during the healing stages.[18–21] Resonance frequency analysis was first introduced by Meredith et al[50] in 1996. Although a recent review has questioned whether RFA measurement at the time of implant placement is sufficiently accurate to determine implant stability and osseointegration during immediate loading protocols,[51] this method is commonly used to assess implant stability over time.[18–21] In previous studies,[52,53] Han et al[54] reported a slight decrease in ISQ values within the first 3 weeks after implant placement; a return to the original ISQ values is generally observed 8 weeks after surgery. However, it has been suggested that if rough-surfaced implants are used, the healing time prior to loading can be reduced to 3 to 4 weeks following implant placement[55]; in addition, after this period, rough-surfaced implants have a steady increase in ISQ values over time.[55] In our study, both IT and RFA were used to assess primary implant stability, immediately after surgery and 1 week, 3 months, and 1 year after placement, respectively. High satisfactory primary implant stability was obtained in both groups. In fact, mean ISQ values at placement were 78.5 ± 3.8 (95% CI: 77.1–79.8) and 79.1 ± 3.7 (95% CI: 77.8–80.3) for implants placed in postextraction sockets and healed sites, respectively. These excellent outcomes may be the result of accurate patient selection: in fact, heavy smokers and bruxers were not enrolled in the present prospective clinical study. Parafunction is one of the major risk factors with immediate loading: excessive occlusal loading should be avoided, as it can cause micromotion at the bone–implant interface, which could result in fibrous encapsulation and implant failure.[3,6,8,9] In addition, the implants used in our study had a tapered design with strong self-cutting threads, which can provide excellent initial stability with high IT and ISQ values at placement.[13] At the 1-year follow-up control, mean ISQ values were 80.1 ± 3.3 (95% CI: 78.9–81.3) and 80.5 ± 3.4 (95% CI: 79.3–81.6) for implants placed in postextraction sockets and healed sites, respectively. A slight increase in ISQ values was observed in both postextraction sockets and healed sites over time. In our study, we used implants with a novel calcium-incorporated surface; this novel implant surface has the potential to accelerate bone healing, enhancing osseointegration and secondary implant stability.[33] No significant differences in ISQ values were reported between the 2 groups (postextraction sockets and healed sites), in each of the different control sessions.

In conclusion, the question of whether immediate implants are at greater risk for failure than implants placed in mature bone has received increasing attention in recent years, but only a few studies have compared the outcomes of immediately loaded implants placed in postextraction sockets and healed sites. In our study, immediately loaded implants placed in postextraction and healed sites achieved similar positive outcomes, with high survival rates, excellent stability, and no complications. Because adequate primary stability is considered a prerequisite for the success of immediate loading protocols, the use of tapered implants with strong self-cutting threads may be beneficial, as it can guarantee an excellent initial stability, with high IT and ISQ values. Further long-term clinical studies on larger samples of patients are needed to confirm these results.

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