Immediate Occlusal Loading of Implants in the Partially Edentate Mandible: A Prospective 1-Year Radiographic and 4-Year Clinical Study

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Purpose: *The purpose of the present prospective clinical study was to evaluate the radiographic and clinical outcome of immediately loaded implants in the partial edentulous mandible over a 4-year follow-up period using a modified surgical protocol, primary implant stability criteria, and splinting for inclusion.* ***Materials and Methods:*** *Patients in need of implant treatment in the partial edentate mandible were consecutively included in the study. The implant sites were underprepared to obtain maximal stability. Inclusion criteria for the study were torque of a least 30 Ncm before final seating of the implant and an ISQ greater than 60. A provisional fixed partial denture was delivered within 24 hours and a definitive fixed partial denture within 3 months. The patients were monitored with clinical and radiographic follow-up examinations for up to 4 years. Stability of the implants was measured with resonance frequency analysis at placement and after 6 months.* ***Results:*** *Ninety-six patients were evaluated, and 77 patients who met the inclusion criteria were included. A total of 111 fixed partial dentures supported by 257 Brånemark System implants (77 turned and 180 TiUnite implants) were delivered. Four (1.6%) of the 257 implants did not osseointegrate, giving an overall survival rate of 98.4% after 4 years. Three turned (3.9%) implants and 1 oxidized implant (0.6%) failed after 4 to 13 months. The average marginal bone resorption was 0.7 mm (SD 0.78) during the first year in function. Turned implants showed an average bone loss of 0.5 mm (SD 0.8) and oxidized implants an average of 0.7 mm (SD 0.8). Resonance frequency analysis showed a mean implant stability quotient of 72.2 (SD 7.5) at placement and 72.5 (SD 5.7) after 6 months of loading.* ***Conclusion:*** *It is concluded that immediate loading of implants with firm primary stability in partially edentulous areas of the mandible appears to be a viable procedure with predictable outcome.* (Comparative Cohort Study) Int J Oral Maxillofac Implants 2008;23:315–322

Key words: *dental implants, immediate loading, insertion torque, partially edentulous mandible, primary stability, prospective study, resonance frequency analysis*

The obvious advantages of early/immediate implant loading for patients have led to an increased focus on the development and evaluation of such protocols. A recent literature review concluded that predictable results can be achieved in the anterior mandible, irrespective of implant type, surface properties, and prosthesis design.[1] However, although good results have been reported for immediate implant loading in the totally edentulous maxilla and partially edentulous jaws as well, the limited number of investigations does not allow for a conclusion regarding the long-term predictability of the treatment. The authors stressed a need for further research in these areas.[1]

Firm initial stability is regarded as one determinant of success for dental implants in 2-stage protocols[2] and may be even more important in immediate loading situations. The clinical assessment of stability is often based on the rotational resistance encountered when placing the implant, which has been shown to reflect bone density at the site.[3] Others have used insertion torque measurements to judge primary stability, and insertion torques of 30 to 40 Ncm may ensure that sufficient stability has been reached.[4–6] In addition, modified surgical techniques using a combination of thinner drills, osteotomes, tapered implants, and wider implants have been utilized to enhance primary stability.[4,7,8] Friberg et al[7]

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could not demonstrate any correlation between insertion torque and implant failure for 2-stage Brånemark implants; however, a correlation was reported in a recent study on immediately loaded Frialit implants for single-tooth replacements.[9]

In a previous study, the primary stability of 905 implants (Brånemark System) placed according to a protocol aiming at high initial stability was evaluated at placement surgery using resonance frequency analysis (RFA).[10] A mean implant stability quotient (ISQ) of 67.4 was obtained for all sites. Sennerby and Meredith[11] found that Brånemark implants with an ISQ around 65 did not show increased stability with time and suggested this to be a safe level for immediate loading. In the study by Östman et al,[10] about 65% of all implants had an ISQ of at least 65. Moreover, implants placed in posterior segments were as stable as or even more stable than anteriorly placed implants in both the mandible and the maxilla. Although posterior regions, especially in the maxilla, are considered more challenging due to the presence of soft bone, the results suggest that sufficient primary implant stability can be achieved in these regions.

The long-term success of immediate loading is dependent on the achievement of osseointegration and the maintenance of implant stability during functional loading. Theoretically, there is a risk for micromotion at the bone-implant interface, which may result in soft tissue encapsulation and implant failure. The splinting of multiple implants with a rigid connection may reduce the risk for failure. Implant surface topography may be another important factor for proper integration in challenging situations. Histologic investigations have demonstrated greater bone contact and a more rapid integration of oxidized implants in comparison with turned titanium implants in both animals[12] and humans.[13] Rocci et al[14] reported higher failure rates for turned implants than for oxidized implants when used for immediate loading in the partially edentate mandible.

In a previous study, direct implant loading was evaluated in the totally edentulous maxilla using inclusion criteria based on primary implant stability.[10] In that study, 6 to 7 implants were placed and, if an insertion torque of at least 30 Ncm was reached and an ISQ of 60 was determined for posterior implants, used for immediate loading. Only 1 of 123 implants in 20 patients failed during the first year of follow-up. The present prospective study was conducted to test the same protocol for the partially edentate mandible.

The aim of the present study was to clinically and radiographically evaluate an immediate loading treatment protocol for implant-supported partial prostheses in the partially edentate mandible.

MATERIALS AND METHODS

Study Group and Preliminary Inclusion Criteria

Consecutive patients with need of implant treatment in the partially dentate mandible were invited to participate in the study if they met the primary inclusion criteria. The patients were thoroughly informed about the procedure and asked to sign a consent form. They were informed that final decision on immediate loading would be made during surgery.

The primary inclusion criteria were

- Need for rehabilitation with an implant-supported prosthesis in the partially dentate mandible.
- Presence of residual bone sufficient to house 2 implants at least 7 mm long or one 15-mm-long implant to be connected with a tooth.
- Implant site free from infection. If the implant was to replace an extracted tooth, a minimum healing period of 4 months was required.
- Signing of consent form.

The exclusion criteria were

- General contraindications for oral surgery
- Age less than 18 years

Surgery and Final Inclusion Criteria

About 1 hour prior to surgery, the patients were given 2 g of amoxicillin (Amimox; Tika Läkemedel, Lund, Sweden) and diazepam (Stesolid; Alpharma, Stockholm, Sweden; 0.3 mg/kg body weight) orally. Infiltration anesthesia (xylocaine-adrenaline; AstraZeneca, Södertälje, Sweden) was used. A midcrestal incision was performed in each case. After reflection of the flap, careful evaluation was made to decide optimal implant position from both esthetic as well as biomechanical points of view (Figs 1a and 1b). No surgical guide was used. Bone quality and quantity were determined according to the criteria of Lekholm and Zarb.[15] Implants were placed in underprepared sites to enhance primary stability.[10] The final drill size was determined as follows: In bone judged to be type 2, 3, or 4 in quality, the final preparation of 2.85 mm was made. In type 4 bone, an MK IV implant was preferred. A shallow countersinking was performed to engage as much of the crestal bone as possible. All implants placed exceeded an insertion torque of 30 Ncm. Implant stability was measured with Osstell (Integration Diagnostics, Göteborg, Sweden). At this stage, a decision was made regarding whether to load directly or to use a 2-stage procedure based on the following criteria:

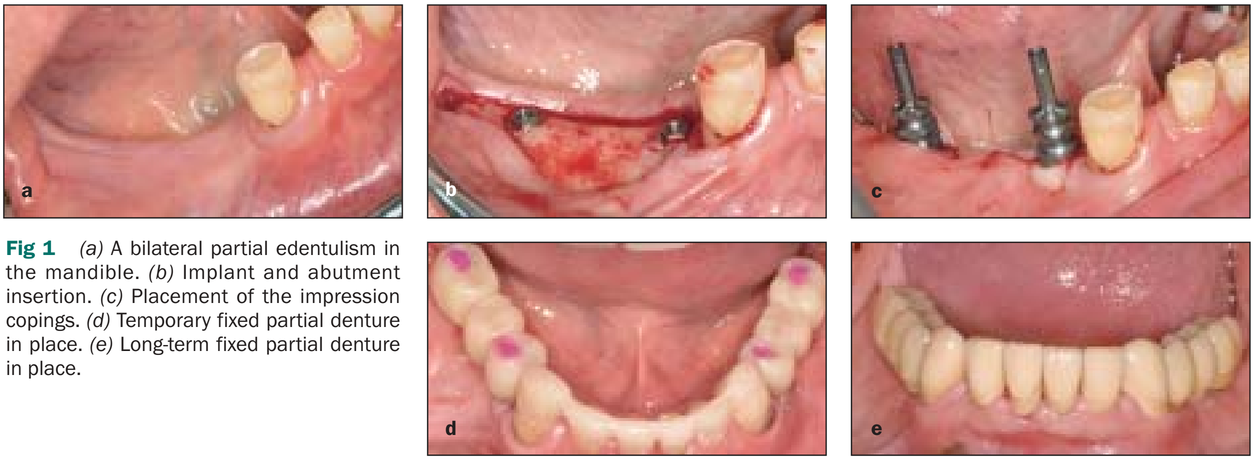

Fig 1 *(a)* A bilateral partial edentulism in the mandible. *(b)* Implant and abutment insertion. *(c)* Placement of the impression copings. *(d)* Temporary fixed partial denture in place. *(e)* Long-term fixed partial denture in place.

- A minimum insertion torque of 30 Ncm before the final seating of the implant as measured with an Osseocare drill unit (Nobel Biocare, Göteborg, Sweden)
- An ISQ value of at least 60

Before adaptation and suturing of the flaps, multi-unit abutments (Nobel Biocare) and impression copings were placed where 2 or more implants were placed (Fig 1c). In cases where 1 implant was going to be connected to a tooth, impression copings were placed at the implant level in order to make an implant-level screw-retained/tooth cement-retained provisional fixed partial denture.

Prosthetic Procedures

Immediately following surgery, a quick-setting high-viscosity polyvinyl siloxane (Dimension Penta H Quick; 3M ESPE, St Paul, MN) impression was made using an open tray. An impression was made of the opposing jaw and an occlusal record was made. Healing caps were placed on the abutments.

Screw-retained provisional fixed partial dentures with cantilevers less than 5 mm were fabricated at a dental laboratory and were delivered within 24 hours. Careful adjustments of occlusion and articulation were performed to minimize lateral forces (eg, light centric occlusal contact and no contacts in lateral movement; Fig 1d).

One to 3 months after implant placement a new impression was made to obtain a master cast on which the long-term fixed partial denture was fabricated (Fig 1e).

Postoperative Measures and Follow-up

For 10 days after implant placement, the patients were given 2 g/d of V-penicillin (Kåvepenin; Astra Zeneca). They were asked to rinse their mouths twice a day with 0.1% chlorhexidine and to eat soft food.

All patients participating in the study agreed to be enrolled in a strict and individually designed maintenance care program focusing on oral hygiene, prosthesis stability, soft tissue condition, and prosthesis function. Post-treatment follow-up examinations were carried out at 3, 6, and 12 months and yearly thereafter. Implant stability was registered by RFA at surgery and 6 months later when the fixed partial dentures were removed. In addition to these planned follow-up examinations, hygiene controls were carried out individually.

Marginal Bone Resorption

The marginal bone level was evaluated in digital periapical radiographs obtained after surgery (baseline; Fig 2a) and after 1 year in function (Fig 2b). To obtain maximal accuracy in the radiographs, a silicone index material was affixed to the maxillary dentition and radiograph holder for each patient. By this technique, the same position of the radiograph could be reproduced even though the occlusal surface changed when the provisional fixed partial denture was replaced by the definitive fixed partial denture. The distance from the implant-abutment junction to the marginal bone level was measured at the mesial and distal aspects of each implant by an independent radiologist. Bone loss was presented as the mean of the distal and mesial measurements for each implant and time point.

Success Rating

Implant success was evaluated using a 4-field table according to Albrektsson and Zarb[16] using the following categories:

- Success: An implant meeting with success criteria. Criteria for success according to Albrektsson et al[17] and Albrektsson and Zarb[16] include absence of implant mobility and absence of pain and neu-

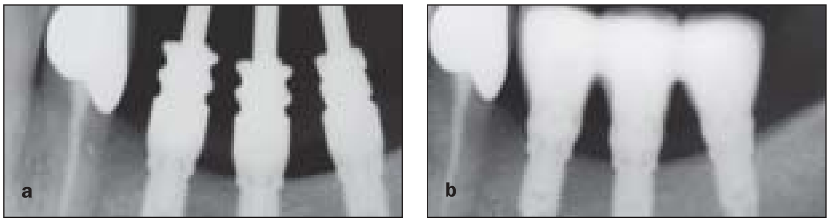

Fig 2a Baseline radiograph showing 3 implants and impression copings.
Fig 2b One-year follow-up of the patient shown in Fig 2a.

Table 1 Age and Gender Distribution Among Study Patients

Age	Male	Female	Total
35–49	1	2	3
50–59	10	12	22
60–69	17	8	25
70–79	9	15	24
80–	1	2	3
Total	38	39	77

Table 2 No. of Implants Placed Relative to Bone Quality and Quantity

Bone quantity	Bone quality				Total no. of implants
	1	2	3	4	
A	–	1	–	–	1
B	–	25	56	14	95
C	–	73 (3)	55 (1)	18	146 (4)
D	–	8	3	4	15
E	–	–	–	–	–
Total	–	107	114	36	257

Failures shown in parentheses.

ropathy. Originally, 1 mm of bone loss from the lower corner of the implant head was acceptable during the first year and less than 0.2 mm annually thereafter. Slightly less strict criteria were used in the present study since implants were individually tested for mobility only after 6 months. Moreover, more bone loss was accepted, since measurements were made from the implant platform, which for MK II and MK III implants is situated 0.8 mm above the reference point used in previous studies. Success grade 1 was defined as an implant with no clinical and radiographic signs of pathology showing less than 2 mm of bone resorption at 1 year of follow-up. Success grade 2 was defined as an implant with no clinical and radiographic signs of pathology showing less than 3 mm of bone resorption at 1 year of follow-up.

- Survival: An implant still in the mandible that did not meet success criteria or was not evaluated using the success criteria.
- Unaccounted for: An implant in an patient who dropped out of the study for any reason.
- Failure: An implant removed for any reason.

RESULTS

Patients, Implants, and Prosthetics

Ninety-four patients were evaluated and 91 were included according to the primary inclusion criteria. Fourteen patients did not meet with one or more of the secondary inclusion criteria, and they therefore underwent a 2-stage procedure. Seventy-seven (77) patients (85%; 39 female, 38 male, age range 33 to 82 years) were finally included (Table 1).

A total of 257 Brånemark implants (Nobel Biocare), 77 turned and 180 oxidized (TiUnite) were placed (Tables 2 to 4).

A total of 111 fixed partial dentures were made (Table 5). Forty-eight patients had 1 restoration, 30 patients had 2 restorations, and 1 patient had 3 restorations. The restorations were supported by 1 to 4 implants (Table 6).

Clinical Observations

Few complications were observed during the follow-up. One patient showed anesthesia of the inferior alveolar nerve for 3 months. Three provisional fixed partial dentures showed mobility due to loosening of the prosthetic screw. Two patients with 3 implants each were withdrawn from the study after the first annual check-up. One of the patients died and 1 moved away.

Implant Survival and Failures

Four (1.6%) of the 257 implants placed did not integrate and were subsequently removed. The overall cumulative survival rate was 98.4% after 1 year—96.1% and 99.4% for turned and oxidized implants, respectively (Table 7).

One patient lost 2 implants, and 2 patients lost 1 implant each. One implant showed no radiographic signs of de-integration but was found rotationally

Table 3 Length and Types of Implants

	Turned				Oxidized		
Implant length	Standard	MK II	MK III	MK IV	MK III	MK IV	Total
7 mm	–	–	4	–	6	–	
8.5 mm	–	–	4 (2)	–	19	–	
10 mm	3	–	11	4	42	–	
11.5 mm	–	2	7	2	13 (1*)	3	
13 mm	–	2	12	6	37	5	
15 mm	–	2	6	–	15	2	
18 mm	–	–	11 (1)	1	25	13	
Total	3	6	55	13	157	23	257

Failures shown in parentheses.

mobile when an impression for fabrication of the definitive prosthesis was made 2 months after placement. Three implants showed peri-implant radiolucency after placement of the definitive fixed partial denture (Fig 3). Radiolucency became evident after 4 months in 1 case and after 13 months in 2 cases. Three (3.9%) of the failed implants had a turned surface and 1 (0.6%) had an oxidized surface (Table 8).

Resonance Frequency Analysis

RFA showed a mean ISQ of 72.2 (SD 7.5) at placement and 72.5 (SD 5.7) after 6 months of loading (Table 9). There were no statistically significant differences between turned and oxidized implants. The initial ISQs for the failed implants were 71, 66, 65, and 82.

Marginal Bone Resorption

Marginal bone measurements could be performed in 228 of the 257 implants placed. The marginal bone level was situated 0.4 (SD 0.7) mm below the implant-abutment junction at baseline and 1.1 (SD 0.8) mm after 1 year of loading. The average bone loss was 0.7 (SD 0.8) mm after 1 year follow-up (Table 10). Turned implants showed an average bone loss of 0.5 (SD 0.8) mm, and oxidized implants an average of 0.7 (SD 0.8) mm.

Fifteen implants (6.6%) showed more than 2 mm bone loss after 1 year, and 1 implant (0.4%) showed 3 mm of bone loss. The corresponding figures were 3.2% and 0% for turned implants and 7.8% and 0.6% for oxidized implants.

Success Rating

Based on available radiographs and examined implants, the total success rate appeared to be 90.7% using the 4-field technique. After 1 year, Success Grade 1 was found to be 82.9% and Success Grade 2 was 88.3%.

Table 4 Implants in Relation to Tooth Position

Tooth position	No. of implants placed
32 (48)	–
31 (47)	25
30 (46)	42
29 (45)	25
28 (44)	19
27 (43)	4
26 (42)	2
25 (41)	3
24 (31)	3
23 (32)	5
22 (33)	2
21 (34)	24
20 (35)	28
19 (36)	45
18 (37)	30
17 (38)	–
Total	257

Table 5 Materials Used for Permanent Partial Prostheses

Materials	No. of prostheses
Procera implant bridge/porcelain	91
Procera implant bridge/composite	5
Gold/porcelain	9
Carbon fibre/composite	2
All-Ceram/Procera abutment	2
Titanium/porcelain	2
Total	111

Table 6 No. of Implants per Prosthetic Restoration

	Cases		
No. of implants	Female	Male	Total
1 (tooth connected)	1	8	9
2	26	35	61
3	24	14	38
4	2	1	3
Total	53	58	111

Table 7 Characteristics of Lost Implants

Position	Implant type (width/length)	Time (mo)	Bone quality	Smoking	Probable cause
30 (46)*	MK III turned (3.75/8.5)	13	2	No	Bruxism
31 (47)*	MK III turned (3.75/8.5)	13	2	No	Bruxism
29 (45)	MK III turned (3.75/18)	7	2	No	Bruxism
28 (44)	MK III TiUnite (3.75/11.5)	4	3	No	Overtightening

*Same patient.
Bone quantity was C for all positions.

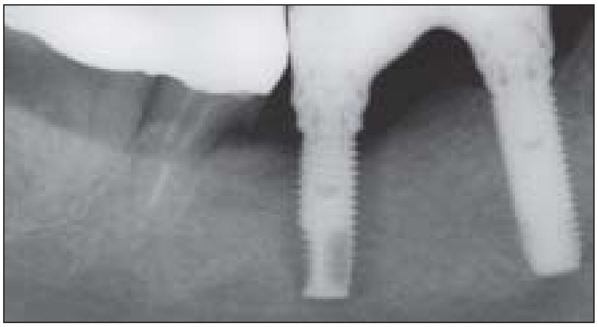

Fig 3 One of the failed implants. There was a radiolucent zone around the entire implant body.

Table 8 Life Table Showing Cumulative Survival Rate

	All implants				Turned implants				Oxidized implants			
Time period	Implants	Out	WD	CSR%	Implants	Out	WD	CSR%	Implants	Out	WD	CSR%
Loading to 1 y	257	4	3*	98.4	77	3	3	96.1	180	1	0	99.4
1 to 2 y	250	0	0	98.4	71	0	0	96.1	180	0	0	99.4
2 to 3 y	136	0	3†	98.4	68	0	0	96.1	72	0	3	99.4
3 to 4 y	125	0	0	98.4	59	0	0	96.1	66	0	0	99.4
≥ 4 y	68	–	–	–	48	–	–	–	20	–	–	–

CSR = cumulative survival rate; WD = withdrawn.
*One patient (3 implants) died in the first year of follow-up.
†One patient (3 implants) moved away before the 3-year follow-up examination.

Table 9 ISQs at Implant Surgery and 6-month Follow-up

	All implants			Oxidized implants			Turned implants		
Time of measurement	No.	Mean	SD	No.	Mean	SD	No.	Mean	SD
Implant surgery	214	72.2	7.5	182	71.8	7.3	32	74.6	8.5
6 months	238	72.5	5.7	184	72.7	5.8	54	71.8	5.5

Table 10 Marginal Bone Level at Baseline and 1-year Follow-up

	Marginal bone level at implant placement		Marginal bone level at follow-up visit		Marginal bone resorption between placement and 1 year	
Bone loss	No.	%	No.	%	No.	%
< 0	–	–	–	–	23	10
0	116	51	25	11	27	12
0.1 to 1.0	72	32	84	37	104	46
1.1 to 2.0	37	16	102	45	60	27
2.1 to 3.0	2	1	14	6	9	4
> 3.0	–	–	3	1	2	1
Total	227	–	228	–	225	–

DISCUSSION

The present prospective clinical study included 77 patients treated with a total of 111 immediately loaded fixed partial dentures in the partially edentulous mandible. Only 4 (1.6%) of 257 implants were lost, and all patients received and maintained a fixed permanent prosthesis throughout the study period. The survival rate was 98.4% after 1 year. The average marginal bone loss was 0.9 mm during the first year. Fifteen implants (6.6%) showed more than 2 mm bone loss and 2 (0.4%) more than 3 mm after 1 year of loading. This in line with other researchers' experiences with immediately/early loaded implants.[6,14,18] There were no differences between turned and oxidized implants with regard to average bone loss, although more oxidized implants showed more than 2 mm of bone loss after 1 year. In addition, a 4-field table according to Albrektsson and Zarb (not shown) was used to evaluate the outcome. With this technique, dropout implants and implants without readable radiographs are not compensated for. No or few dropout patients are required to get success rates in range of those calculated with life table analysis. In the present study, only 2 examined implants were not found to meet with the less strict criteria of 3 mm bone loss. However, the success rate was calculated as 88.3%, since not all implants had readable radiographs.

An increasing number of publications reporting clinical outcomes from immediate loading protocols are available. Recent literature reviews and consensus reports seem to show that this is a well-documented treatment modality for the totally edentulous mandible but that more research is needed for other indications.[1,19–21] For instance, only a few studies have focused on immediate implant loading in the partially edentate mandible,[6,14,22] which was one reason for conducting the present study. As revealed in previous studies using RFA,[10,23] high primary stability can be achieved in the posterior mandible, and it was anticipated that predictable outcomes could be obtained with immediate loading. A modified drilling protocol[10] and primary stability–based inclusion criteria were used,[4] which may explain the low failure rate.

Of the 257 implants installed in the present study, 77 had a turned surface, and 180 had an oxidized, moderately rough surface. Interestingly, 3 of the 4 implants that failed had a turned surface, resulting in a failure rate of 3.9% for turned implants and 0.6% for oxidized implants. Histologic research has shown a stronger bone response and a more rapid integration of oxidized implants compared to turned ones,[12,13] which may explain the differences in clinical outcome. A similar observation has been made by Rocci et al[14] who reported a 10% higher survival rate for oxidized implants in comparison with turned implants after 1 year. Moreover, they reported on a significantly higher failure rate for turned implants among smokers. In the present study, all failures occurred in nonsmokers. Glauser et al[18,24] evaluated turned and oxidized implants for immediate loading in 2 different studies. They experienced a failure rate of 17% for turned implants and 3% for oxidized implants. In both studies, they observed an initial drop in stability during the first 3 to 4 months, followed by an increase (RFA). In an analysis of turned implants from the first study, it was revealed that failing implants showed a continuous decrease of stability until the clinical manifestation of failure.[25] In a separate study, Glauser et al[26] demonstrated a significantly lower initial decrease of stability for oxidized implants in comparison with turned implants during functional loading in the posterior maxilla, which indicated a higher resistance to loading forces.

In the present study, RFA showed small changes of stability from placement up to 6 months. Turned implants showed a slightly higher primary stability than oxidized ones. This may be explained by a grinding effect of the rough surface on the bone during placement, which resulted in a looser fit compared with the smooth-surfaced turned implants. However, the differences had diminished after 6 months of healing. Implant failure could not be correlated with primary stability. Glauser et al[25] showed a significantly lower stability for failing implants after 1 and 2 months of loading compared to successful ones. Since repeated measurements were not conducted in the present study, it is not known whether the failed implants in this sample would have shown a similar pattern.

Direct loading protocols offer obvious advantages for the patient, such as a momentary reduction of oral handicap, which is important from a psychological point of view and in other ways as well. Another benefit is fewer postoperative complaints, as the wound is not loaded with a removable denture but protected by the temporary fixed prosthesis during chewing. Moreover, less surgery and chair time are needed, since abutment connection surgery and relining of the removable prosthesis are not needed. However, the use of direct loading in clinical routine is uses resources, and logistic problems may be faced. In this study, a surgeon, restorative dentist, and a laboratory technician worked as a team to provide patients with a temporary fixed partial prosthesis within 24 hours. One way to further simplify the concept would be to evaluate techniques for chairside manufacturing of provisional fixed partial dentures.[27] One way of making a cost-effective, "easy-to-use" chairside temporary fixed partial denture is the use of a translucent vacuum template made in the dental laboratory before surgery. The template is made on a tooth setup of the area being rehabilitated. After implant insertion temporary plastic cylinders are mounted at the implant or abutment level. The template is filled with a self-setting composite material. After the composite is fully seated, the temporary fixed partial denture is trimmed and polished. In a test group including 69 patients with partially edentulous mandibles, this treatment concept was used with the same results as in the present study.[27]

Within the limitations of this study, it is concluded that direct loading of Brånemark implants in the partially edentate mandible results in a predictable outcome.

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