

Immediate/early loading of dental implants. Clinical documentation and presentation of a treatment concept

PÄR-OLOV ÖSTMAN

During the past 40 years, prosthetic rehabilitation of the edentulous patient with implant-supported bridges has developed into a viable and predictable treatment option. High clinical success rates with the original implant protocols (5) have given clinicians and researchers confidence to further develop and refine the osseointegrated technique and, consequently, implants are used in increasingly more challenging situations and on broader indications (117). For example, the dental profession has progressed from rehabilitation of the totally edentulous mandible with implants in the interforamina region to single implants in grafted areas in the posterior part of the maxilla. A similar trend is seen for the timing of implant loading. A submerged healing period of 3–6 months was originally considered a prerequisite for achieving osseointegration of titanium implants (4). However, during the past 10–15 years this traditional protocol has been questioned and numerous clinical studies have reported on the outcome of early and immediate loading of implants in various clinical situations (29, 61). There has also been a change of focus in implant therapy from being originally a strictly functional rehabilitation to being a treatment modality with a major emphasis on aesthetics (27).

Another consequence of the widespread use of the osseointegration technique is the rapid launching of new implant designs and treatment concepts. Although some of the new implant systems are supported by clinical research data, the majority is not. In some sense, it is therefore the task of clinicians and researchers to critically scrutinize new implant and treatment concepts. Dentists should rely on

proper scientific studies rather than on the partly unsupported claims of implant manufacturers. One example of insufficient information is the Nobel Direct implant (Nobel Biocare, Göteborg, Sweden); at the time of its introduction, with little or no documentation, it was claimed to reduce marginal bone loss and to improve the aesthetic outcome as a result of 'soft tissue integration'. Recent studies showed higher failure rates and more bone loss with the Nobel Direct implant system than with conventional implants (7, 87, 110). Having said this, it should be remembered that manufacturers have also been instrumental in developing implant surfaces and designs that have increased the predictability of implant therapy in challenging situations, such as the use of immediate-loaded implants. This paper reviews the literature on and presents a protocol for immediate/early loading of implants.

Terminology

The terminology in implant dentistry is often confusing despite attempts to agree upon proper definitions (11, 19). The following definitions are used in the present article.

Definition of timing of implant loading

- *Immediate/direct loading*: the provisional/definitive prosthetic construction is attached to the implant within 24 hours of the implant being placed.

- *Early loading / Early functional loading*: the provisional / definitive prosthetic construction is attached to the implant within days / weeks of the implant being placed.
- *Delayed loading*: the provisional / definitive prosthetic construction is attached at a second procedure after a conventional healing period of 3–6 months.
- *One stage*: the implant heals without protection of the oral mucosa and is accessible through the mucosa during healing time.
- *Two stage*: the implant heals under the soft tissue and is, after a healing period, accessed through a second-stage surgery.

Definition of prosthetic load of implant

- *Occlusal loading*: the crown / bridge is in contact with the opposing dentition in centric occlusion.
- *Non-occlusal loading*: the crown / bridge is *not* in contact in centric occlusion with the opposing dentition in the natural jaw position.

Why immediate loading?

Immediate oral handicap relief

Edentulous patients seeking dental treatment to restore function and aesthetic appearance have traditionally received removable full or partial dentures. However, use of removable dentures may lead to a sense of patient insecurity, reduced chewing capacity and taste, and low self-esteem. In a controlled study, Blomberg et al. (20) investigated 26 denture patients before and at 3 months and 2 years after the insertion of an implant-supported bridge. The majority of patients stated that there had been a significant improvement in their lives, that they had gained in self-confidence, and that, in contrast to their conventional denture, they had accepted the fixed bridge as part of their body. However, the insertion of implants according to traditional protocols includes a prolonged period of healing time, especially if the treatment involves tooth extraction and healing before implant surgery. Extended periods with no teeth or with removable dentures have the disadvantages discussed above. The use of immediate / early-loaded implants has obvious advantages because patients can be rehabilitated with functional crowns for immediate function and aesthetics.

Biological response

The original Brånemark implant protocol (Nobel Biocare) required a stress-free submerged healing time of 3–6 months to obtain osseointegration (2–4, 6, 24–26). The prolonged undisturbed healing time was thought to be necessary to avoid fibrous tissue encapsulation around the implants instead of osseointegration (8, 9). However, later clinical and experimental evidence revealed that implants osseointegrate even when left exposed to the oral cavity during healing (12, 18, 33, 109, 123).

Experimental histological studies of clinically retrieved implants have shown similar, and sometimes improved, bone–implant contact with immediate-loaded implants compared with conventional implants (38, 60, 92–94, 99, 104, 119, 120). Piattelli et al. (92) compared the histology of non-submerged, unloaded and early-loaded titanium screw implants in monkeys. They found a tight contact of new bone to implant surfaces in all the samples examined. However, around the implant neck of early-loaded implants, they observed lamellar cortical bone that was thicker than that in unloaded implants. A pilot study in monkeys examined bony reactions to early-loaded titanium plasma-sprayed implants (93). Twenty implants were immediately loaded and four implants served as controls. The mean bone–implant contact of immediate-loaded implants was 67.2% in the maxilla (10 implants) and 80.71% for implants in the mandible (10 implants). Also, the bone of the loaded implants had a more compact appearance than that of controls. Testori et al. (119) reported bone–implant contact of 64.2% for a single immediate-loaded Osseotite implant (Biomet 3i, Palm Beach, FL, USA) compared to a bone–implant contact of 38.9% for a single submerged implant. Rocci et al. (99) retrieved nine oxidized titanium implants after 5–9 months in use. Two implants were loaded at the day of insertion and seven implants were loaded after 2 months of submerged healing. Eight of the implants were able to be used for histology. The mean bone–implant contact value was 92.9% for the two immediate-loaded implants and 81.4% for the six early-loaded implants. Despite the limited number of implants studied, immediate-loaded implants seem to yield a higher bone–implant contact value than non-immediate-loaded implants. Frost (60) postulated that not only excessive loading but also too modest loading of implants might result in a negative tissue response.

The present author studied immediate-loaded implants in total edentulous maxillae (84). One

hundred and twenty-six immediate-loaded implants were compared to 120 submerged implants with a healing period of 6 months. Resonance frequency analysis showed a tendency toward a more rapid increase in implant stability and less marginal bone resorption for the immediate-loaded implants compared with the submerged implants. Fischer & Stenberg (52) also found statistically less marginal bone resorption with immediate-loaded, sand-blasted, large-grit, acid-etched implants (Straumann, Basel, Switzerland) than with a delayed loading group of implants. Although more histological studies are needed comparing immediate-loaded with delayed-loaded implants, the available data indicate not only a similar but also a more beneficial bony response for immediate-loaded implants, at least for implants with a moderately rough surface topography.

Clinical outcome studies

Totally edentulous mandible

Early loading

Scientific reports in the past decade have described acceptable outcomes with early loading implants (17, 34, 45, 48, 50, 73). Engquist et al. (46) studied 108 patients with edentulous mandibles. Each patient was treated with a full fixed prosthesis attached to four Brånemark System implants (Nobel Biocare). Patients were distributed into four groups: group A (one-stage surgery), group B (two-stage surgery), group C (one-piece implants), and group D (early loading). Twenty-six patients in group D received a total of 104 implants. The healing time before loading the permanent fixed prosthesis ranged from 10 days to 3 weeks. Seven of the 104 (6.7%) implants in group D failed within 3 years of loading. In the control group (group B), three of 120 (2.5%) implants failed. The difference in failure rates between the two groups was not statistically significant. Patients in group D exhibited significantly less marginal bone loss than those in the control group, whereas no difference in marginal bone change was detected among patients in the other study groups.

Friberg et al. (56) studied 152 individuals with 750 Brånemark System implants of various designs placed in edentulous mandibles by means of one-stage surgery. The fixed prosthesis was inserted approximately 13 days after implant placement. A total of 18 implants in 12 patients in the study group were found to be mobile at the first annual check-up, equivalent to a 1-year implant cumulative survival

rate of 97.5%. The corresponding cumulative implant survival rate in the control group was 99.7%. The mean marginal bone resorption during the first year of function was 0.4 mm in both groups.

Immediate loading

Table 1 presents a summary of articles on immediate-loaded implants with a fixed prosthesis in the fully edentulous mandible.

Ledermann (74) showed as early as 1979 that immediate-loaded titanium plasma-sprayed screw implants (Straumann) could support overdentures in the mandible. The first report on immediate-loaded Brånemark implants with fixed prostheses was presented in 1990 by Schnitman et al. (108). Five or six Brånemark implants were placed between, and two additional fixtures were placed distally to, the mental foramina. Three of the installed implants in strategic positions were connected to a provisional prosthesis, converted from the patient's denture. The remaining fixtures were allowed to heal in a conventional manner. The authors concluded that the implant treatment was successful in seven patients, who were reconstructed with a mandibular fixed-detachable bridge without ever wearing a removable prosthesis. Also, the overall, long-term implant therapy was not adversely affected by using the immediate-loading technique. In a follow-up study by Schnitman et al. (107), 28 Brånemark implants in 10 patients were immediately loaded with a screw-retained fixed provisional prosthesis. Four (15.3%) of the immediate-loaded implants failed, while all implants with a conventional healing time survived. Statistical analysis showed a significantly higher failure rate for the immediate-loaded implant group. The authors concluded that although immediate-loaded implants in the mandible in the short-term can support a fixed provisional prosthesis, the long-term prognosis is guarded for implants placed into immediate function distally to the incisor region.

Ten consecutive patients were treated by Tarnow et al. (114) with immediate-loaded implants. A minimum of 10 implants was placed in each patient's arch, and a minimum of five submerged implants was allowed to heal without loading. The remaining implants were loaded at the day of stage 1 surgery. All 10 patients received a fixed provisional prosthesis at the time of stage 1 surgery, and all were restored with a definitive prosthesis. Two implants that had been immediately loaded and one of the submerged implants failed. The authors concluded that immediate loading of multiple implants, which are rigidly splinted, can be a viable treatment modality in a

Table 1. Immediate-loaded implants with fixed prosthesis in the totally edentulous mandible

Authors	Type of study	No. of patients	No. of loaded implants	Years of follow-up	No. of lost implants	Implant survival rate in %
Schnitman et al. (107)	Prospective	10	28	10	4	85.7
Tarnow et al. (114)	Prospective	6	36	1–5	2	97.4
Brånemark et al. (22)	Prospective	50	150	6 months to 3 years	3	98
Balshi & Wolfinger (16)	Prospective	10	40	1	8	80
De Bruyn et al. (37)	Prospective	20	60	1	6	90
Chow et al. (30)	Prospective	14	56	1	0	100
Testori et al. (116)	Prospective	15	103	4	1	98.9
Testori et al. (118)	Prospective / multicenter	62	325	1–5	2	99.4
Wolfinger et al. (125)	Prospective	24	144	3–5	5	97
Engstrand et al. (47)	Prospective	95	295	1–5	18	93.3
Henry et al. (68)	Prospective	51	153	1	14	91
Aalam et al. (1)	Prospective	16	90	3	3	96.6
Total		373	1480	–	–	94

completely edentulous jaw. Other investigators, who used the same study design of a mixture of submerged and non-submerged implants in the same patient, reported similar results (16, 125).

Studies have found three to be the minimum number of implants that is required to support a fixed partial denture in the totally edentulous mandible (22, 37, 47, 67, 68, 76, 96, 121). De Bruyn et al. (37) studied 19 patients, who received five implants in the mandible, of which three were functionally loaded using the one-stage technique. The loaded implants were inserted in a tripod position, one implant placed in the symphysis and two anterior to the mental foramen in the bicuspid area. Two additional implants were inserted for safety reasons but were not loaded. Immediately following surgery, the implants were loaded with a relined denture. The patients received a 10- to 12-unit prosthetic reconstruction 4–5 weeks after implant surgery. Six of the 60 functionally loaded implants (10%) and three of 20 prostheses (15%) failed within the first year. The authors concluded that the outcome of treatment with one-stage surgery using three implants to support a fixed mandibular arch reconstruction was less favorable than the expected outcome of a standard four- to six-implant construction.

At present, four to six implants in a fully edentulous mandible seem to be sufficient to retain a fixed

prosthesis with good long-term results. Chow et al. (30) studied 14 patients, each of whom had four implants placed in the interforamina area in the fully edentulous mandible. The implants were loaded within 24 hours with a screw-retained temporary prosthesis. At a 1-year follow-up the survival rate was 100%. Testori et al. (116) treated 15 patients who received a total of 103 Osseotite implants. The first two patients received both immediately loaded and submerged implants, while the remaining patients were treated with immediate-loaded implants. Temporary prosthesis was delivered 4–36 hours after implant insertion. Of the 92 immediate-loaded implants, one failed as the result of infection after 3 weeks. A cumulative success rate of 98.9% was achieved at 48 months, while the prosthetic cumulative success rate in the same period was 100%. The level of marginal bone loss for the immediate-loaded implants was similar to that described for implants inserted by a delayed loading protocol.

In a prospective four-center study, Testori et al. (118) examined 325 Osseotite implants in 62 patients. The temporary prosthesis was inserted 4 hours following implant surgery. Two implants failed to integrate within 2 months. A cumulative implant success rate of 99.4% was achieved over a period of 12–60 months (mean 28.6 months). Crestal bone loss around the immediate-loaded implants was similar

to that reported for standard delayed loading of implants. It was concluded that the rehabilitation of the edentulous mandible by an immediate-loaded protocol supported by five to six Osseotite implants represents a viable treatment alternative to delayed loading protocols.

Aalam et al. (1) studied 16 patients with completely edentulous mandibles, who received a total of 90 immediate-loaded Brånemark System Mk III implants (Nobel Biocare) with cross-arch screw-retained hybrid prostheses. Seventy-seven (85.5%) of the dental implants were placed in high-density bone. At the 3-year follow-up, three implants failed to meet the criteria of success, bringing the cumulative success rate to 96.6%. The prosthetic success rate was 100%. The average bone loss was 1.2 ± 0.1 mm.

Conclusion for immediate-loaded implants in the fully edentulous mandible

Survival/success rates of immediate-loaded implants should be compared with those of the classic two-stage implant approach. In the fully edentulous mandible, an immediate-implant survival rate of 99% after 15 years was reported by Lindquist et al. (77). The use of three immediate-loaded implants to carry a fixed prosthesis has resulted in survival rates ranging from 90 to 98%. Obviously, re-treatment and extra expense are required if an implant is lost, but a lower number of implants initially reduces the up-front costs of therapy. Four or more immediate-loaded implants are sufficient to support a fixed prosthesis in the totally edentulous mandible, with a success rate of 95–100%. However, patient selection must be considered if predictable, high success rates are to be achieved. The slightly lower survival rate of immediate-loaded implants compared with the two-stage implant approach may be acceptable when considering the benefits of immediate handicap reduction, one-time surgery, and fewer total visits to the dental office.

Totally edentulous maxilla

There are relatively few long-term data on immediate-loaded implants in the fully edentulous maxilla, and most papers are case reports (41, 65, 69, 83, 114).

Early loading

Fischer & Stenberg (53) studied early implant loading of 24 patients with completely edentulous maxillae, randomized into a test group of 16 patients and a control group of eight patients. All patients received five or six solid, screw-type titanium implants with

sandblasted, large-grit, acid-etched surfaces. In total, 142 implants were placed and 139 implants were loaded with full-arch prostheses. The cumulative implant success rate after 3 years of loading was 100%. The 3-year radiographic evaluation showed less marginal bone resorption in the early-loaded group compared to controls. No significant differences between the study groups were noted for any other outcome measures. The authors concluded that the early loading protocol was a viable alternative to the standard protocol in the rehabilitation of the fully edentulous maxilla with an implant-supported fixed prosthesis.

Olsson et al. (90) studied 10 patients with a total of 61 oxidized titanium implants over a period of 1 year. The patients had received a fixed full-arch provisional bridge in the maxilla at 1–9 days after implant placement. Nine patients had six implants and one patient had eight implants supporting the bridge. The provisional bridge was replaced with a permanent bridge after 2–7 months of loading. Four implants failed (6.6%), and they were all lost as the result of infection in one patient after 10 weeks of loading. The remaining 57 implants were clinically stable with a mean marginal bone loss of 1.3 mm after 1 year of loading.

Immediate loading

Table 2 presents a summary of articles on immediate-loaded implants with a fixed prosthesis in the totally edentulous maxilla.

The survival rate of 168 immediately loaded sandblasted, large-grit, acid-etched implants in the edentulous maxilla of 28 patients after 8 months of loading was evaluated by Bergkvist et al. (19). Each patient received a fixed provisional prosthesis within 24 hours of implant surgery. After a mean healing time of 15 weeks, the patient received a definitive, screw-retained, implant-supported fixed prosthesis. Three implants failed during the healing period (1.8%). The mean marginal bone resorption was 1.6 mm during an 8-month follow-up. The authors discussed the importance of splinting implants immediately after placement.

Ibanez et al. (71) treated 26 patients who had fully edentulous maxillae with implants that were loaded within 48 hours with either resin provisional prostheses, metal-reinforced provisional prostheses, or definitive prostheses (metal–acrylic or metal–ceramic). Double acid-etched surface implants (Osseotite) were used, and patients were followed for 12–74 months. The success rate was 100% after 12–74 months. The average radiographic bone level

Table 2. Immediate-loaded implants with fixed prosthesis in the totally edentulous maxilla

Authors	Type of study	No. of patients	No. of loaded implants	Years of follow-up	No. of lost implants	Implant survival rate in %
Tarnow et al. (114)	Prospective / cross-sectional	4	14	1–4	0	100
Horiuchi et al. (69)	Prospective / cross-sectional	5	44	1–2	2	96.5
Grunder (65)	Retrospective / cross-sectional	5	48	1–5	6	87.5
Bergkvist et al. (19)	Prospective	28	168	8 months	3	98.2
Degidi et al. (39)	Retrospective	43	388	5	8	98
Balshi et al. (15)	Prospective	55	522	1	5	99
Östman et al. (84)	Prospective	20	123	1	1	99.2
Fisher et al. (53)	Prospective	24	139	3	0	100
Total		184	1446	–	–	97.3

change was 0.56 mm at 12 months and 0.94 mm at 72 months. The authors concluded that a high success rate could be achieved when double acid-etched surface implants were immediately loaded with fixed full-arch restorations in the maxilla.

Forty-three patients with a total of 388 implants (mean nine implants per patient) were studied by Degidi et al. (39). Their implants were loaded with cross-arch acrylic provisional restorations at the time of implant surgery and at the 5-year follow-up, the survival rate was 98%. All failures occurred within 6 months of loading. The authors concluded that immediate functional loading was a reliable surgical-prosthetic procedure in edentulous maxillae. Their findings also suggested that implants with a wider diameter were associated with a higher risk of failure.

Balshi et al. (15) included 55 patients in an investigation of immediate functional loading of 552 Brånemark System implants placed in immediate extraction sockets or in healed sites of edentulous maxillae. A mean number of 10 implants were placed per patient. All implants were immediately loaded with screw-retained, all-acrylic, fixed prostheses at the time of implant surgery. Each patient received a definitive metal-reinforced prosthesis 4–6 months after surgery. The immediate-loaded implants had a cumulative survival rate of 99.0%, and the prosthesis survival rate was 100%.

Conclusion of immediate-loaded implants in the fully edentulous maxilla

Few studies have been published on immediate-loaded implants in the edentulous maxilla. Most papers report treatments using a high number of implants,

more than six, to support the prosthesis. Three studies on early loading and one study on immediate loading with six to eight implants report implant survival rates from 93.4 to 100% after 1–3 years, which is comparable with the 5-year survival rates reported for two-stage implant protocols. One study presenting 5-year data found no change in survival rate after initial failures that had occurred during the first 6 months (39). The data indicate that if good primary implant stability is achieved in sites with medium to dense bone quality, a successful outcome of immediate-loaded implants in the fully edentulous maxilla can be expected. However, more long-term data are needed before immediate loading of implants can be recommended as a standard procedure in the maxilla.

Partially edentulous maxilla / mandible

Early / immediate loading is theoretically more challenging in the partially edentulous maxilla / mandible compared to the totally edentulous jaw. Implants in partially edentulous patients are fewer and are often placed in a straight line and therefore exposed to lateral forces, whilst implants in edentulous patients can be placed in an arch shape to efficiently counteract bending forces. Moreover, the posterior region of the oral cavity usually has less dense bone and experiences stronger bite forces compared to the anterior part of the mouth (21). However, histological studies have shown favorable results with immediate implant loading in the posterior mandible. For instance, Rocci et al. (99) retrieved nine oxidized Brånemark implants; two implants were loaded on

the day of implant surgery and seven implants were loaded after 2 months of healing. A gross histological examination showed an undisturbed healing pattern of mucosal and bony tissues with no apparent difference in tissue response between immediate-loaded and early-loaded implants. Lamellar bone surrounded the implants with evidence of bone remodeling, which was most pronounced close to the implant surface. Morphometric measurements showed bone-implant contact values as high as 84–92%.

Early loading

Testori et al. (115) reported on 475 Osseotite implants in a longitudinal, prospective, multicenter study of early implant loading. All implants were placed in the posterior region of 175 patients and restored within 2 months. Six of the 475 implants were classified as early failures and three implants were classified as late failures, giving a cumulative survival rate of 97.7% after 3 years. Cochran et al. (31) presented a longitudinal, prospective, multicenter study on 383 sandblasted, large-grit, acid-etched implants placed in the posterior jaws of 307 patients. Healing time was 42 to 63 days for implants in class 1–3 quality bone and 105 days for class 4 bone. At the time of abutment placement, three implants were mobile and removed. In addition, three implants were not rotationally stable and six were associated with pain. These nine implants were allowed to heal and eventually became stable. The survival rate after 1 year was 99.1%. Rocuzzo & Wilson (103) reported on 36 implants placed in the posterior maxilla of 29 non-smoking patients. Abutments were placed after 43 days and the implants were loaded with a temporary bridge in infraocclusion. After an additional 6 weeks the definitive prosthesis was inserted. One implant failed, giving a survival rate of 97.2% after 1 year of loading. In a split-mouth prospective study, Rocuzzo et al. (102) compared 68 sandblasted, large-grit, acid-etched implants loaded 6 weeks after implant surgery and 68 titanium plasma-sprayed screw implants loaded 12 weeks after implant surgery. Four of the 68 sandblasted, large-grit, acid-etched implants were rotationally unstable at 6-week abutment placement and were allowed to heal for an additional 6 weeks. After 1 year, a 100% survival rate was noticed for both groups of implants, and no significant differences in clinical and radiographic measurements could be observed between the two groups.

A multicenter 1-year follow-up study of an immediate / early loading implant protocol in the posterior

maxilla and mandible was reported by Luongo et al. (79). Eighty-two sandblasted, large-grit, acid-etched implants in 40 patients were loaded between 0 and 11 days after implant placement. For inclusion in the study, two implants had to support either two splinted crowns or a three-unit bridge. The torque value was between 15 and 45 N cm. Four sites had a bone quality of 4. One implant failed during the first year, giving an overall survival rate of 98.8%. The mean bone loss at 1 year was 0.52 ± 0.98 mm. The authors concluded that early and immediate loading of two implants in the posterior maxilla or mandible may be suitable in selected patients. On the basis of 1 year of observation, the results appeared similar to those achieved with a delayed loading implant protocol.

Vanden Bogaerde et al. (122) included 31 consecutive patients in a multicenter study. A total of 111 implants were inserted in 37 edentulous areas. Of these, 69 implants were inserted in 22 partial edentulous ridges in the maxilla, and 42 implants were inserted in 15 partial edentulous posterior ridges in the mandible. Bruxism and uncontrolled periodontal disease were exclusion criteria. Temporary prostheses were generally placed within 9 days of, but not 16 days after, the time of implant placement. Of the 111 implants installed, one failed, giving an overall survival rate of 99.1% after 18 months. The failed implant was located in the posterior maxilla. The prosthesis survival rate was 100%. The marginal bone resorption from readable (about 85%) radiographs was 0.8 mm. The authors concluded that a clinical protocol, aimed at achieving high primary implant stability, which uses oxidized titanium implants for early functional loading in the maxilla or in the posterior mandible, can result in a high implant survival rate and a favorable marginal bone level.

A prospective controlled clinical trial by Salvi et al. (105) evaluated the effect of early loading of sandblasted, large-grit, acid-etched implants. Twenty-seven consecutively admitted patients with bilateral edentulous posterior mandibular areas were included. Sixty-seven implants were installed bilaterally in the molar and premolar regions according to a one-stage surgical protocol. One week (test) and 5 weeks (control) after implant placement, abutments were connected using a torque of 35 N cm. No provisional restoration was used. Two test implants and one control implant rotated at the time of abutment connection and were left unloaded for a further 12 weeks. Two weeks (test) and 6 weeks (control) after implant placement the porcelain-fused-to-metal, single-tooth crowns were cemented. After 1 year, the implant survival rate was 100%. At the 1-year

examination, no statistically significant differences were found between the test and control sites with respect to pocket probing depth, mean clinical attachment level, mean percentage of sites bleeding on probing, mean width of keratinized mucosa, mean PerioTest values or mean crestal bone loss measurement. The authors concluded that early implant loading (2 weeks) did not appear to jeopardize the osseointegration healing process in the posterior mandible.

Immediate loading

Table 3 presents a summary of articles on immediate-loaded implants with a fixed prosthesis in the partially edentulous maxilla / mandible.

Rocci et al. (101) studied immediate-loaded implants with partial fixed dentures in the posterior mandible. Forty-four patients were randomized for test and control therapy. In the test group, 22 patients received 66 Brånemark System TiUnite surface implants (Nobel Biocare) supporting 24 fixed partial bridges, all of which were connected on the day of implant insertion. In the control group, 22 patients received 55 Brånemark System turned-surface implants supporting 22 fixed partial bridges, which were also connected on the day of implant insertion. All restorative constructions were two- to four-unit bridges. Three TiUnite and eight turned-surface implants failed during the first 7 weeks of loading. The cumulative success rate was 95.5% for TiUnite

surface implants after 1 year of prosthetic loading in the posterior mandible. The corresponding cumulative success rate for turned-surface implants was 85.5%. The marginal bone resorption after 1 year of loading showed no difference between the two types of implants. The authors concluded that a rough surface, such as that of TiUnite implants, provided a 10% decrease in failure rate compared to turned implants.

Drago & Lazzara (42) reported on 93 Osseotite implants that were restored with fixed provisional crowns without occlusion immediately after implant placement. Thirty-eight partially edentulous patients were included in the study. All implants were immediately restored with pre-fabricated abutments and cement-retained provisional crowns without centric or eccentric occlusal contacts. Definitive restorations were inserted approximately 8–12 weeks after implant placement. All patients included in the study were followed for at least 18 months after implant placement. Seventy-seven of the 93 implants satisfied the inclusion criteria, and 75 implants became osseointegrated. The overall implant survival rate was 97.4%. Bone loss on radiographs at 18 months after implant placement (the mean of both interproximal surfaces) was 0.76 mm.

Twenty chronic periodontitis patients, who were treated with implants in the partially edentulous mandible, were studied by Machtei et al. (80). Five of the 49 (10%) implants failed. The authors concluded

Table 3. Early / immediate-loaded implants with fixed prosthesis in the partially edentulous maxilla / mandible

Authors	Type of study	Immediate / early loading	No. of patients	No. of loaded implants	Years of follow-up	No. of lost implants	Implant survival rate in %
Testori et al. (115)	Prospective	Early (2 months)	175	405	3	9	97.7
Cochran et al. (32)	Prospective	Early (3 weeks)	307	383	1	3	99.1
Roccuzzo et al. (103)	Prospective	Early (6 weeks)	29	36	1	1	97.2
Roccuzzo et al. (102)	Prospective	Early (6 weeks)	32	68	1	0	100
Luongo et al. (79)	Prospective	Early	40	82	1	1	98.8
Vanden Bogaerde et al. (122)	Prospective	Early	31	111	1	1	99.1
Rocci et al. (101)	Prospective	Immediate	22	55	1	3	95.5
Östman et al. (86)	Prospective	Immediate	77	257	1–4	4	98.4
Schincaglia et al. (106)	Prospective	Immediate	20	44	1	2	95
Cornellini et al. (35)	Prospective	Immediate	20	40	1	1	97.5
Machtei et al. (80)	Prospective	Immediate	20	49	1	5	90
Total			159	445	–	–	96.6%

that immediate loading protocols provide a predictable therapy in periodontally susceptible patients, but careful consideration should be given to implants placed in the molar region.

Schincaglia et al. (106) studied 10 patients with bilateral partially edentulous posterior mandibles. A split-mouth study design compared implants with either a turned surface or a titanium oxide surface. Forty-two implants, 20 test and 22 control, were placed and loaded within 24 hours. No implant was lost in the test group and two failed in the control group. The overall implant success rate was 95%. No statistically significant difference was seen between the test and control groups although there was a tendency to less bone resorption in the test group. The authors concluded that immediate loading of implants in the posterior mandible may be an acceptable treatment option if implants are inserted with a torque exceeding 20 N cm and show an Implant Stability Quotient value above 60 N cm.

Twenty patients were treated by Cornelini et al. (35) with a total of 40 immediate-loaded implants supporting 20 three-unit bridges in the posterior mandible. At 1-year follow-up, one implant had failed, giving a survival rate of 97.5%.

Conclusion of immediate-loaded implants in the partially edentulous maxilla / mandible

The longest published follow-up period of early loading implants is 3 years and of immediate-loaded implants is 1 year. The published implant survival rate ranges from 85 to 98.8%, which is less than the 5-year survival rates of 94–96% obtained for two-stage implant procedures. More long-term studies are needed before immediate loading of implants can be recommended as a standard procedure in the posterior maxilla / mandible.

Early / immediate loading implants for single-tooth replacement in the maxilla / mandible

Single tooth loss is probably the most common indication for implant placement (112). The loss of a single tooth is a traumatic experience for many patients and early / immediate implant loading is therefore an attractive treatment option. On the other hand, single teeth replaced by implants in the aesthetic zone are one of the most challenging situations facing a clinician, even when using a two-stage implant protocol. Careful assessment must be made of mucosal and bone volumes in relation to implant placement. In case of significant bone resorption,

bone and mucosal augmentation procedures may be needed. A retrospective study by Vermeylen et al. (124) determined patient opinion and professional evaluation of 43 implant supported single-tooth restorations. Single implant crowns were evaluated according to design, fit, occlusion / articulation, and aesthetics. Patients were very positive with regard to aesthetics, phonetics, eating comfort, and overall satisfaction. Nevertheless, six of the 40 patients would not undergo the same treatment again, although all patients would recommend the treatment to others.

Early loading

Andersen et al. (10) evaluated immediate / early loading of single-tooth implants in the maxilla. Temporary acrylic resin restorations, which were fabricated from impressions obtained immediately after implant placement, were connected 1 week later. The temporary restorations were adjusted to avoid any direct occlusive contacts. At 6 months, the provisional crowns were replaced by definitive ceramic crowns. If the strict definition of immediate loading (within 24 hours) is used, this article describes a group of early-loaded implants. Eight implants in eight different patients were followed for 5 years. No implant was lost, and the mean marginal bone level for the eight implants increased by 0.53 mm between placement and the final examination. Only minor complications were noted, and overall patient satisfaction was high.

Immediate loading

Table 4 presents a summary of articles on immediate-loaded single implants in the maxilla / mandible.

Ericsson et al. (49) performed a prospective study on single tooth replacements with artificial crowns retained to implants installed according to an immediate loading protocol and compared that to the original two-stage implant procedure. The immediate loading group comprised 14 patients (14 implants) and the two-stage control group comprised eight patients (eight implants), all with single tooth losses anterior to the molars. The patients had to be non-smokers and have sufficient bone to receive a 13-mm implant with the regular platform diameter of 3.75 mm. Moreover, the jaw relationship had to allow for bilateral occlusal stability and the patients had to be judged as not displaying bruxism. In the immediate-loaded group, a temporary crown was connected to the implant within 24 hours following implant installation, and the permanent crown was installed at 6 months. Of the 14 implants

Table 4. Early / immediate-loaded implants with single restorations in the maxilla / mandible

Authors	Type of study	No. of patients	No. of loaded implants	Years of follow-up	No. of lost implants	Implant survival rate in %
Andersen et al. (10)	Retrospective / Early loading	8	8	5	0	100
Ericsson et al. (49)	Prospective	14	14	1	2	86
Hui et al. (70)	Prospective	24	24	1–15 months	0	100
Calandriello et al. (28)	Prospective	44	50	6–12 months	0	100
Rocci et al. (100)	Retrospective	27	27	3	5	81
Lorenzoni et al. (78)	Retrospective	12	12	1	0	100
Digidi et al. (40)	Retrospective	111	111	5	5	95.5
Total		240	246	–	–	95.2

in the immediate-loaded group, two (14%) were lost after 5 months in function. The remaining 12 implants were stable. No implant losses were recorded in the traditional two-stage protocol group and all implants were stable at follow-up. The radiographic analysis at the 12-month follow-up showed a mean loss of bone support of about 0.1 mm for both implant groups.

Twenty-four patients who had received single-tooth implants according to an immediate-loaded implant placement protocol were evaluated by Hui et al. (70). Thirteen of the 24 patients received the implants immediately after tooth extraction. All implants were placed in the aesthetic zone. The surgical protocol aimed to enhance primary implant stability with a minimum insertion torque of at least 40 N cm. Within a follow-up period of 1 month to 15 months, all implants in the 24 patients were stable. A crestal bone loss greater than one implant thread was not detected. All patients considered the aesthetic result to be satisfactory.

Calandriello et al. (28) reported on a prospective multicenter study including 44 patients with a total of 50 Brånemark System TiUnite Wide-Platform implants (Nobel Biocare). All implants received provisional crowns in centric occlusion at the time of surgery. No implant was lost at the 6-month and the 1-year follow-ups. Marginal bone level was found to be in accordance with normal biological width requirements. Resonance frequency analysis showed high and consistent implant stability.

Rocci et al. (100) evaluated 97 Brånemark System Mk IV implants that were placed flapless and immediately loaded; 27 of the implants were single-

unit restorations. Nine implants in eight patients failed during the first 8 weeks of loading. Five of the eight patients lost single-tooth implants, of which two had been inserted in fresh extraction sites. Three patients lost four implants incorporated in fixed prosthesis restorations. After 3 years of prosthetic load, the survival rate for implants with fixed prostheses was 94% and that with single implant restorations was 81% ($P = 0.04$). The marginal bone resorption was on average 1.0 mm during the first year of loading, 0.4 mm during the second year, and 0.1 mm during the third year.

The clinical outcome of immediate-loaded FRIALIT-2 Synchro implants (FRIADENT GmbH, Mannheim, Germany) was evaluated by Lorenzoni et al. (78) 12 months after placement in the maxillary anterior region. The implants were inserted with an increasing torque of up to 45 N cm. All implants were immediately restored with unsplinted acrylic resin provisional crowns and the patients were provided with an occlusal stent. No implant failed within 12 months of insertion, providing a survival rate of 100%. The authors noted on radiographs taken after 6 and 12 months that coronal bone resorption was less than that of implants placed by a standard two-stage procedure.

Digidi et al. (40) evaluated 111 single implants that non-functionally had been immediately loaded. All implants were placed with a minimum insertion torque of 25 N cm. During 5 years of follow-up, the implant survival rate was 95.5%. A statistically significant difference in implant survival rate was found for healed and fresh-extraction implant sites (100% and 92.5%, respectively) and for type 1 and 4 quality bone (100% and 95.5%, respectively).

Conclusion of immediate-loaded single implants in the partially edentulous maxilla/mandible

The longest follow-up period recorded is 5 years for early-loaded and 1 year for immediate-loaded implants. The overall implant survival rate in available papers ranges from 81 to 100%. Additional long-term studies are needed before immediate-loaded single implants can be recommended as a standard procedure in the maxilla/mandible.

A practical concept for treatment with immediate-loaded implants

The present author has, since 1998, developed and evaluated a therapeutic concept for immediate loading of implants. A total of 1,420 immediate-loaded implants, with a minimum of 3 years follow-up, in 519 patients has been inserted on a variety of indications following a protocol aimed at reducing negative biomechanical factors. Emphasis is placed upon obtaining firm primary implant stability, as measured by insertion torque and resonance frequency analysis, to allow splinting within 12 hours in a fixed bridge construction with controlled occlusion. Part of the concept is also the use of surface-modified implants, which in challenging clinical situations are believed to perform better than turned implants. The period of evaluation ranged from 3 to 7 years.

Table 5 shows a summary of two-stage vs. immediate-loaded implant placement. A total of 670

implants were placed by a two-stage method and 1,303 implants were immediately loaded. Excluded from this summary are two cases of Teeth-in-an-Hour implants (Nobel Biocare) and 48 cases of Nobel Direct implants; the problems with the latter implant system have already been discussed in this article. No statistically significant difference in clinical outcome was found between the two-stage and the immediate-loaded implants. A failure rate of 1.0% was seen in the two-stage group compared to 1.2% in the immediate-loaded group.

Treatment planning

Today, most patients seeking implant treatment are not totally edentulous. If following a traditional protocol, a 4- to 6-month healing time after tooth extraction would be standard. In addition, a two-stage procedure often requires a healing time of 4–6 months. In other words, a complete implant treatment often takes 8–12 months (Fig. 1A). During that time, the patient is wearing a removable denture or, worse, no dentures. As therapists, we have to cause as little dental handicap as possible to our patients. Therefore, the first task in planning an implant therapy is to evaluate whether some teeth can remain during the primary healing phase of bone and mucosa. Fig. 1(B–E) illustrate different options for oral rehabilitations without using a complete denture during primary healing. Key teeth, such as canines, can often be maintained and used in a temporary bridge construction during the healing phase. By leaving some strategic teeth, the dentist has

Table 5. Outcome summary of two-stage vs. immediate-loaded implants

	Two-stage implants			Immediate-loaded implants			Total patients/implants		
	No. (%) of patients	No. (%) of implants	No. (%) of failed implants	No. (%) of patients	No. (%) of implants	No. (%) of failed implants	Total no. of patients	Total no. of implants	Total no. of failed implants
	279 (38%)	670 (34%)	7 (1.0%)	453 (62%)	1303 (66%)	16 (1.2%)	732	1973	23
Site of implant placement									
Total mandible	0	0	0	88	388	4 (1%)	88	388	4
Total maxilla	44	261	4 (1.5%)	56	336	1 (0.3%)	100	597	5
Partial mandible	22	45	0	149	350	4 (1.1%)	171	395	4
Partial maxilla	95	246	2 (0.8%)	41	110	3 (2.7%)	136	356	5
Single mandible	39	39	0	55	55	3* (5.4%)	94	94	3
Single maxilla	79	79	1 (1.3%)	64	64	1 (1.5%)	143	143	2

*All first or second molars, without posterior tooth protection.

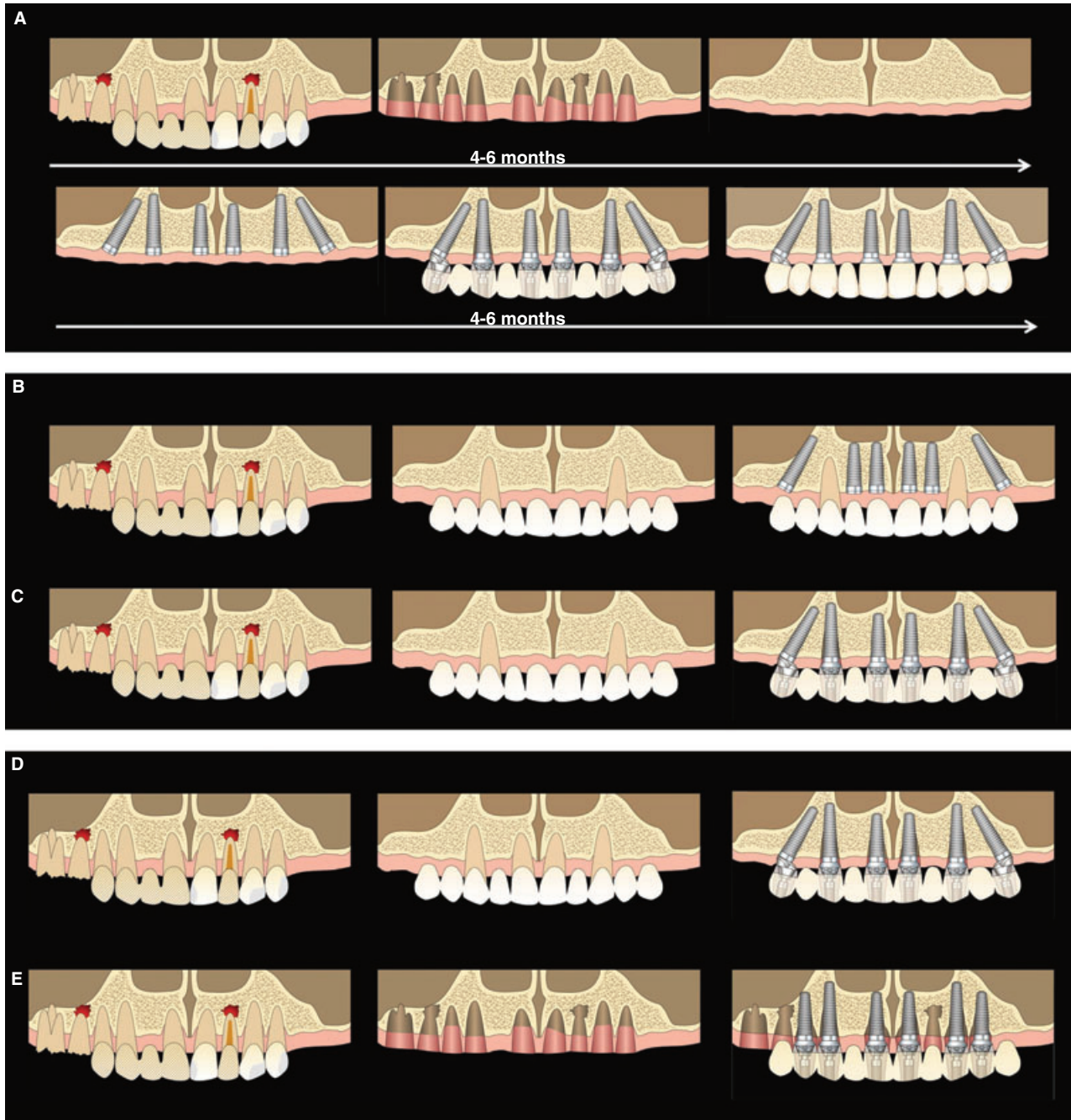


Fig. 1. Different approaches to maintenance of teeth during implant treatment. (A) A traditional implant protocol that requires a 4- to 6-month healing time after tooth extraction and an additional 4–6 months for sub-

merged healing. (B–E) Different options for oral rehabilitation without using a complete denture during the primary healing phase.

not only helped the patients but also provided different treatment options. If the patient case is not suitable for immediate loading, a two-step procedure can be performed without leaving the patient orally handicapped with a removable prosthesis (Fig. 1B). If immediate loading is feasible, the remaining teeth can be extracted during surgery and replaced by implants (Fig. 1C). Fig. 1(D) shows a patient in which both canines and first incisors were left during primary heal-

ing. At the time of implant surgery, the posterior maxillary region has healed sufficiently to place implants in a tilted position to allow for adequate space between individual fixtures. The remaining implants are placed in fresh extraction sites or in healed bone adjacent to the extraction socket. In the latter situation, it can be difficult to achieve optimal fixture position. Fig. 1(E) illustrates a treatment option with all implants placed in extraction sites. However,

such treatment may give rise to a less predictable healing of bone and mucosa.

Patient selection

Inclusion criteria

Candidates for immediate loading implant therapy must often receive occlusal and articulation adjustment before or during the temporary phase to avoid unnecessary trauma to the fixtures. As the final decision of immediate loading is made at the time of implant surgery, the type of fixed restoration should not be promised to patients before the placement of the fixtures.

Exclusion criteria

Patients who are skeptical about the concept of immediate-loaded implants are not candidates for this type of treatment. One firm contraindication for immediate loading is a history of implant failure. Also, irradiated cancer patients and smokers with uncontrolled diabetes are poor candidates for immediate-loaded implants. Less strict contraindications are factors such as bruxism, large deviations in sagittal/vertical bite relations, and deep bite that may influence the loading of implants in an unfavorable way.

Clinical assessments during surgery

Bone quality/quantity

Bone quantity and quality at the implant site are the most important parameters in immediate-loading protocols. Critical bone features are difficult to evaluate solely by radiography. The Lekholm & Zarb (75) index originally served to standardize preoperative planning of an implant case to make the outcome of various studies comparable. However, this author suggests that the precise bone quality can only be determined pre-operatively. Bony features differ within the edentulous jaw of the same patient, which often necessitates a site-specific analysis.

Class 4 quality bone is often referred to as 'poor' bone for implants because it is soft, which from a biomechanical view can challenge efforts to obtain a firm initial stability for an implant. Jaffin & Berman (72) showed a high implant failure rate (35%) in class 4 bone. In a study of early outcome of 4,641 Brånemark fixtures, Friberg et al. (57) concluded that most implant losses occurred in fully edentulous maxillae, in which the jawbone exhibited soft quality and severe resorption. More than 40% of class 4 bone

gives rise to implant failures. It should be emphasized that these pioneering works correlating bone quality with implant failure were conducted with turned implants and conventional protocols, involving pre-tapping even in bone of class 4 quality. From a biological point of view, trabecular bone represents a superior tissue compared to cortical bone. Trabecular bone exhibits a high surface area, which is contiguous with the bone marrow compartment (36), and bone healing is far more rapid compared to the healing pattern present in cortical bone.

Stability of an implant can be defined as its capacity to withstand loading forces in axial, lateral, and rotational directions. Sennerby & Roos (111) stated that primary implant stability is determined by bone quality and quantity, implant design, and surgical technique. Depending on bone quality and quantity, dentists need to adapt the drilling protocol and choice of fixture to the clinical situation to achieve sufficient primary implant stability.

Drill protocol, type of fixture, fixture diameter, numbers, and degree of countersink

The ability of the dentist to judge the implant site is of critical importance in succeeding with an immediate-loading protocol. Bone quality and quantity, as well as the thickness of cortex, must be determined before proceeding to final drill and implant placement. Several scientific reports have described modified drill protocols according to varying bone quality (13, 14, 54, 59, 85). Östman et al. (85) analyzed a total of 905 Brånemark-type implants, which, depending on differing bone quality, were placed by using varying final drill diameters and implant designs. Implant stability was assessed by resonance frequency analysis at the time of placement surgery. The influence of different patient, implant, and surgical factors on implant stability was estimated. It was concluded that high primary stability could be achieved in all regions of the jaw when using an adapted surgical protocol. Although the use of thin drills and/or tapered implants cannot fully compensate for the effect of soft bone, slightly tapered or tapered implant design and implant surface modification can dramatically improve implant survival rate in soft bone. Glauser et al. (64) showed that significantly higher torque values were achieved if pre-tapping was avoided before placing MKIV (Nobel Biocare) implants in class 3 bone. Friberg et al. (58) showed that the slightly tapered MKIV implant more frequently required a higher insertion torque and showed a significantly higher primary stability compared to standard implants. The difference in implant

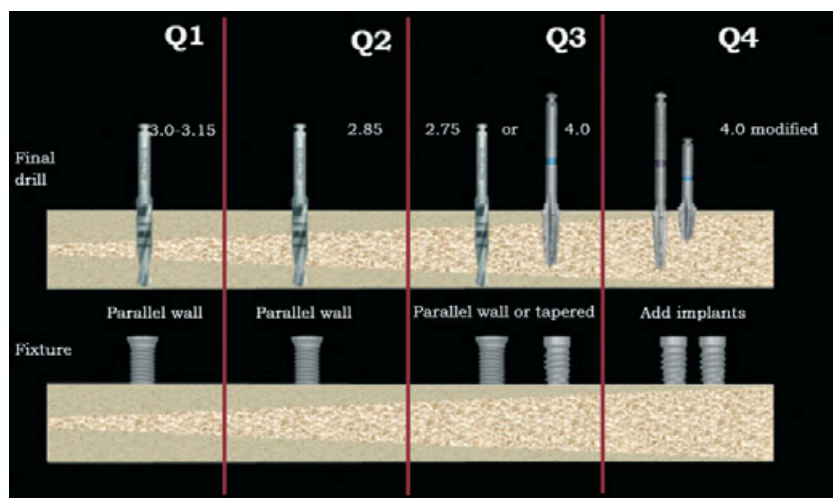


Fig. 2. Type of final drill and implant with various bone densities to obtain high initial implant stability.

stability leveled off over time, and the two different implants exhibited similar secondary stability at abutment placement and at the 1-year follow-up visit. The author's own results (84) showed a high survival rate (99.2%) of immediate-loaded implants in the fully edentulous maxilla when using adapted surgical protocol and slightly tapered (MKIV) or tapered Replace Select Tapered implants, even in bone of quality class 3 and 4.

Besides a modified drill protocol and implant design, enhanced primary stability can be accomplished by choosing a wider implant diameter. A wider implant will engage the buccal and palatal compacta bone more easily, and will enlarge the bone-metal surface contact. Our research group (125) found significant higher initial implant stability, measured with resonance frequency analysis, with wider implants compared to narrow / regular implant designs. Friberg et al. (55) suggested a drilling protocol that used a 3.0-mm end-burr, and a short-peg countersink to widen the implant site entrance enough to fit a 5.0-mm implant.

Cortical compacta bone differs both in thickness and density and is almost non-existent in class 4 bone. Pierrisnard et al. (95) showed that bony stress is concentrated in the cervical area of an implant. It is also assumed that the 1-mm cervical cortical bone layer serves as the major anchoring point for an implant. In the case of a thin cortex, countersinking is not recommended at all. Thus, the final burr diameter and countersinking should not be standardized to fit all clinical situations.

Recommendation for drill protocol with various bone quality

The following guidelines are based on the 3.75-mm diameter, straight cylindrical implant design (e.g.

Brånemark MKIII, Osseotite), the slightly conical implant design (MKIV), and the tapered implant design with a diameter of 4.3 mm [e.g., Replace Select Tapered, Nanotite NT (Biomet 3i)]. The final torque should be between 30 and 50 N cm. It is recommended to start with a thinner final drill. Two options exist if the bone quality is misjudged and the implant stops at 50 N cm before being finally seated; either unscrew the implant and choose a wider final drill, or manually, with a torque wrench, tighten the implant into position, thereafter loosening the fixture by reverse torque and then using a machine at 50 N cm seating the implant to its final depth. Those methods aim to eliminate the risk of over-tightening the implant. Fig. 2 describes the recommended type of final drill and implant with bone of various density.

Distribution of implants

The biomechanical rules in implant treatment have long been known and should be adhered to ensure a successful outcome. A carefully planned / treated implant patient has by the far best long-term prognosis. To allow implants to osseointegrate without unnecessary stress is of utmost importance in placing immediate-loaded implants. Implants should preferably be positioned in a tripod or horseshoe pattern.

Evaluation of installed implants

A final torque of 30 N cm and an implant stability quotient above 60 is needed to securely insert immediate-loaded implants. Deviation from this rule can be made if several implants are inserted in the maxilla or the mandible in a cross-arch pattern. The most posterior implant should always show a torque of 30 N cm and an implant stability quotient of 60 or higher. If not achievable, the implant placement may proceed as a two-step procedure.

Post-operative care

During the initial 10-day post-operative period, it is recommended that the patient consume soft food, rinse twice daily with chlorhexidine, and, perhaps, take penicillin-V to minimize the risk of infection.

Prosthetic considerations

Splinting by a temporary construction

Different approaches to temporary denture construction are available to implant patients. Dental technicians, for example, may convert an existing denture into an acrylic bridge. Compared to making a chair-side temporary construction, laboratory procedures are well controlled and provide a better finish and aesthetics, and possibly reduce the risk for contamination of newly operated areas. On the other hand, a laboratory-produced temporary construction tends to be more expensive and have a longer production time. Temporary constructions made chair-side have the advantage of immediate handicap reduction, immediate splinting, cost effectiveness, and installation during the anesthesia phase of implant placement.

Several papers on implant-supported dental prostheses argue that splinting reduces the occlusal load transfer more effectively than freestanding implant units. According to Glantz et al. (62, 63), favorable loading conditions are achieved via a rigid implant supported bridge. Conceivably, splinting of implants to each other via a temporary bridge decreases micromotions at the bone-implant interface, which in turn helps to reinforce osseointegration. Therefore, a provisional bridge should be connected to implants as soon as possible after fixture placement.

Splinting provides an option for reducing lateral forces on implants, if three or more implants are placed in a tripod or a cross-arch configuration (97, 98). Such positioning allows lateral forces to be converted to more favorable axial implant forces. Two splinted implants will not offer the same load reduction because they will be placed 'in-line' with no offsetting counteracting lateral forces. The benefit of cross-arch stabilization is well-documented clinically (81, 82) and by load measurements *in vivo* (44).

Reduction of micromotion

The degree of micromotion of implants can be of major importance for implant integration. It has even been postulated that the absence of micromotion of an implant is more important for osseointegration

than the timing of implant loading. Brunski (23) proposed the threshold level of micromotion for a turned implant to be 100 μm . Søballe et al. (113) suggested the acceptable micromotion for roughened implants to be 50–150 μm .

Prosthetic procedures

Chair-side-made temporary bridge – according to the QuickBridge™ concept

The QuickBridge™ concept from Biomet 3i aims to convert a screw-retained temporary prosthesis to a cement-retained temporary prosthesis during the healing period. The QuickBridge components fit onto conical abutments and consist of two parts. A conical titanium alloy part is mounted, with an integrated screw, onto the conical abutment, and a PEEK (polyetheretherketone) plastic cap, which covers the abutment (Fig. 3A), will become part of the provisional prosthesis. The retention of the PEEK cap to the titanium cone is firm, which will allow the provisional prosthesis to be retained only by a snap.

Fig. 3(A–R) shows a typical treatment of a partial/total implant treatment. The treatment starts with selective extraction and a fixed temporary denture during the healing period (Fig. 3B–D). Extraction of the remaining teeth can occur during implant surgery, if sufficient stability of the fixtures is obtained. Before surgery, an alginate impression of both jaws is made. In patients with full dentures, impressions are made of the denture. An occlusal record is preformed. At the dental laboratory, stone casts are made and placed in an articulator. In case of missing teeth, a tooth wax-up is made. A translucent vacuum template is fabricated using a 2.5-mm thick thermoformed material (ethyl-vinyl-acetate, Ergoflex 95, Erkodent®, Pfalzgrafeweiler, Germany). On the template, an impression is obtained of the opposite jaw to orient the template in the mouth.

The bony crest is exposed through a mid-crestal surgical incision. After reflecting the surgical flap, the optimal implant position is decided upon based on aesthetic and biomechanical considerations. Insertion torque and resonance frequency analysis measurements are used to check the stability of the fixtures and to evaluate the feasibility of employing immediate-loaded implants. Next, the conical abutments are mounted (Fig. 3E), and the QuickBridge™ titanium cone and PEEK cap are placed onto the conical abutments (Fig. 3F,G) before closing the surgical flap (Fig. 3H).

The translucent template is mounted to verify that the temporary parts fit the template. Protemp™ 3 Garant, (3M, ESPE, St Paul, MN, U.S.A.) is then injected into the template. The template is seated with guidance from adjacent teeth and/or the opposite jaw, and allowed to set for 4 minutes (Fig. 3I) while the patient is biting together. The temporary prosthesis is removed from the titanium interface and trimmed outside the mouth and remounted (Fig. 3J). During the initial healing time, which is approximately 10 days, the temporary prosthesis is fixed with a 1% chlorhexidine gel. Cantilevers cannot exceed 5 mm.

After an additional 3–6 months of healing, the temporary prosthesis is snapped off and impression copings are mounted on the titanium copings (Fig. 3K,L). A closed tray impression is then made. A translucent template bite registration is produced by filling the mould with bite registration material. This procedure provides an exact index that can be mounted on the QuickBridge titanium copings, and can give the dental technician additional information about tooth shape (Fig. 3M,N). The template can be reused by the dental laboratory to make the framework master for copy-milled frameworks, e.g. Cam StructSURE™ (Biomet 3i) (Fig. 3O–Q). The final screw-retained porcelain/titanium construction is then delivered (Fig. 3R).

Check-up and maintenance

Check-ups are initially carried out 2 weeks post-treatment and then once every month. Oral hygiene, mucosal healing, the stability of the provisional bridge, and fixture status are evaluated. After obtaining adequate mucosal healing at 1–6 months, depending on the oral site and the healing capability of the patient, the permanent prosthetic rehabilitation is constructed, preferably using a biocompatible material such as titanium or zirconia. Occlusion and articulation contacts are carefully adjusted to minimize lateral forces. Oral hygiene measures are reinforced at the time of delivery of the final prosthesis. Thereafter, check-ups are individualized but, at a minimum, are performed at 6 and 12 months post-implant insertion, and then once a year.

Clinical documentation of the presented technique

Totally edentulous mandible

Eighty-four consecutive patients scheduled for prosthetic rehabilitation with implant-supported bridges in the totally edentulous mandible were evaluated. A

total of 377 implants (66 turned and 311 oxidized implants, Nobel Biocare) were inserted using a surgical protocol for enhanced primary stability, meaning a reduced final drilling in soft bone to maximize bone to implant contact. Patients received three (one patient, three implants), four (41 patients, 164 implants) or five (42 patients, 210 implants) implants. All patients were also provided with a temporary, 10- to 12-unit fixed prosthesis within 12 hours of implant surgery. No cantilever exceeded 5 mm. Permanent prosthetic delivery took place from 10 days to 3 months following implant surgery. Using the criteria of Lekholm & Zarb (75), bone of class 1 quality was seen in four (5%) patients, of class 2 in 32 (38%) patients, of class 3 in 38 (45%) patients and of class 4 quality in 10 (12%) patients. Five of the 377 implants failed, giving a cumulative implant survival rate of 98.5% after 12 months of loading. Two of the implant failures were probably the result of overload and three implants were lost because of infection.

Totally edentulous maxilla (84)

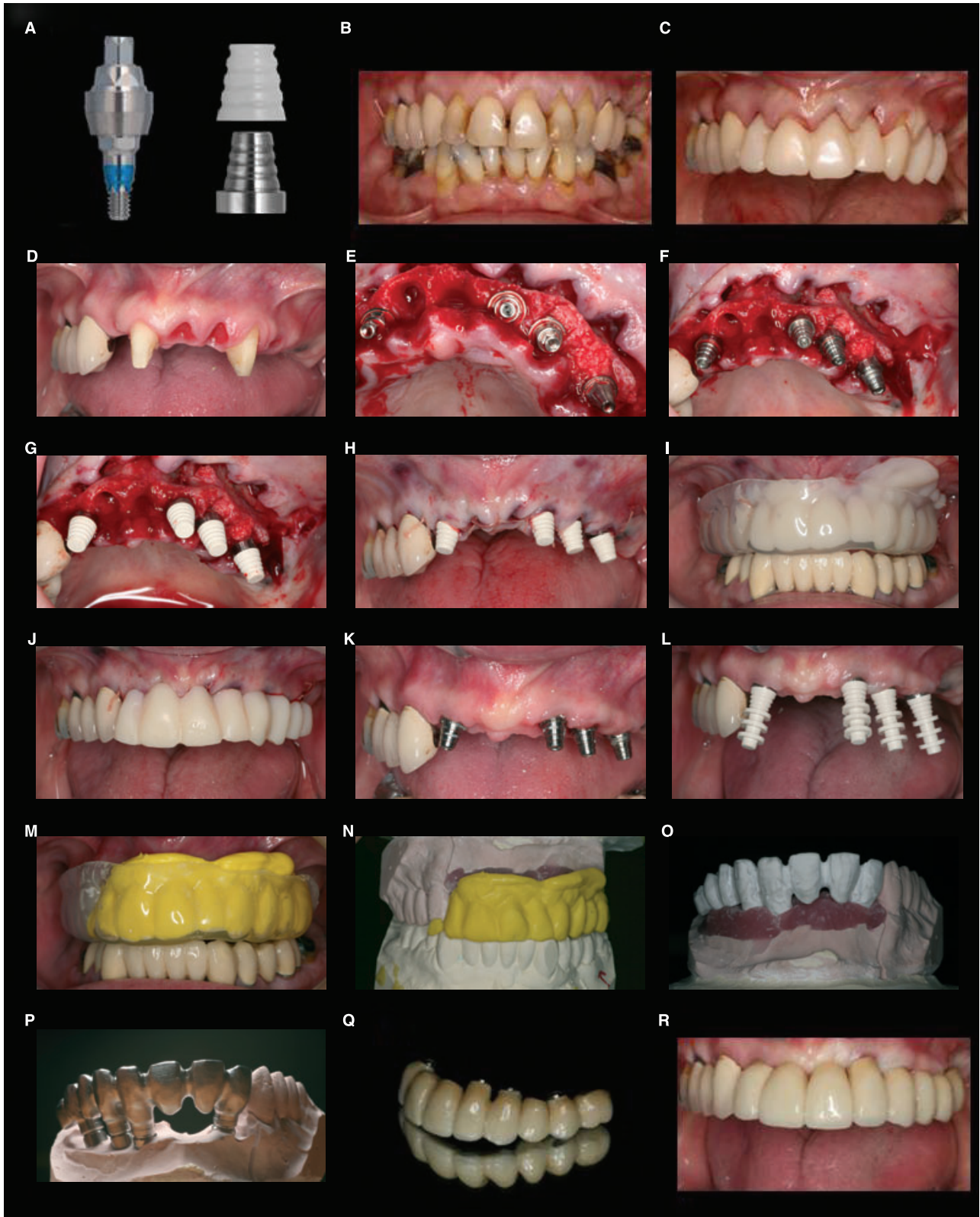
Twenty patients scheduled for prosthetic rehabilitation with implant-supported bridges in the edentulous maxilla were studied. A total of 123 oxidized implants (TiUnite, Nobel Biocare) were placed using a surgical protocol for enhanced primary stability. A screw-retained temporary bridge was delivered within 12 hours and a final bridge within 3 months of implant placement. Twenty patients with 120 implants treated according to a two-stage protocol were included for comparison. One (0.8%) of the immediate-loaded implants failed, whereas no two-stage inserted implant failed. The marginal bone resorption was 0.78 mm in the immediate-loaded implant group and 0.91 mm in the two-stage implant group. At 6 months after implant insertion, the immediate-loaded implants tended to show a higher implant stability quotient than implants inserted by the two-stage procedure. However, no statistically significant difference was found between the two implant groups at any time or parameter.

Partially edentulous mandible (86)

Seventy-seven consecutive patients in need of implant treatment in the partially edentulous mandible were included in the study. A total of 111 bridges supported by 257 Brånemark System® implants (77 turned and 180 TiUnite™ implants) were studied. The implants were placed with enhanced initial stability. A temporary bridge was delivered within 24 hours and a final bridge was placed within 3 months of implant surgery. Stability of the fixtures

was measured using resonance frequency analysis at the time of placement and after 6 months. Four (1.6%) of the 257 implants did not integrate, giving an overall survival rate of 98.4% after 4 years. Three turned implants (3.9%) and one oxidized implant

(0.6%) failed after 4–13 months in three patients with bruxism. The average marginal bone resorption was 0.7 ± 0.7 mm during the first year in function. Resonance frequency analysis showed a mean implant stability quotient value of 72.2 ± 7.5 at the time of



placement and 72.5 ± 5.7 after 6 months of loading. Apparently, direct loading of implants with firm primary stability in partially edentulous areas of the mandible constitutes a viable therapeutic procedure with a predictable outcome.

Provisional implants (88)

Provisional or temporary implants can be used to provide patients with a temporary fixed denture during the healing period of submerged fixtures. Twenty female and 25 male patients were consecutively included in a prospective study of provisional implants. The 45 patients were treated for either partial (16 patients) or total (29 patients) edentulism of the maxilla. The permanent implants were placed first, and as many provisional implants as possible were then installed between the permanent implants. After implant placement and suturing, impressions were taken to manufacture provisional bridges to be cemented onto the provisional implants. Five (2.2%) of the 230 permanent Brånemark System implants did not integrate. None of the failures could be related to the presence of the provisional implants between the permanent implants. Seven provisional implants failed during the study period. In addition, 17 (9%) of the 192 provisional implants showed mobility at the second-stage surgery despite having supported the provisional bridges without clinical symptoms. Forty-four of 45 patients showed stable provisional implant bridges at the time of second-stage surgery. It is concluded that provisional implants can be successfully used to provide patients with a fixed provisional bridge during the healing period of permanent implants.

Provisional implant prosthesis according to a chair-side concept (89)

Thirty-seven partially or totally edentulous older patients (mean age 66.7 years) were treated with chair-side QuickBridge temporary restorations. The

prostheses ranged from two unit bridges supported by two implants to a full arch construction supported by six implants. The functional period of the temporary prostheses ranged from 3 to 6 months. No implants were lost during the observation time. One (3%) temporary prosthesis fractured and two (6%) prostheses became loose during the follow-up period.

Nobel Direct[®] and Nobel Perfect[®] One-Piece Implants (87)

The Nobel Direct[™] and Nobel Perfect[™] one-piece implant systems represent a novel immediate loading concept, including flapless surgery and placement of a one-piece titanium implant (43, 66, 91). The technique offers a simple solution to the problem of missing teeth because surgery is minimally invasive and conventional prosthetic methods are used. The implant systems are also intended for use in immediate replacement of extracted teeth. This one-piece implant system is allegedly designed to minimize marginal bone resorption because there is no sub-mucosal microgap, which is believed to cause the initial bone loss usually associated with two-piece implants (43). Moreover, the entire implant has a moderately rough surface (TiUnite), which is suggested to facilitate attachment of the mucosa to the implant surface, thereby promoting a better 'soft tissue integration' and long-term aesthetic outcome.

Forty-eight patients were provided with 115 one-piece implants for loading with a provisional crown or a bridge within 24 hours and were followed for at least 12 months with clinical and radiographic examinations. Ninety-seven patients previously treated under identical conditions by the same team with 380 two-piece implants for immediate loading in the mandible and maxilla served as controls. Six (5.2%) one-piece implants failed during the follow-up period because of extensive bone loss. Five (1.3%)

Fig. 3. Reconstruction of a partially edentulous maxilla with QuickBridge and Cam Structure. (A–R) An implant treatment of a partially edentulous patient. (A) shows the QuickBridge[™] components, a titanium cone and a polyetheretherketone (PEEK) snap on cap. (B–D) shows selective extraction and fixed temporary construction during appropriate healing time. Conical abutments (Biomet 3i) are mounted (E). On the conical abutments, the QuickBridge titanium coping and PEEK cap are mounted (F,G) before the surgical flap is closed (H). The translucent template is mounted to verify that the temporary parts fit into the template. Protemp[™] 3 Garant (3M, ESPE, St Paul, MN, U.S.A) is injected into the tem-

plate. The template is seated and allowed to set for 4 minutes (H). The temporary prosthesis is removed from the titanium interface and trimmed outside the mouth and remounted (I,J). After additional healing for 3–6 months the temporary prosthesis is snapped off and impression copings are mounted on the titanium copings (K,L). A closed tray impression is made. Using the translucent template, bite registration is made by filling up the mould with bite registration material (M,N). The template can be reused at the dental laboratory to make the framework master for copy milled frameworks, e.g. Cam StructSURE[™] (Biomet 3i) (O–Q). The final copy milled porcelain / titanium is delivered (R).

implants failed in the two-piece implant group. After 1 year, the mean marginal bone loss was 2.1 ± 1.3 mm for one-piece implants and 0.8 ± 1.0 mm for two-piece implants. Twenty per cent of one-piece implants and 0.6% of two-piece implants showed bone loss exceeding 3 mm. When compensating for vertical placement depth, one-piece implants still showed a lower marginal bone level and thus more exposed threads than two-piece implants. Depending on the criteria used, the success rate for one-piece implants was 46.1–72.2% compared to 85.0–91.6% for two-piece implants. It was concluded that the Nobel Direct and Nobel Perfect one-piece implants showed lower success rates and more bone resorption than two-piece implants after 1 year in position. Factors such as implant design, insertion depth, rough implant surface towards the mucosa, *in situ* preparation, and immediate loading may have influenced the clinical outcome.

This critical opinion about the Nobel Direct / Nobel Perfect one-piece implants is supported by recent papers by Albrektsson et al. (5) and Sennerby et al. (110). Finne et al. (51) reported a 1-year cumulative survival rate of 98.7% for the one-piece implant system. However, Finne et al. (51) studied bone level, not bone loss, and 16.5% of implants were not evaluated radiographically. Also, 17 of a total of 152 implants experienced a bone loss exceeding 3 mm. Thus, the actual success rate would be less than 70% if the entire study material were included.

Conclusions

Obviously, more short- and long-term data are needed to fully evaluate the benefits and risks of immediate/early-loaded implants. Only the outcome of immediate-loaded implants in the totally edentulous mandible can be regarded as well documented. With good primary implant stability, immediate-loaded implants in the totally edentulous maxilla show good short- and medium-term outcomes, although more data are needed before the safety of the treatment can be fully established. Excellent short-term data have been presented for immediate/early loaded implants in partially edentulous jaws. However, it must be remembered that most of the papers reviewed here are produced by practitioners who are highly trained in dental implant placement. Few long-term multicenter studies are available. More studies on patient benefits are also needed. Besides shorter treatment time for the doctor/patients with immediate/early-loaded implants, are there psy-

chological factors for the patients that warrant more attention?

Implants with high initial primary stability seem to function well under the influence of immediate loading. Available bone quality needs to be evaluated to ensure the proper implant diameter. By using surgical methods capable of enhancing primary implant stability, the placement of immediate-loaded implants in less dense bone can result in a successful outcome. A successful integration of immediate-loaded implants may require a final torque exceeding 30 N cm and an implant stability quotient value above 60. No difference in bone remodeling seems to exist between immediate-loaded and two-stage implants. Splinting of implants with temporary prostheses reduces the lateral forces on the fixtures and can be important in maximizing osseointegration.

Requirements for long-term success with immediate-loaded implants include:

- excellent primary implant stability,
- moderately rough implant surface,
- prolonged implant stabilization by splinting,
- controlled occlusion, and
- biocompatible prosthetic material.

References

1. Aalam AA, Nowzari H, Krivitsky A. Functional restoration of implants on the day of surgical placement in the fully edentulous mandible: a case series. *Clin Implant Dent Relat Res* 2005; **7**: 10–16.
2. Adell R, Lekholm U, Brånemark PI. Surgical procedures. In: Brånemark PI, Zarb GA, Albrektsson T, editors. *Tissue integrated prostheses: osseointegration in clinical dentistry*. Chicago: Quintessence Publishing Company, 1985: 211–232.
3. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981; **10**: 387–416.
4. Albrektsson T, Brånemark PI, Hansson HA, Lindstrom J. Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. *Acta Orthop Scand* 1981; **52**: 155–170.
5. Albrektsson T, Gottlow J, Meirelles L, Östman PO, Rocci A, Sennerby A. Survival of NobelDirect implants: an analysis of 550 consecutively placed implants at 18 different clinical centers. *Clin Implant Dent Relat Res* 2007; **9**: 65–70.
6. Albrektsson T, Sennerby L. State of the art in oral implants. *J Clin Periodontol* 1991; **18**: 474–481.
7. Albrektsson T. Direct bone anchorage of dental implants. *J Prosthet Dent* 1983; **50**: 255–261.
8. Albrektsson T, Brånemark PI, Hansson HA, Lindström J. Osseointegrated titanium implants: requirements for ensuring a long-lasting, direct bone to implant anchorage in man. *Acta Orthopaed Scand* 1981; **52**: 155–170.

9. Albrektsson T, Hansson T, Lekholm T. Osseointegrated dental implants. *Dent Clin North Am* 1986; **30**: 151–174.
10. Andersen E, Haanaes HR, Knutsen BM. Immediate loading of single-tooth ITI implants in the anterior maxilla: a prospective 5-year pilot study. *Clin Oral Implants Res* 2002; **13**: 281–287.
11. Aparicio C, Rangert B, Sennerby L. Immediate / early loading of dental implants: a report from the Sociedad spanola de Implantes World Congress Consensus Meeting in Barcelona, Spain, 2002. *Clin Implant Dent Relat Res* 2003; **5**: 57–60.
12. Babbush CA, Kent JN, Misiek DJ. Titanium plasma-sprayed (TPS) screw implants for the reconstruction of the edentulous mandible. *J Oral Maxillofac Surg* 1986; **44**: 274–282.
13. Bahat O. Brånemark system implants in the posterior maxilla: clinical study of 660 implants followed for 5 to 12 years. *Int J Oral Maxillofac Implants* 2000; **15**: 646–653.
14. Bahat O. Treatment planning and placement of implants in the posterior maxillae: report of 732 consecutive Nobelpharma implants. *Int J Oral Maxillofac Implants* 1993; **8**: 151–161.
15. Balshi SF, Wolfinger GJ, Balshi TJ. A prospective study of immediate functional loading, following the Teeth in a Day protocol: a case series of 55 consecutive edentulous maxillas. *Clin Implant Dent Relat Res* 2005; **7**: 24–31.
16. Balshi TJ, Wolfinger GJ. Immediate loading of Brånemark implants in edentulous mandibles: a preliminary report. *Implant Dent* 1997; **6**: 83–88.
17. Becker W, Becker BE, Huffstetler S. Early functional loading at 5 days for Brånemark implants placed into edentulous mandibles: a prospective, open-ended, longitudinal study. *J Periodontol* 2003; **74**: 695–702.
18. Becker W, Becker BE, Israelson H, Lucchini JP, Handelsman M, Ammons W, Rosenberg E, Rose L, Tucker LM, Lekholm U. One-step surgical placement of Brånemark implants: a prospective multicenter clinical study. *Int J Oral Maxillofac Implants* 1997; **12**: 454–462.
19. Bergkvist G, Sahlholm S, Karlsson U, Nilner K, Lindh C. Immediately loaded implants supporting fixed prostheses in the edentulous maxilla: a preliminary clinical and radiologic report. *Int J Oral Maxillofac Implants* 2005; **20**: 399–405.
20. Blomberg S, Lindquist LW. Psychological reactions to edentulousness and treatment with jawbone-anchored bridges. *Acta Psychiatr Scand* 1983; **68**: 251–262.
21. Book K, Karlsson S, Jemt T. Functional adaptation to full-arch fixed prosthesis supported by osseointegrated implants in the edentulous mandible. *Clin Oral Implants Res* 1992; **3**: 17–21.
22. Brånemark PI, Engstrand P, Ohnell LO, Grondahl K, Nilsson P, Hagberg K, Darle C, Lekholm U. Brånemark Novum: a new treatment concept for rehabilitation of the edentulous mandible. Preliminary results from a prospective clinical follow-up study. *Clin Implant Dent Relat Res* 1999; **1**: 2–16.
23. Brunski J. In vivo bone response to biomechanical loading at the bone / dental implant interface. *Adv Dent Res* 1999; **13**: 99–119.
24. Brånemark PI. Osseointegration and its experimental background. *J Prosthet Dent* 1983; **50**: 399–410.
25. Brånemark PI, Hansson BO, Adell R, Breine U, Lindström J, Hallén O, Öhman H. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plastic Reconstructive Surg* 1977; **16**: 1–132.
26. Brånemark PI, Zarb GA, Albrektsson T, editors. *Tissue integrated prostheses: osseointegration in clinical dentistry*. Chicago: Quintessence Publishing Company, 1985: 1–343.
27. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004; **19**(Suppl.): 43–61.
28. Calandriello R, Tomatis M, Vallone R, Rangert B, Gottlow J. Immediate occlusal loading of single lower molars using Brånemark System Wide-Platform TiUnite implants: an interim report of a prospective open-ended clinical multicenter study. *Clin Implant Dent Relat Res* 2003; **5**(Suppl. 1): 74–80.
29. Chiapasco M. Early and immediate restoration and loading of implants in completely edentulous patients. *Int J Oral Maxillofac Implants* 2004; **19**(Suppl.): 76–91.
30. Chow J, Hui E, Liu J. Immediate loading of Brånemark system fixtures in the mandible with a fixed provisional prosthesis. *Appl Osseointegration Res* 2001; **1**: 30–35.
31. Cochran DL, Buser D, ten Bruggenkate CM, Weingart D, Taylor TM, Bernard JP, Peters F, Simpson JP. The use of reduced healing times on ITI implants with a sandblasted and acid-etched (SLA) surface: early results from clinical trials on ITI SLA implants. *Clin Oral Implants Res* 2002; **13**: 144–153.
32. Cochran DL, Morton D, Weber HP. Consensus statements and recommended clinical procedures regarding loading protocols for endosseous dental implants. *Int J Oral Maxillofac Implants* 2004; **19**(Suppl.): 109–113.
33. Collaert B, De Bruyn H. Comparison of Brånemark fixture integration and short-term survival using one-stage or two-stage surgery in completely and partially edentulous mandibles. *Clin Oral Implants Res* 1998; **9**: 131–135.
34. Collaert B, De Bruyn H. Early loading of four or five Astra Tech fixtures with a fixed cross-arch restoration in the mandible. *Clin Implant Dent Relat Res* 2002; **4**: 133–135.
35. Cornelini R, Cangini F, Covani U, Barone A, Buser D. Immediate loading of implants with 3-unite fixed partial dentures: a 12-month clinical study. *Int J Oral Maxillofac Implants* 2006; **21**: 914–918.
36. Davies JE. Understanding peri-implant endosseous healing. *J Dent Educ* 2003; **67**: 932–949.
37. De Bruyn H, Kisch J, Collaert B, Linden U, Nilner K, Dvarsater L. Fixed mandibular restorations on three early-loaded regular platform Brånemark implants. *Clin Implant Dent Relat Res* 2001; **3**: 176–184.
38. Degidi M, Petrone G, Iezzi G, Piattelli A. Histologic evaluation of human immediately loaded titanium implant with a porous anodized surface. *Clin Implant Dent Relat Res* 2002; **4**: 110–114.
39. Degidi M, Piattelli A, Felice P, Carinci F. Immediate functional loading of edentulous maxilla: a 5-year retrospective study of 388 titanium implants. *J Periodontol* 2005; **76**: 1016–1024.
40. Degidi M, Piattelli A, Gehrik P, Felice P, Carinci F. Five-year outcome of 111 immediate non-functional single restorations. *J Oral Implantol* 2006; **32**: 277–285.

41. Degidi M, Piattelli A. Immediate functional and non-functional loading of dental implants: a 2- to 60-month follow-up study of 646 titanium implants. *J Periodontol* 2003; **74**: 225–241.
42. Drago CJ, Lazzara RJ. Immediate provisional restoration of Osseotite implants: a clinical report of 18-month results. *Int J Oral Maxillofac Implants* 2004; **19**: 534–541.
43. Dragoo MR. Prototyp eines einteiligen Implantats. *Dental-praxis* 2005; **XXII**: 319–325.
44. Duyck J, Van Oosterwyck H, Vander Sloten J, De Cooman M, Puers R, Naert I. Magnitude and distribution of occlusal forces on oral implants supporting fixed prostheses: an in vivo study. *Clin Oral Implants Res* 2000; **11**: 465–475.
45. Engquist B, Astrand P, Anzén B, Dahlgren S, Engquist E, Feldmann H, Karlsson U, Nord PG, Sahlholm S, Svärdröström P. Simplified methods of implant treatment in the edentulous lower jaw. A controlled prospective study. Part II: Early loading. *Clin Implant Dent Relat Res* 2004; **6**: 90–100.
46. Engquist B, Åstrand P, Anzén B, Dahlgren S, Engquist E, Feldmann H, Karlsson U, Nord P, Sahlholm S, Svärdröström P. Simplified methods of implant treatment in the edentulous lower jaw: a 3-year follow-up report of a controlled prospective study of one-stage versus two-stage surgery and early loading. *Clin Implant Dent Relat Res* 2005; **7**: 95–104.
47. Engstrand P, Grondahl K, Ohrnell LO, Nilsson P, Nannmark U, Brånemark PI. Prospective follow-up study of 95 patients with edentulous mandibles treated according to the Brånemark Novum concept. *Clin Implant Dent Relat Res* 2003; **5**: 3–10.
48. Ericsson I, Nilner K. Early functional loading using Brånemark dental implants. *Int J Periodontics Restorative Dent* 2002; **22**: 9–19.
49. Ericsson I, Nilson H, Lindh T, Nilner K, Randow K. Immediate functional loading of Brånemark single tooth implants. An 18 months' clinical pilot follow-up study. *Clin Oral Implants Res* 2000; **11**: 26–33.
50. Ericsson I, Randow K, Nilner K, Peterson A. Early functional loading of Brånemark dental implants: 5-year clinical follow-up study. *Clin Implant Dent Relat Res* 2000; **2**: 70–77.
51. Finne K, Rompen EJ, Toljanic J. Clinical evaluation of a prospective multicenter study on 1-piece implants. Part 1: Marginal bone level evaluation after 1 year of follow up. *Int J Oral Maxillofac Implants* 2007; **22**: 226–234.
52. Fischer K, Stenberg T. Early loading of ITI implants supporting a maxillary full-arch prosthesis: 1-year data of a prospective, randomized study. *Int J Oral Maxillofac Implants* 2004; **19**: 374–381.
53. Fischer K, Stenberg T. Three-year data from a randomized, controlled study of early loading of single-stage dental implants supporting maxillary full-arch prostheses. *Int J Oral Maxillofac Implants* 2006; **21**: 245–252.
54. Friberg B, Ekstubb A, Mellstrom D, Sennerby L. Brånemark implants and osteoporosis: a clinical exploratory study. *Clin Implant Dent Relat Res* 2001; **3**: 50–56.
55. Friberg B, Ekstubb A, Sennerby L. Clinical outcome of Brånemark System implants of various diameters: a retrospective study. *Int J Oral Maxillofac Implants* 2002; **17**: 671–677.
56. Friberg B, Henningsson C, Jemt T. Rehabilitation of edentulous mandibles by means of turned Brånemark System implants after one-stage surgery: a 1-year retrospective study of 152 patients. *Clin Implant Dent Relat Res* 2005; **7**: 1–9.
57. Friberg B, Jemt T, Lekholm U. Early failures in 4,641 consecutively placed Brånemark dental implants: a study from stage 1 surgery to the connection of completed prostheses. *Int J Oral Maxillofac Implants* 1991; **6**: 142–146.
58. Friberg B, Jisander S, Widmark G, Lundgren A, Ivanoff CJ, Sennerby L, Thoren C. One-year prospective three-center study comparing the outcome of a 'soft bone implant' (prototype Mk IV) and the standard Brånemark implant. *Clin Implant Dent Relat Res* 2003; **5**: 71–77.
59. Friberg B, Sennerby L, Meredith N, Lekholm U. A comparison between cutting torque and resonance frequency measurements of maxillary implants. A 20-month clinical study. *Int J Oral Maxillofac Surg* 1999; **28**: 297–303.
60. Frost HM. A 2003 update of bone physiology and Wolff's law for clinicians. *Angle Orthod* 2004; **74**: 3–15.
61. Ganeles J, Wismeijer D. Early and immediately restored and loaded dental implants for single-tooth and partial-arch applications. *Int J Oral Maxillofac Implants* 2004; **19**(Suppl): 92–102.
62. Glantz P-O, Strandman E, Randow K. On functional strain in fixed mandibular reconstructions. II. An in vivo study. *Acta Odontol Scand* 1984; **42**: 269–276.
63. Glantz P-O, Strandman E, Svensson SA, Randow K. On functional strain in fixed mandibular reconstructions. I. An in vitro study. *Acta Odontol Scand* 1984; **42**: 241–249.
64. Glauser R, Ree A, Lundgren A, Gottlow J, Hammerle CH, Scharer P. Immediate occlusal loading of Brånemark implants applied in various jawbone regions: a prospective, 1-year clinical study. *Clin Implant Dent Relat Res* 2001; **3**: 204–213.
65. Grunder U. Immediate functional loading of immediate implants in edentulous arches: two-year results. *Int J Periodontics Restorative Dent* 2001; **21**: 545–551.
66. Hahn J. One-piece root-form implants: a return to simplicity. *J Oral Implantol* 2005; **31**: 77–84.
67. Hatano N. The Maxis New. A novel one-day technique for fixed individualized implant-supported prosthesis in the edentulous mandible using Brånemark System implants. *Appl Osseointegration Res* 2001; **2**: 40–43.
68. Henry PJ, van Steenberghe D, Blomback U, Polizzi G, Rosenberg R, Urgell JP, Wendelhag I. Prospective multicenter study on immediate rehabilitation of edentulous lower jaws according to the Brånemark Novum protocol. *Clin Implant Dent Relat Res* 2003; **5**: 137–142.
69. Horiuchi K, Uchida H, Yamamoto K, Sugimura M. Immediate loading of Brånemark system implants following placement in edentulous patients: a clinical report. *Int J Oral Maxillofac Implants* 2000; **15**: 824–830.
70. Hui E, Chow J, Li D, Liu J, Wat P, Law H. Immediate provision for single-tooth implant replacement with Brånemark system: preliminary report. *Clin Implant Dent Relat Res* 2001; **3**: 79–86.
71. Ibanez JC, Tahhan MJ, Zamar JA, Menendez AB, Juaneda AM, Zamar NJ, Monqaut JL. Immediate occlusal loading of double acid-etched surface titanium implants in 41 consecutive full-arch cases in the mandible and maxilla: 6- to 74-month results. *J Periodontol* 2005; **76**: 1972–1981.

72. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone: a 5-year analysis. *J Periodontol* 1991; **62**: 2–4.
73. Kronström M, Widbom T, Löfquist LE, Henningson C, Widbom C, Lundberg T. Early functional loading of conical Brånemark implants in the edentulous mandible: a 12 month follow-up clinical report. *J Prosthet Dent* 2003; **89**: 335–340.
74. Ledermann PD. Stegprothetische Versorgung des zahnlosen Unterkiefers mit Hilfe plasmabeschichteten Titanschraubimplantaten. *Dtsch Zahnärztl Z* 1979; **34**: 907–911.
75. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark PI, Zarb GA, Albrektsson T, editors. *Tissue-integrated prostheses: osseointegration in clinical dentistry*. Chicago: Quintessence, 1985: 199–209.
76. Lekholm U. Patient selection for Brånemark Novum treatment. *Appl Osseointegration Res* 2001; **2**: 36–40.
77. Lindquist LW, Carlsson GE, Jemt T. A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. *Clin Oral Implants Res* 1996; **7**: 329–336.
78. Lorenzoni M, Pertl C, Zhang K, Wimmer G, Wegscheider WA. Immediate loading of single-tooth implants in the anterior maxilla. Preliminary results after one year. *Clin Oral Implants Res* 2003; **14**: 180–187.
79. Luongo G, Di Raimondo R, Filippini P, Gualini F, Paoleschi C. Early loading of sandblasted, acid-etched implants in the posterior maxilla and mandible: a 1-year follow-up report from a multicenter 3-year prospective study. *Int J Oral Maxillofac Implants* 2005; **20**: 84–91.
80. Machtei EE, Frankenthal S, Blumenfeld I, Gutmacher Z, Horwitz J. Dental implants for immediate fixed restorations of partially edentulous patients: a 1-year prospective pilot clinical trial in periodontally susceptible patients. *J Periodontol* 2007; **78**: 1188–1194.
81. Maló P, Rangert B, Nobre M. 'All-on-4' immediate-function concept with Brånemark System implants for completely edentulous maxilla: a 1-year retrospective clinical study. *Clin Implant Dent Relat Res* 2005; **7**(Suppl. 1): 88–94.
82. Maló P, Rangert B, Nobre M. 'All-on-Four' immediate-function concept with Brånemark System implants for completely edentulous mandibles: a retrospective clinical study. *Clin Implant Dent Relat Res* 2003; **5**(Suppl. 1): 2–9.
83. Misch CE, Degidi M. Five-year prospective study of immediate/early loading of fixed prostheses in completely edentulous jaws with a bone quality-based implant system. *Clin Implant Dent Relat Res* 2003; **5**: 17–28.
84. Östman P-O, Hellman M, Albrektsson T, Sennerby L. Direct loading of Nobel Directs and Nobel Perfects one-piece implants: a 1-year prospective clinical and radiographic study. *Clin Oral Impl Res* 2007; **18**: 409–418.
85. Östman PO, Hellman M, Nilson H, Ericsson I. Provisional implants: a clinical prospective study in 45 patients, from implant placement to delivery of the final bridge. *Clin Implant Dent Relat Res* 2004; **6**: 142–149.
86. Östman PO, Hellman M, Sennerby L, Wennerberg A. Provisional implant prosthesis according to a chair-side concept – technical note and results of 37 temporary fixed prosthesis. *Clin Implant Dent Relat Res* 2008, in press.
87. Östman PO, Hellman M, Sennerby L. Direct implant loading in the edentulous maxilla using a bone density-adapted surgical protocol and primary implant stability criteria for inclusion. *Clin Implant Dent Relat Res* 2005; **7**(Suppl. 1): S60–69.
88. Östman PO, Hellman M, Wendelhag I, Sennerby L. Resonance frequency analysis measurements of implants at placement surgery. *Int J Prosthodont* 2006; **19**: 77–83.
89. Östman PO, Hellman PO, Sennerby L. Direct loading of Brånemark System® implants in the partially edentate mandible: a prospective 1-year radiographic and up to 4-year clinical study. *J Oral Maxillofac Implants* 2008, in press.
90. Olsson M, Urde G, Andersen JB, Sennerby L. Early loading of maxillary fixed cross-arch dental prostheses supported by six or eight oxidized titanium implants: results after 1 year of loading, case series. *Clin Implant Dent Relat Res* 2003; **5**(Suppl. 1): 81–87.
91. Parel SM, Schow SR. Early clinical experience with a new one-piece implant system in single tooth sites. *J Oral Maxillofac Surg* 2005; **63**(9 Suppl. 2): 2–10.
92. Piattelli A, Corigliano M, Scarano A, Costigliola G, Paoantonio M. Immediate loading of titanium plasma-sprayed implants: an histologic analysis in monkeys. *J Periodontol* 1998; **69**: 321–327.
93. Piattelli A, Corigliano M, Scarano A, Quaranta M. Bone reactions to early occlusal loading of two-stage titanium plasma-sprayed implants: a pilot study in monkeys. *Int J Periodontics Restorative Dent* 1997; **17**: 162–169.
94. Piattelli A, Ruggeri A, Franchi M, Romasco N, Trisi P. An histologic and histomorphometric study of bone reactions to unloaded and loaded non-submerged single implants in monkeys: a pilot study. *J Oral Implantol* 1993; **19**: 314–320.
95. Pierrisnard L, Renouard F, Renault P, Barquins M. Influence of implant length and bicortical anchorage on implant stress distribution. *Clin Implant Dent Relat Res* 2003; **5**: 254–262.
96. Raghoebar GM, Friberg B, Grunert I, Hobkirk JA, Tepper G, Wendelhag I. 3-year prospective multicenter study on one-stage implant surgery and early loading in the edentulous mandible. *Clin Implant Dent Relat Res* 2003; **5**: 39–46.
97. Rangert B, Jemt T, Jörneus L. Forces and moments on Brånemark Implants. *Int J Oral Maxillofac Implants* 1989; **4**: 241–247.
98. Rangert B, Sullivan R, Jemt T. Load factor control for implants in the posterior partially edentulous segment. *Int J Oral Maxillofac Implants* 1997; **12**: 360–370.
99. Rocci A, Martignoni M, Burgos PM, Gottlow J, Sennerby L. Histology of retrieved immediately and early loaded oxidized implants: light microscopic observations after 5 to 9 months of loading in the posterior mandible. *Clin Implant Dent Relat Res* 2003; **5**(Suppl. 1): 88–98.
100. Rocci A, Martignoni M, Gottlow J. Immediate loading in the maxilla using flapless surgery, implants placed in predetermined positions, and prefabricated provisional restorations: a retrospective 3-year clinical study. *Clin Implant Dent Relat Res* 2003; **5**(Suppl. 1): 29–36.
101. Rocci A, Martignoni M, Gottlow J. Immediate loading of Brånemark System TiUnite and turned-surface implants in the posterior mandible: a randomized open-ended clinical trial. *Clin Implant Dent Relat Res* 2003; **5**(Suppl. 1): 57–63.

102. Rocuzzo M, Bunino M, Prioglio F, Bianchi SD. Early loading of sandblasted and acid-etched (SLA) implants: a prospective split-mouth comparative study. *Clin Oral Implants Res* 2001; **12**: 572–578.
103. Rocuzzo M, Wilson T. A prospective study evaluating a protocol for 6 weeks' loading of SLA implants in the posterior maxilla: one year results. *Clin Oral Implants Res* 2002; **13**: 502–507.
104. Romanos GE, Toh CG, Siar CH, Swaminathan D. Histologic and histomorphometric evaluation of peri-implant bone subjected to immediate loading: an experimental study with *Macaca fascicularis*. *Int J Oral Maxillofac Implants* 2002; **17**: 44–51.
105. Salvi GE, Gallini G, Lang NP. Early loading (2 or 6 weeks) of sandblasted and acid-etched (SLA) ITI implants in the posterior mandible. A 1-year randomized controlled clinical trial. *Clin Oral Implants Res* 2004; **15**: 142–149.
106. Schincaglia GP, Marzola R, Scapoli C, Scotti R. Immediate loading of dental implants supporting fixed partial dentures in the posterior mandible: a randomized controlled split-mouth study—turned versus titanium oxide implant surface. *Int J Oral Maxillofac Implants* 2007; **22**: 35–46.
107. Schnitman PA, Wohrle PS, Rubenstein JE, DaSilva JD, Wang NH. Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. *Int J Oral Maxillofac Implants* 1997; **12**: 495–503.
108. Schnitman PA, Wohrle PS, Rubenstein JE. Immediate fixed interim prostheses supported by two-stage threaded implants: methodology and results. *J Oral Implantol* 1990; **16**: 96–105.
109. Schroeder A, van der Zypen E, Stich H, Sutter F. The reactions of bone, connective tissue, and epithelium to endosteal implants with titanium-sprayed surfaces. *J Maxillofac Surg* 1981; **9**: 15–25.
110. Sennerby L, Becker W, Jonsson L, Johansson L-Å, Albrektsson T. Short-term clinical results of Nobel Direct implants. A retrospective multicentre analysis. *Clin Oral Implants Res* 2008, in press.
111. Sennerby L, Roos J. Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. *Int J Prosthodont* 1998; **11**: 408–420.
112. Sulzer TH, Bornstein MM, Buser D. Indications for oral implantology in a referral clinic. A three-year retrospective analysis of 737 patients with 1176 implants. *Schweiz Monatsschr Zahnmed* 2004; **114**: 444–450.
113. Søballe K, Hansen ES, Brockstedt-Rasmussen H, Bünger C. The effects of osteoporosis, bone deficiency, bone grafting and micromotion on fixation of porous-coated hydroxyapatite-coated implants. In: Gesink RGT, Manley MT editors. *Hydroxylapatite coatings in orthopaedic surgery*. New York: Raven Press, 1993: 107–136.
114. Tarnow DP, Emthiaz S, Classi A. Immediate loading of threaded implants at stage 1 surgery in edentulous arches: ten consecutive case reports with 1- to 5-year data. *Int J Oral Maxillofac Implants* 1997; **12**: 319–324.
115. Testori T, Del Fabbro M, Feldman S, Vincenzi G, Sullivan D, Rossi R Jr, Anitua E, Bianchi F, Francetti L, Weinstein RL. A multicenter prospective evaluation of 2-months loaded Osseotite implants placed in the posterior jaws: 3-year follow-up results. *Clin Oral Implants Res* 2002; **13**: 154–161.
116. Testori T, Del Fabbro M, Szmukler-Moncler S, Francetti L, Weinstein RL. Immediate occlusal loading of Osseotite implants in the completely edentulous mandible. *Int J Oral Maxillofac Implants* 2003; **18**: 544–551.
117. Testori T, Meltzer A, Del Fabbro M, Zuffetti F, Troiano M, Francetti L, Weinstein RL. Immediate occlusal loading of Osseotite implants in the lower edentulous jaw. A multicenter prospective study. *Clin Oral Implants Res* 2004; **15**: 278–284.
118. Testori T, Szmukler-Moncler S, Francetti L, Del Fabbro M, Scarano A, Piattelli A, Weinstein RL. Immediate loading of Osseotite implants: a case report and histologic analysis after 4 months of occlusal loading. *Int J Periodontics Restorative Dent* 2001; **21**: 451–459.
119. Testori T, Szmukler-Moncler S, Francetti L, Del Fabbro M, Trisi P, Weinstein RL. Healing of Osseotite implants under submerged and immediate loading conditions in a single patient: a case report and interface analysis after 2 months. *Int J Periodontics Restorative Dent* 2002; **22**: 345–353.
120. Testori T, Wiseman L, Woolfe S, Porter SS. A prospective multicenter clinical study of the Osseotite implant: four-year interim report. *Int J Oral Maxillofac Implants* 2001; **16**: 193–200.
121. van Steenberghe D, Molly L, Jacobs R, Vandekerckhove B, Quirynen M, Naert I. The immediate rehabilitation by means of a ready-made final fixed prosthesis in the edentulous mandible: a 1-year follow-up study on 50 consecutive patients. *Clin Oral Implants Res* 2004; **15**: 360–365.
122. Vanden Bogaerde L, Pedretti G, Dellacasa P, Mozzati M, Rangert B, Wendelhag I. Early function of splinted implants in maxillas and posterior mandibles, using Brånemark System Tiunite implants: an 18-month prospective clinical multicenter study. *Clin Implant Dent Relat Res* 2004; **6**: 121–129.
123. Weber HP, Buser D, Fiorellini JP, Williams RC. Radiographic evaluation of crestal bone levels adjacent to nonsubmerged titanium implants. *Clin Oral Implants Res* 1992; **3**: 181–188.
124. Vermynen K, Collaert B, Linden U, Bjorn AL, De Bruyn H. Patient satisfaction and quality of single-tooth restorations. *Clin Oral Implants Res* 2003; **14**: 119–124.
125. Wolfinger GJ, Balshi TJ, Rangert B. Immediate functional loading of Brånemark system implants in edentulous mandibles: clinical report of the results of developmental and simplified protocols. *Int J Oral Maxillofac Implants* 2003; **18**: 250–257.