"All-on-Four" Immediate-Function Concept with Brånemark System® Implants for Completely Edentulous Mandibles: A Retrospective Clinical Study

Paulo Maló, DDS;* Bo Rangert, PhD, MechEng;† Miguel Nobre, RDH‡

ABSTRACT

Background: Immediate-function Brånemark System® implants (Nobel Biocare AB, Gothenburg, Sweden) have become an accepted alternative for fixed restorations in edentulous mandibles, based on documented high success rates. Continuous development is ongoing to find simple protocols for their use.

Purpose: The purpose of this study was to develop and document a simple, safe, and effective surgical and prosthetic protocol for immediate function (within 2 hours) of four Brånemark System implants supporting fixed prostheses in completely edentulous mandibles: the "All-on-Four" concept.

Materials and Methods: This retrospective clinical study included 44 patients with 176 immediately loaded implants, placed in the anterior region, supporting fixed complete-arch mandibular prostheses in acrylic. In addition to the immediately loaded implants, 24 of the 44 patients had 62 rescue implants not incorporated in the provisional prostheses but incorporated in final prostheses later on.

Results: Five immediately loaded implants were lost in five patients before the 6-month follow-up, giving cumulative survival rates of 96.7 and 98.2% for development and routine groups, respectively. The prostheses' survival was 100%, and the average bone resorption was low.

Conclusions: The high cumulative implant and prostheses survival rates indicate that the "All-on-Four" immediate-function concept with Brånemark System implants used in completely edentulous mandibles is a viable concept.

KEY WORDS: acrylic prosthesis, angulated abutments, Brånemark System implants, complete arch, fresh extraction sites, immediate function, immediate load, mandible, retrospective study, surgical guide, tilted implants, titanium framework

Immediate loading of implant-supported dental prostheses is documented with high and predictable success rates for the edentulous mandible.[1–4] The challenge today is not to prove functionality but, rather, to develop simple and cost-effective protocols. One such attempt is Brånemark Novum® (Nobel Biocare AB, Gothenburg, Sweden),[5] in which all components are premanufactured.

The development of protocols for immediate loading has switched focus from the placing of several implants, of which some are submerged and included in the prosthesis at a second surgery, to immediately loading a few implants.[4,6,7] The development to fewer implants is encouraged by the results from implant load analyses,[8] demonstrating that four implants is an optimal number for complete-arch prosthesis provided they are placed as "cornerstones": two posteriorly and two anteriorly, all well spread. If these implants are anchored optimally, the probability for success is high. Such has been presented in a recent clinical study,[9] which demonstrated that tilting of implants may be advantageous and that longer implants may be placed with good cortical anchorage in optimal positions for prosthetic support. The present protocol uses a simple

*Private practice, Department of Surgery and Prosthodontics, CM—Clínica Malo, Lisbon, Portugal; †Nobel Biocare AB, Gothenburg, Sweden; ‡private practice, Department of Oral Hygiene, CM—Clínica Malo, Lisbon, Portugal

Reprint requests: Paulo Maló, DDS, CM—Clínica Malo, Avenida des Combatentes, 43 – 43A, Ed. Green Park, 1600-042 Lisbon, Portugal; e-mail: clinicamalo@mail.telepac.pt

guide for the best positioning and inclination of the implants, giving superior loading conditions for the implants and a simple technique.

The purpose of this article is to demonstrate the development of this standardized concept, "All-on-Four," and to present its clinical documentation. It is believed that these results will encourage dentists to offer a simple and low-cost procedure to patients with edentulous mandibles.

MATERIAL AND METHODS

This retrospective clinical study was performed in a private clinic, Clínica Malo (CM), in Lisbon, Portugal. From April 1998 to June 2002, 44 patients were treated with immediately loaded complete-arch prostheses in mandibles supported by four implants per patient placed anterior to the foramina—in total, 176 implants. Forty-five of these implants (in 12 patients) were placed in fresh extraction sites.

The inclusion criterion was edentulous mandibles, or mandibles with hopeless teeth, in need of fixed implant restorations as requested by the patient. The patients were included consecutively if they accepted the treatment.

In addition to the 176 immediately loaded implants, 24 of the first 30 patients had 62 rescue implants placed both anterior and posterior to the foramina. These implants were provided with final abutments at surgery but were not incorporated in the provisional prostheses. This "development group" included 11 males and 19 females who ranged from 30 to 79 years of age (mean 59 yr). Encouraged by the results from the development group, the subsequent 14 patients (56 implants), the "routine group," had no rescue implants. This group included 4 males and 10 females who ranged in age from 41 to 78 years (mean 60 yr).

The opposing dentitions for 18 patients were removable prostheses, for 14 patients were implant-supported fixed prostheses, for 7 patients were natural teeth, and for 5 patients were fixed prostheses on teeth.

Surgical Protocol

Bilateral inferior dental nerve and mental nerve blocks were performed with mepivicaine cloridrate with epinephrine 1:100,000 (Scandinibsa 2%®, Inibsa Laboratory, Barcelona, Spain). Most patients were sedated with diazepam (Valium® 10 mg, Roche, Amadora, Portugal) prior to surgery. Antibiotics (Clavamox DT® 1 g, Bial Laboratory, S. Mamede do Coronado, Portugal) were given at 8 hours and 1 hour prior to surgery and then daily for 10 days following surgery. Corticoid medication (prednisone, Meticorten®, Schering-Plough Farma, Cacém, Portugal) was also given at 8 hours and 1 hour before surgery and was prescribed postsurgically for 4 days. Anti-inflammatory medication (Nimed®, Aventis Pharma, Mem Martins, Portugal) was prescribed postsurgically from days 5 to 10. Analgesics (Clonix®, Janssen-Cilag, Barcarena, Portugal) were given prior to surgery and were prescribed postsurgically if needed for pain. After surgery a chlorhexidine 0.2% gel (Elugel®, Pierre Fabre Laboratory, Boulogne, France) was placed around the implants.

The insertion of the implants (Brånemark System® Mk II and Mk III, Nobel Biocare AB) followed standard procedures, except that underpreparation was employed when needed to get a final torque of over 40 Ncm before the final seating of the implant. Countersinking was omitted to preserve marginal bone. The length of the immediately loaded implants (all anterior to the foramina) ranged from 10 to 18 mm.

The two most anterior implants followed the jaw anatomy in direction; in severe jawbone resorption cases, this meant a posterior tilting. Two additional implants were inserted just anterior to the foramina and were tilted distally about 30º relative to the occlusal plane (Figures 1 and 2). This arrangement allowed for good implant anchorage, short cantilever length, and large interimplant distance.[9] The posterior implants, which were 4 mm in diameter, typically emerged at the second premolar position. Anterior implants were either 4 or 3.75 mm in diameter. Any rescue implants were placed in remaining sites on both sides of the foramina.

Implant placement was assisted by a special guide, designed by one of the authors (P.M.) (Figure 3A and B). The guide was placed into to a 2 mm hole made at the midline of the mandible, and its titanium band was bent so that the occlusal centerline of the opposing jaw was followed. In this way it was possible to guide the implants to be placed in the center of the opposing prosthesis and concurrently to find the optimal position and inclination for best implant anchorage and prosthetic support.

In case of immediate extraction, the sockets were freed of soft tissue remnants and cleaned to avoid infection. Implants placed between sockets were not accounted for as placed in extraction sites. If periodon-

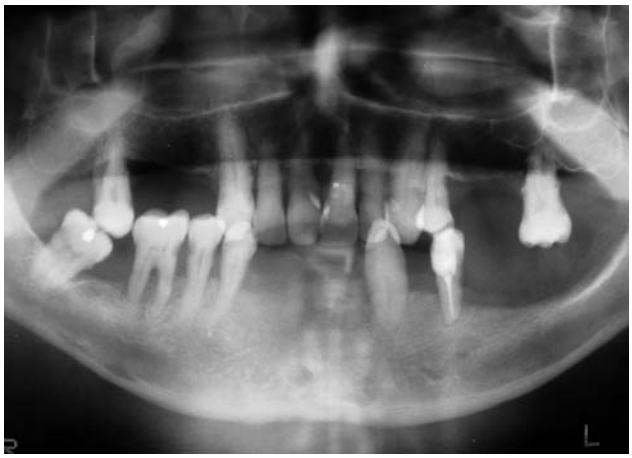

Figure 1 Patient case before treatment.

titis was present at the four lower incisors, extraction, curettage, and bone shaping were performed and virtually no socket was left. Again, the implants were not classified as placed in extraction sites.

The lower corner of the implant neck was aimed positioned at bone level, and bicortical anchorage was established whenever possible. The implant in immediate function had a final insertion torque of at least 40 Ncm. The soft tissues were readapted and sutured back into position with 4–0 nonresorbable suture.

Angulated abutments (Brånemark System) for anterior implants were set at either 17° or 30° and those for posterior implants at 30°. These abutment angulations were chosen so that the prosthetic screw-access holes were in an occlusal or lingual location (Figure 4).

Patients were informed that the surgical area should be kept cool and under slight pressure for the first 48 hours after the surgery; only soft and cold foods were to be ingested during that period.

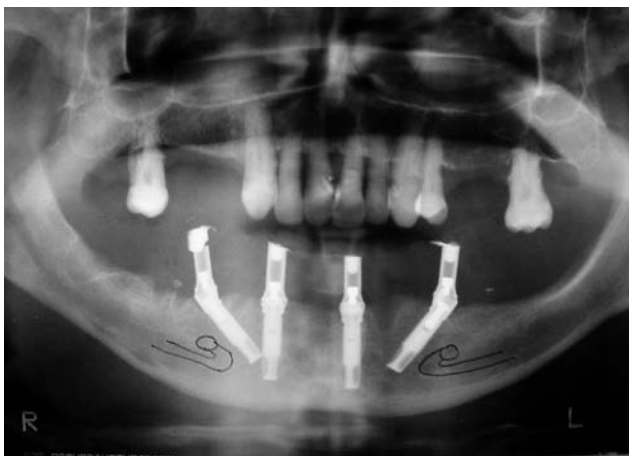

Figure 2 Patient from Figure 1: tilted positions of the four implants placed between the foramina. Notice that the left anterior implant was placed to avoid the socket of tooth 33.

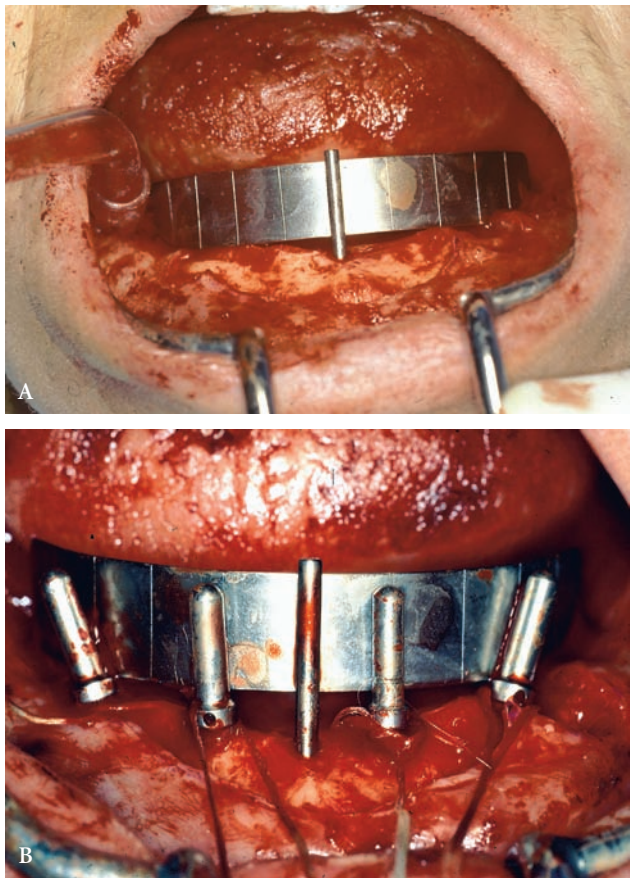

Figure 3 *A* and *B*, Maló surgical guide in place.

Immediate Prosthetic Protocol

An acrylic prosthesis, reinforced by a metal strip, was delivered within 2 hours after surgery (Figure 5). The emergence positions of the screw-access holes at the posterior implants of the prostheses were normally at the level of the second premolar, and the prostheses were designed to hold a minimum of 10 teeth because of the favorable position achieved by the posterior tilting of the distal implants. Owing to the results with the acrylic prostheses in the development group, the prostheses for the routine group were made with an increased material dimension, and the acrylic-curing procedure was improved by the use of higher pressure.

Final Prosthetic Protocol

For the development group, final prostheses were made 4 to 6 months after surgery, incorporating the rescue implants. The first 7 patients had conventional cast metal–frame fixed prostheses; the other 23 had

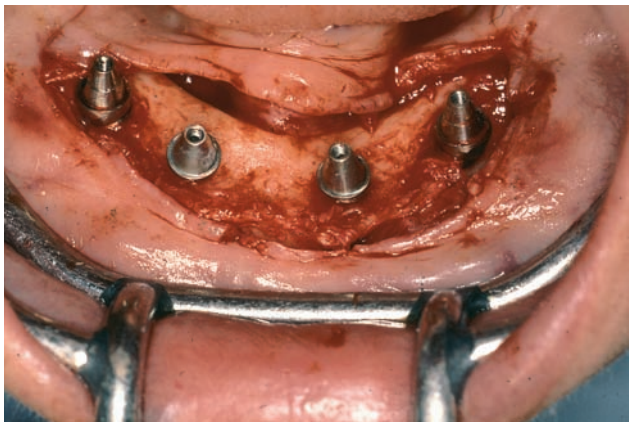

Figure 4 Correction of implant angulations by means of angulated abutments.

milled high-precision titanium prosthetic frameworks[10] (Procera® Implant Bridge, Nobel Biocare) (Figure 6A–C). Because of the favorable position of the tilted posterior implants, the final prostheses included as many as 12 teeth.

In the routine group, the provisional acrylic prostheses were maintained throughout the study period, except in two patients who received titanium prosthetic frameworks after 12 months.

Drop-out Rate and Implant Survival Criteria

No patients withdrew from the study. Survival was based on function, individual implant stability (checked manually), absence of pain and infection, and radiographic analysis at time of evaluation.

Marginal Bone Loss

The marginal bone levels, evaluated on periapical or panoramic radiographs, were registered at the last follow-up visit within the study time frame. A conventional radiograph holder was used, and its position was adjusted manually for an estimated orthogonal film position. Owing to the high degree of ridge resorption, it was difficult to obtain an orthogonal placement of the holder in some patients. An independent radiologist performed the radiographic readings.

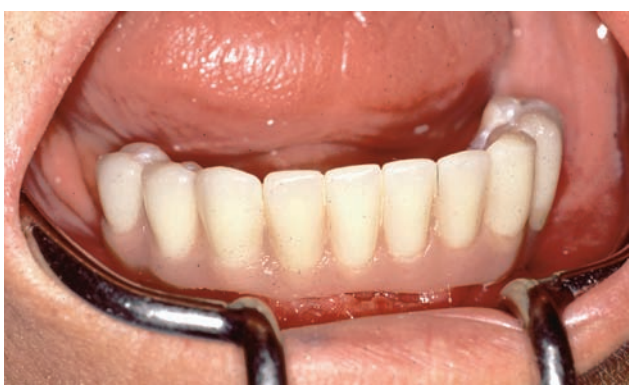

Figure 5 Acrylic prosthesis placed within 2 hours after surgery.

RESULTS

Implant Survival

Four immediately loaded implants in 4 patients of the development group were lost prior to the 6-month follow-up. The rest of the implants (120 – 4 = 116) passed the 1-year follow-up, and 69 (58%) passed the 2-year

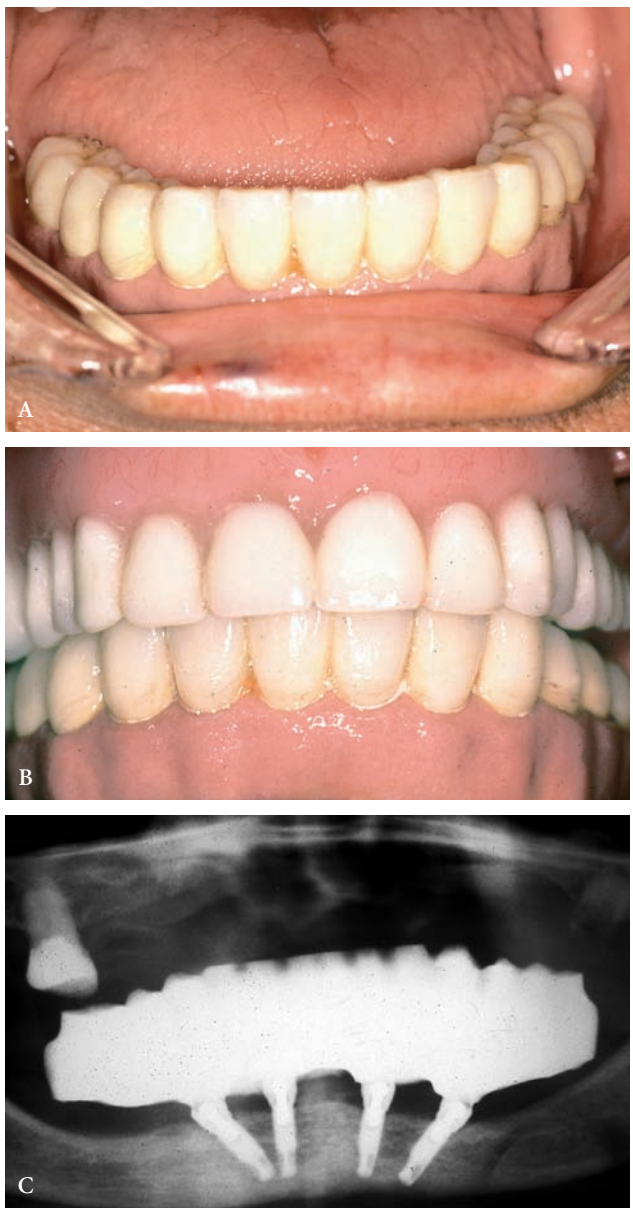

Figure 6 *A–C*, Final prosthesis made within 6 months post surgery using the Procera Implant Bridge.

follow-up, giving a cumulative survival rate of 96.7% (Table 1). Three rescue implants were lost before loading in 3 of these same patients, giving a cumulative survival rate of 95.2% (Table 2). Both the provisional and final prostheses survival rates were 100%.

In the routine group, 1 implant was lost in the first 3 months. The rest of the implants (56 – 1 = 55) passed the 6-month follow-up, and 12 (20%) passed the 1-year follow-up. The survival rates were 98.2% for the implants (Table 3) and 100% for the prostheses, respectively.

Of the 45 implants placed in fresh extraction sites in both patient groups (all anterior to the foramina and all loaded immediately), 2 were lost in 2 patients within 1 month, giving a failure rate of 4.4%. Three of the 131 immediately loaded implants placed in healed sites in both groups were lost in 3 patients (2.3% failure rate). The difference in survival rates between implants placed in fresh extraction sockets and implants placed in healed sites was evaluated by a log-rank test[11] and found to be statistically not significant ($p > .30$).

Description of the Failures and Remedies

One patient with opposing teeth lost one immediately loaded implant (position 42) and one rescue implant (position 46) after 3 months, but the provisional prosthesis survived on the remaining three implants. A replacement for the immediately loaded implant that was lost was loaded 5 months later at the placement of the final prosthesis. The final prosthesis was then supported by five implants (the three immediately loaded, the remaining rescue implant, and the extra inserted implant). This patient also had loosening of a gold screw in the provisional prosthesis, which was adjusted by retightening.

Another patient, wearing an opposing removable prosthesis, lost one of the immediately loaded implants (position 31) and one rescue implant (position 33) after 1 month. The provisional bridge survived on the remaining three implants. The lost implants were replaced 4 months later and loaded at the placement of the final prosthesis. The final prosthesis was supported by three immediately loaded implants, one rescue implant, and two replaced implants.

A third patient, with an opposing implant-supported prosthesis, lost an immediately loaded implant (position 43) and one rescue implant (position 33) after 1 month, but the provisional prosthesis survived on the remaining three implants. Replacements for the two lost implants were loaded at the placement of the final prosthesis 4 months later. The final prosthesis was supported by the three immediately loaded implants, the remaining rescue implant, and two replacement implants. This patient also had a reparable fracture of the provisional prosthesis.

A fourth patient, with an opposing removable prosthesis, lost an immediately loaded implant (position 34) after 4 months, but the provisional prosthesis survived on the remaining three implants. The lost implant was replaced and loaded 3 months later at the placement of the final prosthesis. The final prosthesis was ultimately supported by three immediately loaded implants, two rescue implants, and one replacement implant. This patient also had a reparable fracture of the provisional prosthesis.

One patient in the routine group with opposing natural teeth lost one implant (position 31) after 3 months, but the prosthesis survived on the remaining three implants. The lost implant was replaced 2 months later and left unloaded. A titanium prosthesis supported by four implants (the three immediately loaded and the extra inserted implant) was delivered 9 months later.

Biologic Complications and Remedies

In one patient it was observed at the first follow-up that the bone around the four immediately loaded implants

TABLE 1 Development Group: Life Table of Immediately Loaded Implants

	No. of Implants				
Time Period	Functioning	Failed	Withdrawn	Survival Rate (%)	CSR (%)
Loading–6 mo	120	4	0	96.7	96.7
6 mo–1 yr	116	0	0	100.0	96.7
1 yr–2 yr	69	0	0	100.0	96.7
2 yr–3 yr	30	0	0	100.0	96.7

CSR = cumulative survival rate.

TABLE 2 Development Group: Life Table of Rescue Implants

Time Period	No. of Implants			Survival Rate (%)	CSR (%)
	In Place	Failed	Withdrawn		
Loading–6 mo	62	3	0	95.2	95.2
6 mo–1 yr	55	0	0	100.0	95.2
1 yr–2 yr	46	0	0	100.0	95.2
2 yr–3 yr	20	0	0	100.0	95.2

CSR = cumulative survival rate.

was showing signs of breakdown: implant mobility and stains present apically to the implant as visible on the radiograph (Figure 7). A rigorous maintenance protocol with monthly controls was employed. The prosthesis was removed temporarily, the area was disinfected, and chlorhexidine and hialuronic acid gels were applied around the implants. The bridge was reattached and the occlusion controlled. The patient was instructed in special care including a soft diet, antibiotics, and anti-inflammatory drugs. On the control appointment 3 months later, the implants were showing good bone apposition on the radiographs (Figure 8). The implants have since passed the 1-year follow-up without any problem and are classified as survivals.

Mechanical Complications

Nine of the acrylic prostheses in the development group (30%) had reparable fractures, but in the routine group no fractures occurred. Besides screw fracture or loosening in conjunction with the prostheses fractures, there were few complications in this latter group.

Marginal Bone Loss Measured from Periapical Panogram

Readable radiographs were taken for 26 of the 30 patients in the development group. The bone level was in average 1.2 mm (SD 1.2 mm) below the abutment-implant interface. All radiographs (14 patients) were readable for the routine group. The bone level was in average 0.6 mm (SD 0.6 mm) below the abutment-implant interface. These results are comparable to values for early loading of mandibular full-arch prostheses.[12]

DISCUSSION

The 96.7% and 98.2% implant cumulative survival rates for the immediate loading protocol are comparable to results from two-stage protocols.[13] Most important to the patients, however, is that the prosthesis survival rate was 100%, although some of the prostheses in the development group had reparable fractures.

Only one loaded implant was lost per patient who encountered implant failure, and all prostheses survived on the remaining three implants until further implants were loaded. Use of four loaded implants seems to be a good strategy with the present protocol as it allows for failure of one implant without failure of the prosthesis.

During the course of the study, it was determined that the rescue implants were not needed; thus, the last one-third of patients received the four immediately loaded implants only. The results in the patients without rescue implants confirmed this finding. In fact, when rescue implants were placed in less favorable bone sites, a higher failure rate occurred than with the immediately loaded ones. They were included in the final prosthesis only for an ethical reason: the patients had paid for them and their abutments were protruding from the gum tissue, so they had to be connected.

TABLE 3 Routine Group: Life Table of Immediately Loaded Implants

Time Period	No. of Implants			Survival Rate (%)	CSR (%)
	Functioning	Failed	Withdrawn		
Loading–6 mo	56	1	0	98.2	98.2
6 mo–1 yr	12	0	0	100.0	98.2

CSR = cumulative survival rate.

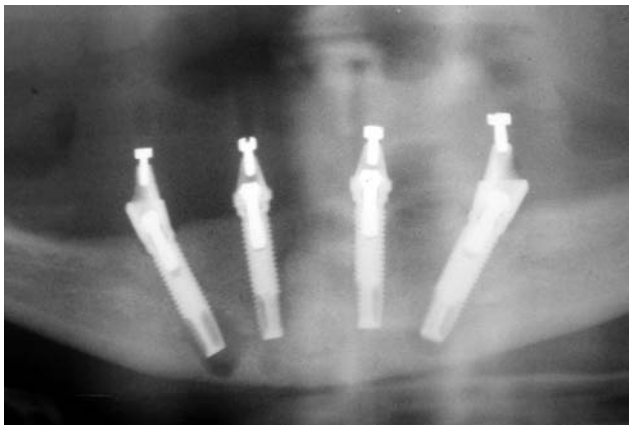

Figure 7 Implants showing signs of breakdown.

At this modification of the protocol, the acrylic prosthesis was reinforced, eliminating the fracture problem that was encountered initially. The result indicates that the reinforced acrylic prosthesis is a good solution for a longer term than just during the healing process and might be used as a low-cost final prosthesis.

It has been pointed out that implants in extraction sites are more sensitive to early losses at immediate loading, although this is not statistically significant.[14–16] The difference in failure rates between the two types of sites was small in this study; this might be a consequence of the comprehensive anti-inflammatory protocol used. In the case of complete-arch implant-supported prostheses in mandibles, however, it is most often possible to avoid the extraction sites and to place the implants in healed bone, especially if only four implants are used. This approach is recommended.

As the majority of implant losses with the Brånemark System take place during healing or the first year of function,[17] it is believed that implant losses related to the procedure per se would have shown up within the time frame of the study. Therefore, the prognosis for the implant success after 1 year of function is believed to be equivalent to that of the two-stage technique.

A follow-up program is considered of great importance. One patient presented with signs of implant breakdown at the first follow-up visit, and several measures were taken to save the implants.

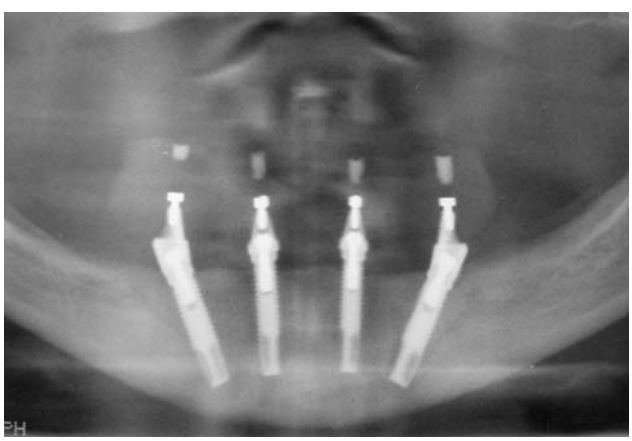

Figure 8 Patient from Figure 7: stable implants at control appointment 3 months later.

CONCLUSIONS

The high implant survival rates (96.7% and 98.2% for two patient groups), the 100% prostheses survival rate, and the low marginal bone resorption demonstrate the viability of the proposed concept of fixed mandibular complete-arch prostheses supported by four immediately loaded implants loaded within 2 hours after surgery. The tilting of the posterior implants allows the final prostheses to hold as many as 12 teeth with only a short cantilever (one molar) and a favorable inter-implant distance. The results also indicate that a reinforced acrylic prosthesis might be used as a low-cost final prosthesis.

ACKNOWLEDGMENTS

The authors acknowledge the personnel at Clínica Malo for their clinical contribution and Dr. Åsa Taylor, Nobel Biocare, Sweden, for assistance with data collection and checking of the manuscript.

REFERENCES

1. Schnitman PA, Wöhrle 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.
2. Balshi TJ, Wolfinger GJ. Immediate loading of Brånemark implants in edentulous mandibles. A preliminary report. Implant Dent 1997; 6:83–88.
3. Randow K, Ericsson I, Nilner K, Peterson A, Glantz PO. Immediate functional loading of Brånemark dental implants. An 18-month clinical follow-up study. Clin Oral Implants Res 1999; 10:8–15.
4. 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.
5. Brånemark PI, Engstrand P, Öhrnell LO, et al. 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.
6. Chow J, Hui E, Liu J, et al. The Hong Kong Bridge protocol. Immediate loading of mandibular Brånemark fixtures using

a fixed provisional prosthesis: preliminary results. Clin Implant Dent Relat Res 2001; 3:166–174.
7. Balshi TJ, Wolfinger GJ. Teeth in a day. Implant Dent 2001; 10:231–233.
8. 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.
9. Krekmanov L, Kahn M, Rangert B, Lindstrom H. Tilting of posterior mandibular and maxillary implants of improved prosthesis support. Int J Oral Maxillofac Implants 2000; 15:405–414.
10. Örtorp A, Jemt T. Clinical experience of CNC-milled titanium frameworks supported by implants in the edentulous jaw: a 3-year interim report. Clin Implant Dent Relat Res 2002; 4:104–109.
11. Peto R, Pike MC, Armitage P, et al. Design and analysis of randomized clinical trials requiring prolonged observation of each patient: II. Analysis and examples. Br J Cancer 1977; 35:1–39.
12. Petersson A, Rangert B, Randow K, Ericsson I. Marginal bone resorption at different treatment concepts using Brånemark dental implants in anterior mandibles. Clin Implant Dent Relat Res 2001; 3:142–147.
13. Adell R, Eriksson B, Lekholm U, Brånemark PI, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990; 5:347–359.
14. Maló P, Rangert B, Dvärsäter L. Immediate function of Brånemark implants in the aesthetic zone: a retrospective clinical study with 6 months to 4 years follow-up. Clin Implant Dent Relat Res 2000; 2:138–146.
15. Chaushu G, Chaushu S, Tzohar A, Dayan D. Immediate loading of single tooth implants: immediate versus non-immediate implantation. A clinical report. Int J Oral Maxillofac Implants 2001; 16:267–272.
16. Hui E, Chow J, Li D, Liu J, Wat P, Law H. Immediate provisional for single-tooth implant replacement with Brånemark System: preliminary report. Clin Implant Dent Relat Res 2001; 3:79–86.
17. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Failure patterns of four osseointegrated oral implant systems. J Materials Science Materials in Medicine 1997; Suppl 8: 843–847.