

Early and Immediate Restoration and Loading of Implants in Completely Edentulous Patients

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Primary stability and postponement of loading of dental implants for approximately 3 to 6 months have been considered for years the “conditio sine qua non” to allow osseointegration of dental implants. However, in recent years, an increasing number of publications on immediate and early loading of dental implants in completely edentulous patients have appeared in the literature, and high survival rates were generally reported. Nevertheless, much controversy still exists over the reliability of the reported data, frequently because the publications are of insufficient methodologic quality (insufficient follow-up, inadequate sample size, absence of randomization, lack of well-defined exclusion and inclusion criteria, lack of well-defined success criteria, etc). The objective of this study was to review the literature to evaluate the reliability of early and immediate loading of implants placed in the edentulous mandible and maxilla and rehabilitated either with implant-supported overdentures or with implant-supported fixed prostheses. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):76–91

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Primary stability and postponement of loading of dental implants for approximately 3 to 6 months have been considered for years the “conditio sine qua non” to allow osseointegration of dental implants. However, the necessity of waiting to load an implant was not scientifically but rather clinically based.^{1,2} It is therefore justifiable to question whether this healing period is an absolute prerequisite for obtaining osseointegration, or if under certain circumstances this period can be shortened without jeopardizing osseointegration and long-term results. In particular, it should be demonstrated whether any kind of motion transmitted to the implants during the early phases of integration can compromise the long-term results, or if there is a threshold below which micromotion may not compromise osseointegration.

Studies in the orthopedic literature^{3–6} have demonstrated the role of macromotion in tissue differentiation around endosseous implants placed in

metaphyseal bones; in these studies, macromotion induced fibrous tissue interposition between the implant surface and bone. Similar results were found with regard to dental implants. Brunski and coworkers⁷ identified early loading as a factor leading to fibrous tissue interposition at the bone-implant interface. In an experimental study in dogs, titanium blade implants were immediately loaded on one side, whereas contralateral blades were left out of function. Immediately loaded implants developed fibrous tissue encapsulation, while the non-loaded implants osseointegrated normally. These observations were confirmed by other studies with titanium screw-type implants.⁸

In contrast to the aforementioned studies, there are also reports in the experimental and clinical literature of implants exposed to early or immediate loading followed by successful osseointegration.^{9–31} In a pilot study in dogs,¹⁴ 3 different groups of titanium alloy implants were compared: a nonsubmerged early loaded group, a nonsubmerged nonloaded group, and a submerged group as a control. The latter 2 groups were loaded after osseointegration occurred. The early loaded group consisted of 3 implants splinted into 1 prosthetic restoration at 1 week postimplantation. The authors found no statistical differences between the groups with regard to the quality of osseointegration, and in none of the groups

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was fibrous encapsulation of implants found. Several studies by Piattelli and associates^{13,20-22} demonstrated in both animals and humans that not only may early loading lead to successful integration, but it may increase the quantity of bone in direct contact with the implant surface. In a study by Rocci and coworkers,³² 5 patients volunteered to have extra implants placed in the posterior mandible for the purpose of histologic examination. Nine oxidized titanium Brånemark System implants (Nobel Biocare, Göteborg, Sweden) were retrieved after 5 to 9 months in function. Two implants had been loaded the day of placement and 7 had been loaded after 2 months of healing. Morphometric measurements of the 2 immediately loaded implants showed a mean bone-to-implant contact value of 92.9%. The corresponding value for the 6 early loaded implants was 81.4%. The authors concluded that implants subjected to immediate or early loading do integrate normally. In a case report, Testori and associates³³ demonstrated histologically that osseointegration may also occur normally in the case of immediate loading. One patient received 11 implants in the edentulous mandible: 6 were immediately loaded to support a provisional fixed prosthesis, and 5 were left submerged. Two months later, 2 submerged implants and 1 immediately loaded implant were retrieved and processed for histologic analysis. All implants achieved osseointegration. The bone-to-implant contact was 38.9% for the submerged implants and 64.2% for the immediately loaded implants.

Different results between the first group of studies,³⁻⁸ in which fibrous encapsulation of immediately loaded implants occurred, and the second group of studies,⁹⁻³¹ in which osseointegration occurred, may be related to differences in study design, loading conditions with different entities of micromotion of implants, bone quality, and/or materials used. In particular, loading conditions in the orthopedic field may be very different from loading conditions in the case of dental rehabilitation. The current trend is not to consider implant motion per se as detrimental to osseointegration, but rather to consider a threshold of acceptable micromotion. The hypothesis for this concept introduced by Cameron and colleagues⁵ is that micromotion at the bone-implant interface can be tolerated below a certain threshold. This has been confirmed by other authors.³⁴⁻³⁷ These studies seem to demonstrate that micromotion up to 150 μm should be considered excessive and therefore deleterious for osseointegration. On the contrary, micromotion of less than 50 μm seems to be tolerated. Thus, the critical threshold, although dependent on implant morphology and implant surface, seems to be between 50 and 150 μm .³⁴⁻³⁷

Despite an increasing number of publications on immediate and early loading of dental implants in completely edentulous patients that report high survival rates for the loaded implants, much controversy still exists over the reliability of the reported data, because frequently the publications are of insufficient methodologic quality (insufficient follow-up, inadequate sample size, absence of randomization, lack of well-defined exclusion and inclusion criteria, lack of well-defined success criteria, etc). The main objective of this review was to evaluate the reliability of studies of early and immediate loading of implants placed in the edentulous mandible and maxilla and rehabilitated with either implant-supported overdentures or implant-supported fixed prostheses.

METHODS

A critical review of the literature was performed to determine the validity and efficacy of available information; full-length articles published in English were analyzed. Pertinent studies were retrieved initially with a computerized literature search (MEDLINE-EMBASE from 1966 to May 2003) of key words. Key words used in the search included: *edentulous jaw*, *edentulous maxilla*, *edentulous mandible*, *osseointegrated implants*, *dental implants*, *implant-supported*, *dental prosthesis*, *dental implantation*, *immediate loading*, *early loading*, *overdenture*, and *implant-supported dental prosthesis*. To expand this, a hand search of journal issues from 1966 through May 2003 was undertaken. The following journals were identified: *Clinical Oral Implants Research*, *The International Journal of Oral & Maxillofacial Implants*, *Journal of Oral and Maxillofacial Surgery*, *International Journal of Oral and Maxillofacial Surgery*, *Journal of Cranio-Maxillo-Facial Surgery*, *Journal of Prosthetic Dentistry*, *Scandinavian Journal of Plastic and Reconstructive Surgery*, *Dental Clinics of North America*, *Oral Surgery Oral Medicine Oral Pathology*, *Clinical Implant Dentistry and Related Research*, *British Journal of Oral and Maxillofacial Surgery*, *International Journal of Periodontics and Restorative Dentistry*, *International Journal of Prosthodontics*, *Journal of the American Dental Association*, *Journal of Biomedical Materials Research*, *Journal of Periodontology*, *Journal of Oral Implantology*, and *Implant Dentistry*.

Other articles were identified from the reference lists of the articles found with MEDLINE and EMBASE and from the review of the aforementioned journals. The review was restricted to publications dealing with endosseous root-form titanium implants with a minimum follow-up of 1 year. Nevertheless,

very frequently many combinations of procedures were present in the same study, and follow-ups varied considerably within the same article and between different articles. Therefore, a meta-analysis was not performed. The data abstracted from the articles were recorded on flow sheets subdivided into the following groups:

1. Immediate loading of implant-supported overdentures in the edentulous mandible
2. Early loading of implant-supported overdentures in the edentulous mandible
3. Immediate loading of implant-supported fixed prostheses in the edentulous mandible
4. Early loading of implant-supported fixed prostheses in the edentulous mandible
5. Immediate loading of implant-supported overdentures in the edentulous maxilla
6. Early loading of implant-supported overdentures in the edentulous maxilla
7. Immediate loading of implant-supported fixed prostheses in the edentulous maxilla
8. Early loading of implant-supported fixed prostheses in the edentulous maxilla

IMMEDIATE LOADING OF IMPLANT-SUPPORTED OVERDENTURES IN THE EDENTULOUS MANDIBLE

The first attempts to test immediate loading of dental implants with implant-supported overdentures were performed by Ledermann in 1979 and 1983,^{9,10} but the first publication with a relevant sample size and well-defined criteria of evaluation appeared only in 1997, authored by Chiapasco and coworkers.¹⁷ This article reported on a retrospective multicenter study involving 4 centers and 226 patients with edentulous mandibles. Well-defined inclusion and exclusion criteria for patient selection were reported, as well as the condition of the opposing arch. Only patients with good bone quality (class 1 to 3 according to the classification of Lekholm and Zarb³⁸) were included in this study. A total of 904 dental implants (ITI, Institut Straumann, Waldenburg, Switzerland; Mathys, Bettlach, Switzerland; Friatec, Friadent, Mannheim, Germany) at least 3.5 mm in diameter and 10 mm long were placed in the interforaminal area of the mandible, immediately connected with a bar, and loaded within 2 days. Of these, 776 implants were followed for a period ranging from 2 to 13 years (mean: 6.4 years). The survival rate of implants according to the criteria of Albrektsson and associates³⁹ was 96.9%, whereas the survival rate of the prostheses was 98.5%. No statistically significant dif-

ferences were found between different centers and different implant systems. This publication was followed by others concerning the same indication, also with very favorable results.

In a prospective study, Gatti and colleagues⁴⁰ presented their experience on 21 patients who received 84 ITI implants placed in the interforaminal area of the mandible that were immediately connected with a bar and loaded with an implant-supported overdenture within 24 hours. Inclusion criteria and success criteria were similar to those reported in the previous article.¹⁷ The follow-up ranged from 24 to 60 months. No implants were lost. The survival rate of implants and prostheses was 100%, while the cumulative success rate according to the criteria of Albrektsson and associates³⁹ was 96%. Splinting of implants with a U-shaped Dolder bar was considered a key factor for long-term success at that time, with the objective to minimize macromovement and micromovement of the implants.

In 2001, Chiapasco and coworkers¹⁸ published a prospective comparative study of immediate and conventional loading of mandibles with Brånemark System implant-supported overdentures. Twenty patients with edentulous mandibles were randomly assigned to 2 groups: immediate loading within 24 hours and conventional loading following a standard protocol for submerged implants (3 to 6 months' waiting period to obtain osseointegration). Well-defined inclusion criteria were similar to those presented in the aforementioned articles.^{17,38,40} The follow-up was 2 years on average and the cumulative success rate, reported according to the criteria of Albrektsson and associates,³⁹ was 97.5% in both groups, with 1 implant in each group lost shortly after the start of occlusal loading. More recently, Romeo and colleagues²⁹ published a prospective comparative study of immediate versus conventional loading of implant-supported overdentures with ITI implants with a protocol identical to that described by Chiapasco and coworkers¹⁷ in a previous publication. Twenty patients with edentulous mandibles were randomly assigned to the 2 groups. The follow-up was 2 years on average and the cumulative success rates reported according to the Albrektsson and associates,³⁹ criteria were 97.5% in both groups. One implant in each group was lost shortly after the start of occlusal loading.

Chiapasco and Gatti¹⁹ have recently published a prospective analysis on this topic. Eighty-two patients with edentulous mandibles were rehabilitated with implant-supported overdentures. Three-hundred twenty-eight screw-type endosseous implants (4 implants per patient) were placed in the intraforaminal area of the mental symphysis (164 HA-TI,

Mathys Dental Implants; 84 ITI, Institut Straumann; 40 Brånemark Conical, Nobel Biocare; 40 Frialoc, Friadent). Inclusion criteria, success criteria, and the surgical-prosthetic protocol were similar to those previously described. Of the 328 implants placed, 296 were followed from a minimum of 36 months to a maximum of 96 months, with a mean follow-up of 62 months. Seven implants were removed, while 18, although integrated, did not fulfill the success criteria. The cumulative survival and success rates of the implants were 96.1% and 88.2%, respectively.

In another study, Gatti and Chiapasco³⁰ prospectively compared the clinical outcome of standard MK II Brånemark System implants and Conical transmucosal Brånemark System implants. Ten patients were randomly assigned to the 2 groups. In both groups, 4 implants per patient were placed anterior to the mental foramina, rigidly splinted with a bar, and immediately loaded with an implant-supported overdenture. The patients were followed for a minimum of 24 months. Implants were evaluated at the time of immediate loading and 12 and 24 months after prosthetic loading with clinical peri-implant parameters. Radiographic evaluation of peri-implant bone level changes was performed with panoramic radiographs taken 12 and 24 months after the beginning of prosthetic loading. No significant differences were found between the 2 groups at 12 and 24 months. The cumulative success rate of implants according to the success criteria was 100% in both groups after 2 years of functional loading. The results of this study demonstrated that the success rate for immediately loaded mandibular implants was similar to that obtained in cases of conventional loading and that there were no significant differences between 2-piece implants and 1-piece transmucosal implants.

Over a 5-year period (1996 to 2001), Degidi and Piattelli⁴¹ treated 152 patients aged between 18 and 75 years presenting both partially and completely edentulous jaws (mandible and maxilla). These patients received a total of 646 titanium implants of different shapes and surfaces. Four hundred twenty-two implants were immediately loaded (235 placed in healed sites and 187 in postextraction sites), whereas 224 were immediately restored with provisional prostheses but were kept out of occlusion. Of the treated patients, 39 had edentulous mandibles and received 241 implants that were immediately loaded. Seventeen patients were treated with an implant-supported overdenture and received 93 implants. The follow-up ranged from 2 to 60 months. The reported survival rate of implants and prostheses was 100%. The authors reported that failures were not related to bone quality and quantity, diameter, length and position of implants, or type of abutment used.

Conclusions Regarding Immediate Loading of Implant-Supported Overdentures in the Edentulous Mandible

Only data from articles with defined survival criteria and with a minimum follow-up of 1 year were reported. A total of 7 articles were selected and reviewed. Of these publications, 2 were retrospective, 2 were prospective, and 3 were prospective and controlled (test group/immediate loading versus control group/conventional loading). Three hundred seventy-six patients with an edentulous mandible were treated and 1,529 implants were placed and immediately loaded (within 2 days of surgery). The minimum implant length was 9 mm. In the selected articles, all implants were rigidly connected with a bar. Only patients with good bone quality were selected for immediate loading. Of these implants, 1,369 were followed from a minimum of 6 months to a maximum of 13 years. Survival rate evaluation according to the Albrektsson and associates³⁹ criteria was the most commonly used system. Thirty-three implants were lost during the follow-up period, whereas 21, although still stable, did not fulfill the survival criteria. The average survival and success rates were 98% and 96.6%, respectively (range of successful implants: 88.2% to 100%; range of surviving implants: 96.0% to 100%) (Table 1).

From the analysis of the available literature, the following preliminary observations can be drawn:

1. Immediate loading of a minimum of 4 implants, rigidly connected with a bar placed in the interforaminal area of the mandible and loaded with an implant-supported overdenture, seems not to jeopardize the long-term survival and success rates of the implants, which are comparable to those obtained with standard conventional loading procedures.⁴²⁻⁴⁵
2. Good bone quality and primary stability seem to be important prognostic factors for the success of the procedure, but more objective measurement criteria, such as insertion torque values, resonance frequency analysis (RFA), and Periotest analysis (Siemens, Bensheim, Germany) were very rarely used.

EARLY LOADING OF IMPLANT-SUPPORTED OVERDENTURES IN THE EDENTULOUS MANDIBLE

In a prospective study, Payne and coworkers⁴⁶ presented their experience with early loading of Brånemark System Conical implants placed in the anterior mandible. Four patients received 4 implants

Table 1 Published Articles Relating to the Immediate Loading of Implant-Supported Overdentures in the Edentulous Mandible

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	No. of implants followed	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Chiapasco et al 1997 ¹⁷	Retro	226	904	904	776	2 to 13	24	96.9	96.9
Gatti et al 2000 ⁴⁰	Prosp	21	84	84	84	2 to 5	0	96.0	96.0
Chiapasco et al 2001 ¹⁸	Prosp/cont	10	40	40	40	2	1	97.5	97.5
Romeo et al 2002 ²⁹	Prosp/cont	10	40	40	40	2	1	97.5	97.5
Chiapasco/Gatti 2003 ¹⁹	Prosp	82	328	328	296	3 to 8	7	96.1	88.2
Gatti/Chiapasco 2002 ³⁰	Prosp/cont	10	40	40	40	2	0	100.0	100.0
Degidi/Piattelli 2003 ⁴¹	Retro	17	93	93	93	1 to 5	0	100.0	No data
Total		376	1,529	1,529	1,369		33		

Retro = retrospective; prosp = prospective; cont = controlled.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

each in the interforaminal area of the mandible. After 2 weeks on average, the implants were loaded unsplinted with implant-supported overdentures and followed for 1 year. The survival rate of implants was 100%.

In a prospective controlled study, the same group of authors⁴⁷ compared the success rates of conventionally loaded versus early loaded pairs of unsplinted ITI implants supporting mandibular overdentures. Twenty-four patients were randomly allocated with maximum concealment to the 2 treatment protocols. In the first group, the implants were allowed to heal for 12 weeks before being functionally loaded (control group), while the second group (test group) had 6 weeks of healing before the start of functional loading. Two ITI implants at least 10 mm long were placed in the interforaminal area of the mandible. Only patients with classes 1 to 3 bone according to Lekholm and Zarb³⁸ were selected. Implant stability (with Periotest and RFA), peri-implant bone resorption, and peri-implant clinical parameters were evaluated. The mean follow-up was 2 years. No implants were lost in the test group (100% success rate), and there were no statistically significant differences between the results of the test group and the control group. Peri-implant bone resorption in all cases was within the limits proposed by Albrektsson and associates.³⁹

Roynesdal and coworkers⁴⁸ presented their experience with 11 patients receiving 2 implants each in the interforaminal area of the edentulous mandible. Implants were loaded within 14 to 21 days with an overdenture supported by ball attachments. The mean follow-up after the start of prosthetic loading was 24 months. No implants were lost in the follow-up period (100% survival rate).

Glauser and colleagues,⁴⁹ as part of a case series of 41 patients, presented the results in 4 patients

who were treated with 4 Brånemark System implants that were placed in the interforaminal area of the mandible, rigidly connected with a bar, and loaded within 1 week with implant-supported overdentures. The mean follow-up was 1 year. During this period, 2 of 16 implants were lost (12.5%). The survival rate was 87.5%.

Tawse-Smith and coworkers⁵⁰ prospectively compared the success rates of 2 different dental implant systems following conventional (12-week waiting period) or early (6-week healing period) loading in patients being rehabilitated with mandibular overdentures. Forty-eight edentulous participants were randomly allocated to 2 different implant systems: Steri-Oss (Nobel Biocare) or Southern (Irene, South Africa). For each system the participants were further divided into 2 groups: conventional and early loading. Two unsplinted implants were placed in the interforaminal area of the mandible to support an overdenture. Mobility tests and marginal bone level changes, as well as peri-implant clinical parameters, were evaluated 1 and 2 years after the start of prosthetic loading. Success rates were evaluated according to the Albrektsson and associates³⁹ criteria. Success rates (including dropouts) for the Steri-Oss implants 2 years after loading were 87.5% in the control group and 70.8% in the test group; for the second implant system these values were 83.3% and 100%, respectively. The authors found the highest failure rate with unsplinted machined-surface implants (7 of 17) in the test group patients.

Raghoebar and coworkers,⁵¹ in a prospective multicenter study, presented their experience in 40 patients with mandibular edentulism who received 170 implants that were prosthetically loaded within 6 weeks. Of these patients, 30 were rehabilitated with implant-supported overdentures (4 implants

Table 2 Published Articles Relating to the Early Loading of Implant-Supported Overdentures in the Edentulous Mandible

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	No. of implants followed	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Payne et al 2001 ⁴⁶	Prosp	4	16	16	16	1	0	100.0	100.0
Payne et al 2002 ⁴⁷	Prosp/cont	12	24	24	24	2	0	100.0	100.0
Roynesdal et al 2001 ⁴⁸	Prosp/cont	11	22	22	22	0 to 2	0	100.0	100.0
Glauser et al 2001 ⁴⁹	Prosp	4	16	16	16	1	2	87.5	87.5
Tawse-Smith et al 2002 ⁵⁰	Prosp/cont	24	48	48	48	2	7	70.8	85.4
Raghoobar et al 2003 ⁵¹	Prosp	30	120	120	120	3	6	93.0	—
Total		85	230	230	230		15	0	

Retro = retrospective; prosp = prospective; cont = controlled.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

per patient in the interforaminal area of the mandible), while the remaining 10 had fixed prostheses (5 implants per patient). The patients were then followed for 3 years after the start of prosthetic loading. The overall survival rate of implants and prostheses was 93%.

Conclusions Regarding Early Loading of Implant-Supported Overdentures in the Edentulous Mandible

Only data from articles with defined inclusion criteria and survival criteria with a minimum follow-up of 1 year were used. A total of 6 articles were selected. Of these publications, 3 were prospective and controlled (test group with immediate loading versus control group with conventional loading), while 3 were only prospective. Eighty-five patients with edentulous mandibles were treated and 230 implants placed and loaded early (range, 1 to 6 weeks). The minimum implant length was 9 mm. In the selected articles, implants were either rigidly connected with a bar (2 articles) or unsplinted (4 articles). Only patients with good bone quality were selected for early loading. Eighty-five patients received 230 implants, which were followed from a minimum of 1 year to a maximum of 3 years. Fifteen implants were lost after the start of prosthetic loading. The average survival rate of the implants was 91.9% (range, 70.8% to 100%), while the overall success rate was 91.7% (range, 85.4% to 100%) (Table 2).

From the analysis of the available literature the following preliminary conclusions may be drawn:

1. Early loading of implants supporting overdentures placed in the interforaminal area of the mandible seems not to jeopardize the long-term survival and success rates of the implants, but the number of implants followed is very low and the follow-up quite short, when compared to the data

regarding immediately loaded implants supporting overdentures.

2. Both splinted and unsplinted implants seem to withstand the biomechanical demands of early loading, although lower success rates compared to success rates obtained in cases of immediately loaded splinted implants were reported in a study⁵⁰ in which unsplinted implants with a machined surface were used.
3. Good bone quality and primary stability seem to be important prognostic factors for the success of the procedure, but evaluation of these factors is quite subjective. Therefore, more objective measurement criteria such as insertion torque values, RFA, and Periotest should be used.
4. On average, survival and success rates for early loaded implants were comparable to those obtained in cases of conventionally loaded implants.⁴²⁻⁴⁵

IMMEDIATE LOADING OF IMPLANT-SUPPORTED FIXED PROSTHESES IN THE EDENTULOUS MANDIBLE

The first reports concerning immediate loading of implants in the edentulous mandible with implant-supported fixed prostheses were presented by Schnitman in 1990⁵² and thereafter in 1995⁵³ and 1997.⁵⁴ In the first 2 studies,^{52,53} 9 patients were selected and 58 Brånemark System implants were placed in the edentulous mandible. Inclusion criteria involved good bone quality and bicortical stabilization in the interforaminal area of the mandible. The follow-up ranged from 3 to 9 years and the survival rate was 85.7%. In the third study,¹⁵ 63 Brånemark System implants were placed in 10 patients and followed for up to 20 years. Twenty-eight implants were immediately loaded, providing support for fixed provisional screw-retained pros-

theses, while 35 adjacent implants were allowed to heal submerged. Following a 3-month healing period, the submerged implants were exposed and definitive reconstruction was accomplished. Of the 28 immediately loaded implants, 4 failed, while all submerged implants survived. The survival rates were 84.7% for the immediately loaded implants and 100% for the submerged implants. Statistical analysis of the submerged versus immediately loaded implants demonstrated significantly higher failure rates for immediately loaded implants. The authors stressed the following factors as important for long-term survival of implants: primary stability, threaded implant design, percentage of implant surface in contact with bone cortex, bone density, screw-retained and passive fitting fixed provisional restorations, and elimination of micromovement during the bone remodeling period with rigid splinting of implants. They also stressed that implants placed distal to mental foramina were more susceptible to failure.

Tarnow and colleagues¹⁶ reported their experience with 10 patients who received 107 implants in the edentulous mandible and maxilla (Brånemark System; ITI; Astra Tech, Mölndal, Sweden; 3i/Implant Innovations, West Palm Beach, FL). A minimum of 10 implants were placed in each patient's edentulous arch. A minimum of 5 implants were left to heal submerged and unloaded. The remaining implants were loaded on the day of surgery with provisional fixed prostheses. Of the 10 patients, 6 received implants in the mandible and 4 in the maxilla. Sixty-four implants were placed in edentulous mandibles, and 36 of these were immediately loaded. The stability of the implants was evaluated with the Periotest. The follow-up ranged between 1 and 5 years, with a survival rate of 97.4% (2 implants failed).

Balshi and Wolfinger⁵⁴ reported their experience with 10 patients receiving a total of 130 Brånemark System implants in the edentulous mandible (minimum 10 implants per patient), both anterior and posterior to the mental foramina. Forty of these implants were immediately loaded with a provisional fixed prosthesis, while the others were left to heal submerged and unloaded. Six weeks afterward, a second prosthesis was delivered. The non-immediately loaded implants were uncovered and loaded 3 months after implant placement. The follow-up period was approximately 1 year, although this was not well specified. Eight of 40 implants failed shortly after the start of loading. All implant losses occurred in patients with poor bone quality. The survival rate of the implants was 80%, while the survival rate of the prostheses was 100%.

In 1999, Brånemark and associates⁵⁵ presented a study with a new implant system (Brånemark Novum, Nobel Biocare). Fifty patients with edentulous mandibles received a total of 150 implants (3 per patient) in the interforaminal area, which were rigidly connected with a prefabricated titanium bar and immediately loaded within 1 day. The minimum length of the implants was 13 mm. Patients were followed from a minimum of 6 months to a maximum of 3 years (1 year on average). Three implants were lost, resulting in an overall survival rate of 98%, while 1 of 50 prostheses failed.

Horiuchi and coworkers²⁴ treated 12 patients with 96 implants in edentulous mandibles. Each patient received at least 5 implants with a minimum length of 10 mm and a minimum insertion torque of 40 Ncm. The follow-up ranged from 8 to 24 months. Two of 96 implants failed, giving an overall survival rate of 97.2%.

Chow and colleagues⁵⁶ presented their experience with 14 patients who received 4 implants each in the interforaminal area of the edentulous mandible. The implants were loaded with a screw-retained fixed provisional prosthesis within 24 hours. Implant survival rates after a 12-month follow-up period were determined according to the criteria of Albrektsson and associates.³⁹ For the 44 implants followed, the survival rate was 100% after 1 year.

In another study, Chow and coworkers⁵⁷ treated 27 consecutive patients with 123 Brånemark System implants placed in the interforaminal area of the mandible (14 patients were already included in the former study by the same group of authors⁵⁶). The implants were followed from a minimum of 3 months to a maximum of 30 months (15 patients were followed up for 1 year or longer). Implants were placed both in fresh extraction sockets and in healed sockets. All implants were placed with insertion torques not lower than 30 Ncm. Two patients were withdrawn from the study. Two of the 115 remaining implants failed, resulting in an overall survival rate of 98.3%.

Ganeles and associates²⁵ reported their experience in 27 patients with edentulous mandibles receiving 186 implants (ITI, Friatec, Astra Tech), 161 of which were immediately loaded using fixed provisional restorations of various designs. Only 1 implant was lost shortly after the start of loading, providing an implant survival rate of 99.4%.

Grunder⁵⁸ reported his experience in 5 patients with edentulous mandibles receiving 43 implants (3i/Implant Innovations), 31 of which were placed in fresh extraction sockets and immediately loaded with fixed provisional prostheses. Six months afterward, provisional prostheses were replaced with

definitive metal-ceramic suprastructures. After a 2-year follow-up, only 1 implant was lost, with a cumulative survival rate of 97.3%.

Cooper and coworkers²⁷ presented their experience in 10 patients treated with tooth extraction, immediate implant placement in the extraction sockets, and immediate loading of the implants. Forty-eight of 54 implants placed in the parasymphyseal region of the mandible were immediately loaded. Of these implants, 34 were placed directly into extraction sockets. After a follow-up period ranging from 6 to 128 months, the survival rate of the implants was 100%. The authors concluded that immediate loading of implants placed into fresh extraction sockets can lead to high survival rates.

Wolfinger and associates³¹ reported 3- to 5-year results for 2 groups of patients. The first group included 9 patients with a minimum of 5 years of follow-up, while the second group included 24 patients. In the first group, every patient received a minimum of 10 Brånemark System implants that were at least 7 mm long, while in the second group patients received an average of 6 implants. Implants were placed in both the anterior and posterior mandible. In the first group of patients, only 4 implants per patient were immediately loaded with acrylic resin provisional restorations, while the others were left submerged and were uncovered 3 months later. The rationale was dictated by the need for using implants as provisional support during integration of the other implants. In the second group, all implants were immediately loaded. In the first group, the survival rate of implants was 80%, while in the second group it was 97%.

Testori and colleagues⁵⁹ presented data concerning 15 patients with edentulous mandibles who received 103 Osseotite implants (3i/Implant Innovations) (5 or 6 implants per patient). The implants were loaded with a provisional screw-retained prosthesis within 36 hours. The authors reported a cumulative success rate of 98.9%.

A further report by Testori and coworkers⁶⁰ presented data from a study conducted on 62 patients treated in 4 centers. A total of 325 Osseotite implants (5 or 6 per patient) were placed in the edentulous mandible and immediately loaded. Inclusion criteria included primary stability of implants with 32 Ncm minimum torque at the time of placement and normal or dense bone corresponding to class 1 to 3 according to the Lekholm and Zarb classification.³⁸ Exclusion criteria included smoking, pregnancy, need for bone augmentation, systemic disease such as diabetes, and active infection in the sites to be implanted. Success criteria according to Albrektsson and associates³⁹ were

recorded. The temporary prosthesis was delivered 48 hours after surgery, on average, while the definitive prosthesis was delivered 6 months after surgery. Data concerning marginal bone loss were recorded from periapical radiographs. Two implants failed to integrate within 2 months of occlusal loading. The mean follow-up was 29 months (range, 12 to 60 months). The cumulative success rate was 99.4%.

Malò and colleagues⁶¹ presented a retrospective analysis of 44 patients, presenting with an edentulous mandible, who received 176 Brånemark System implants in the interforaminal region that supported fixed acrylic resin complete-arch mandibular prostheses. In addition to the immediately loaded implants, 24 of the 44 patients had 62 additional implants not incorporated in the provisional prostheses but incorporated in definitive prostheses later on. Postextraction implants were also considered in this group, and heavily angulated implants were placed close to the mental foramina to obtain a more distal position of the suprastructure without compromising inferior alveolar nerve function. The follow-up period ranged from 1 to 3 years. Survival criteria were: functional implant stability, absence of pain, and radiographic evaluation of the marginal bone level. No data regarding peri-implant bone resorption were reported. Five implants were lost in 5 patients shortly after implant loading, giving a cumulative survival rate of 96.7%. Prosthesis survival was 100%.

Engstrand and coworkers⁶² presented the long-term results of 95 patients with edentulous mandibles treated with fixed prostheses supported by 3 implants per patient placed in the anterior mandible (results for 50 of these patients were already presented in a previous article⁵⁵). The Brånemark Novum System was used. A total of 285 implants were placed; of these implants, 67% were immediately loaded, while the remaining 33% were loaded on average 5.6 days afterward (range, 1 to 40 days). The follow-up time was 1 to 5 years (mean, 2.5 years). Eighteen implants (6.3%) failed in 13 patients. Kaplan-Meier survival estimates demonstrated a probability of implant survival of 95% at 1 year, 93.3% at 3 years, and 93.3% at 5 years. Peri-implant bone loss mesial and distal to each implant was within the limits proposed by Albrektsson and associates³⁹ after 5 years of loading. The authors concluded that immediate loading of this type of implant system produced a survival rate comparable to that obtained in a traditional 2-stage procedure.

Misch and Degidi⁶³ presented the long-term results of a 2-center study performed on 31 edentulous patients; 19 presented with edentulous mandibles and 12 with edentulous maxillae. In the edentulous mandible group, 14 patients received a total of 100

implants (range, 5 to 10 implants), which were loaded the same day with a provisional acrylic resin prosthesis. Four to 7 months afterwards, definitive prostheses were fabricated. The follow-up ranged from 1 to 5 years after the start of prosthetic loading. No implants were lost and no implants presented signs of failure (excessive peri-implant bone loss, paresthesia, pain, etc). The survival and success rates of both the implants and the prostheses were 100%.

Over a 5-year period (1996 to 2001), Degidi and Piattelli⁴¹ treated 152 patients with partially or totally edentulous jaws (for details, see first section). Of the treated patients, 22 presenting with edentulous mandibles received 148 implants and were rehabilitated with implant-supported fixed prostheses. The follow-up ranged from 2 to 60 months. The reported survival rate of implants supporting fixed prostheses was 100%. The authors reported that failures were not related to bone quality or quantity; diameter, length, or position of implants; or type of abutment used.

Conclusions Regarding the Immediate Loading of Implant-Supported Fixed Prostheses in the Edentulous Mandible

Twenty articles were analyzed, but only 16 had adequate data (as defined by this review) concerning survival criteria and follow-up. Of these articles, 13 were prospective case series and 3 were retrospective case series. No randomized controlled clinical trials were found in the literature. The total number of patients treated in the selected articles was 387, and the total number of implants placed was 2,088. Of these implants, 1,804 were immediately loaded with fixed implant-supported prostheses. The follow-up ranged from 1 to 10 years. Survival rates ranged from 80% to 100% (mean, 95%; Table 3).

The available data suggest that survival rates of immediately loaded implants with implant-supported fixed prostheses compare favorably to those obtained with conventional loading.^{1,40,64-69} However, several factors must be considered. Eight of the 15 selected articles did not specify success criteria. In many of these articles a large number of implants were used for fixed implant-supported restorations. Eight articles did not specify the dentition in the opposing arch. The majority of articles did not present defined inclusion and exclusion criteria. The majority of the authors agreed that:

1. At least 4 implants are needed in the anterior mandible to support a fixed prosthesis.
2. Primary stability with insertion torques up to 35 Ncm is an important factor for long-term survival of implants.

3. Good bone quality (classes 1 to 3 according to the Lekholm and Zarb³⁸ classification) is an important factor for the long-term prognosis of implants.

As already stressed in the conclusions to the earlier sections, the application of standardized criteria to define success rates is fundamental to reaching conclusions on the long-term reliability of this procedure.

EARLY LOADING OF IMPLANT-SUPPORTED FIXED PROSTHESES IN THE EDENTULOUS MANDIBLE

Randow and coworkers²³ performed a clinical and radiographic study to compare the outcome of oral rehabilitation in the edentulous mandible by fixed suprastructures connected to implants. The implants were placed according to either a 1-stage surgical procedure and early loading (experimental group) or the original 2-stage concept (reference group). The results were presented by the same group of authors in a more recent publication by Ericsson and coworkers.⁷⁰ The second article also reported on a clinical and radiographic study comparing the outcome of oral rehabilitation of edentulous mandibles with fixed prostheses connected to implants. The implants were placed according to either a 1-stage procedure and early loading (experimental group) or the original 2-stage procedure (reference group). The groups comprised 16 and 11 patients, respectively. In the experimental group, a total of 88 implants were placed in the interforaminal area of the mandible, compared to 30 in the reference group. In the experimental group, fixed prostheses were connected to the implants 20 days after implant placement, while the fixed prostheses in the reference group were connected 4 months later. Radiographic examination was performed at the time of prosthesis delivery and then repeated at the 18-month and 60-month follow-ups. Analysis of the radiographs from the experimental group showed a mean peri-implant bone loss of 0.2 mm. In the reference group, the corresponding value was 0.0 mm. During the 60-month observation period, no implant was lost in either of the 2 groups. This study demonstrated that it was possible to successfully load dental implants soon after placement (20 days) with a permanent fixed cross-arch suprastructure.

Petersson and colleagues²⁶ compared the peri-implant marginal bone level changes in a prospective study using Brånemark System dental implants placed according to either a 1-stage or a 2-stage surgical procedure combined with early functional loading. The same patients had already been described in the previous studies by Randow and coworkers²³ and

Table 3 Published Articles Relating to the Immediate Loading of Implant-Supported Fixed Protheses in the Edentulous Mandible

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Schnitman et al 1997 ¹⁵	Prosp	10	63	28	10	4	85.7	No data
Tarnow et al 1997 ¹⁶	Prosp	6	64	36	1 to 5	2	97.4	No data
Balshi/Wolfinger 1997 ⁵⁴	Prosp	10	130	40	1	8	80.0	No data
Brånemark et al 1999 ⁵⁵	Prosp	50	150	150	0.5 to 3	3	98.0	98.0
Horiuchi et al 2000 ²⁴	Prosp	12	105	96	1 to 2	2	97.2	No data
Chow et al 2001 ⁵⁶	Prosp	14	56	56	1	0	100.0	100.0
Chow et al 2001 ⁵⁷	Prosp	27	123	123	1 to 2	2	98.3	98.3
Ganeles et al 2001 ²⁵	Prosp	27	186	161	1 to 3	1	99.0	No data
Grunder 2001 ⁵⁸	Retro	5	43	43	2	1	97.3	97.3
Cooper et al 2002 ²⁷	Prosp	10	54	48	1	0	100.0	No data
Malò et al 2003 ⁶¹	Retro	44	176	176	1 to 3	5	96.7	No data
Wolfinger et al 2003 ³¹	Prosp	24	144	144	3 to 5	5	97.0	96.5
Testori et al 2003 ⁵⁹	Prosp/mc	62	325	325	1 to 5	2	99.4	99.4
Engstrand et al 2003 ⁶²	Prosp	95	295	295	1 to 5	18	93.3	93.3
Misch/Degidi 2003 ⁶³	Prosp/mc	14	100	100	1 to 5	0	100.0	100.0
Degidi/Piattelli 2003 ⁴¹	Retro	17	148	148	1 to 5	0	100.0	100.0
Total		387	2,086	1,804				

Retro = retrospective; prosp = prospective; mc = multicenter.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

Ericsson and associates.⁷⁰ Seven patients were treated with a split-mouth technique, using a 1-stage surgical technique on one side and a 2-stage technique on the other side. In this latter group, the implants were submerged during a 3- to 4-month healing period before abutment connection and loading. In 13 patients the definitive prosthetic suprastructure was connected within 20 days of a 1-stage procedure. This group of patients received 5 or 6 implants each in the anterior edentulous mandible. Marginal bone level changes were followed for up to 5 years from implant placement. After connection of the suprastructure, the marginal bone resorption was significantly less in the early functional loading group than in groups who received implants via the 1-stage and 2-stage surgical techniques with conventional loading. However, after 18 months and after 5 years, the marginal bone was located approximately 1 mm apical to the implant abutment level in all 3 groups. The authors concluded that over the long term there was no difference in marginal bone resorption between 1-stage and 2-stage surgical procedures and a 1-stage procedure with early functional loading of dental implants. This study also indicated that elimination of the second stage of surgery might reduce early bone resorption.

In a prospective multicenter study, De Bruyn and coworkers⁷¹ evaluated the 1-year and 3-year success rates of implants loaded within 1 month after implant placement, as well as the outcome of prosthetic treatment and the opinions of patients regard-

ing the treatment procedure. A fixed 10- to 12-unit prosthesis was loaded on 3 regular-platform Brånemark System implants in the mandible. Twenty patients received 5 implants in the mandible, of which 3 were functionally loaded with the 1-stage technique (group 1). The loaded implants were placed in a tripod position, while 2 implants were placed for safety reasons but not loaded. The latter implants served as either an unloaded 1-stage control implant (group 2) or an unloaded control implant placed with a submerged technique (group 3). Immediately after surgery, the implants were loaded with a relined denture. The patients received a 10- to 12-unit prosthetic restoration an average of 31 days (range, 4 to 53 days) after surgery. Implant stability was clinically assessed at 3, 12, and 36 months. Radiographs were taken at corresponding follow-up visits to calculate the peri-implant bone level and marginal resorption. Six of 60 functionally loaded implants and 3 of 20 prostheses failed within the first year. The cumulative implant failure rate in group 1 after both 1 and 3 years was 9.5%. No implant failures occurred in groups 2 and 3. The average marginal bone resorption at 1 and 3 years was 1.6 mm and 2.1 mm, respectively, for group 1; 1.5 mm and 2.4 mm for group 2; and 0.8 mm and 0.7 mm for group 3. The results of treatment using 3 regular-platform Brånemark System implants supporting a fixed mandibular prosthesis were less favorable than the outcome that can be expected with a standard 4- to 6-implant treatment with 1-stage surgery.

Misch and Degidi⁶³ presented the long-term results of a 2-center study performed on 31 edentulous patients, 19 of whom had edentulous mandibles and 12 with edentulous maxillae. In the edentulous mandible group, 5 patients received 36 implants (range: 5 to 10 implants), which were loaded within 2 weeks with a provisional acrylic resin prosthesis. Four to 7 months afterwards, definitive prostheses were fabricated. The follow-up ranged from 1 to 5 years after the start of prosthetic loading. No implants were lost and no implants showed signs of failure (excessive peri-implant bone loss, paresthesia, pain, etc). The survival and success rates of the implants as well as the prostheses were 100%.

In a prospective multicenter study, Raghoobar and colleagues⁵¹ described their experience in 40 patients with mandibular edentulism. The patients received 170 implants, which were prosthetically loaded within 6 weeks. Of these patients, 10 were rehabilitated with implant-supported fixed prostheses (5 implants per patient). The patients were followed for 3 years after the start of prosthetic loading. The overall survival rate of implants and prostheses was 94%.

Conclusions Regarding the Early Loading of Implant-Supported Fixed Prostheses in the Edentulous Mandible

Fewer data are available on early loading than on immediate loading of implants in the edentulous mandible. Six prospective articles were analyzed, one of which was controlled with a reference group receiving conventionally loaded implants. A total of 51 patients were treated, 272 implants placed, and 234 implants subjected to early loading. Survival rates of implants ranged from 90.5% to 100%, with a mean of 97.3%, whereas the survival rate of the prostheses was 96.3% (Table 4). However, the sample of patients and implants is limited because of the fact that the same patients were analyzed in different studies.^{23,26,70}

IMMEDIATE LOADING OF IMPLANT-SUPPORTED OVERDENTURES IN THE EDENTULOUS MAXILLA

No articles concerning this topic were found. No conclusions can be drawn.

EARLY LOADING OF WITH IMPLANT-SUPPORTED OVERDENTURES IN THE EDENTULOUS MAXILLA

No articles concerning this topic were found. No conclusions can be drawn.

IMMEDIATE LOADING OF IMPLANT-SUPPORTED FIXED PROSTHESES IN THE EDENTULOUS MAXILLA

Tarnow and coworkers¹⁶ reported their experience with 10 patients who received 107 implants in the edentulous mandible and maxilla. Of these patients, 4 presented with an edentulous maxilla. The patients received 43 implants of 3 different systems (Astra Tech; 3i/Implant Innovations; Brånemark System, Nobel Biocare), with a minimum of 10 implants per patient. Of these implants, 33 were immediately loaded with provisional fixed prostheses. The follow-up ranged from 1 to 4 years. Six months after the start of prosthetic loading, provisional prostheses were substituted with definitive ones. None of the immediately loaded implants failed, leading to a survival rate of 100%.

Horiuchi and coworkers²⁴ presented their experience in 5 patients with edentulous maxillae who received 52 Brånemark System implants. Each patient received a minimum of 8 implants with a minimum length of 10 mm. Only implants with an insertion torque greater than 40 Ncm were immediately loaded with screw-retained provisional fixed prostheses, while the other implants were left to heal submerged. A total of 44 implants were immediately loaded. After a 4- to 6-month healing period, definitive prostheses were placed. Two of the 44 immediately loaded implants failed, while none of the conventionally loaded implants failed. The cumulative survival rate of immediately loaded implants was 96.5%.

Grunder⁵⁸ reported his experience in 5 patients with edentulous maxillae who received 48 3i/Implant Innovations' implants, 35 of which were placed in fresh extraction sockets. Implants were placed in both high- and low-quality bone (classes 2 to 4 according to the Lekholm and Zarb³⁸ classification). Of the 35 implants placed in fresh extraction sockets, 3 failed, as did 3 of the 13 implants placed in healed alveolar bone. The survival rate of maxillary implants was 87.5%.

Misch and Degidi⁶³ presented the long-term results of a 2-center study performed on 31 edentulous patients, 19 presenting with edentulous mandibles and 12 with edentulous maxillae. In the edentulous maxilla group, 2 patients received a total of 18 implants (range, 8 to 10 implants), which were loaded the same day with provisional acrylic resin prostheses. Four to 7 months afterward, definitive prostheses were placed. The follow-up ranged from 1 to 5 years after the start of prosthetic loading. No implants were lost and no implants presented signs of failure (excessive peri-implant bone loss, paresthesia,

Table 4 Published Articles Relating to Early Loading of Implant-Supported Fixed Protheses in the Edentulous Mandible

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Randow et al 1999 ²³	Prosp/cont	16	88	88	1.5	0	100.0	100.0
Ericsson et al 2000 ⁷⁰	Prosp/cont	16	88	88	1 to 5	0	100.0	100.0
Petersson et al 2001 ²⁶	Prosp/cont	13	70	70	1.5 to 5	0	100.0	100.0
De Bruyn et al 2001 ⁷¹	Prosp/cont	20	100	60	1 to 3	6	90.5	90.5
Misch/Degidi 2003 ⁶³	Prosp/mc	5	36	36	1 to 5	0	100.0	100.0
Raghoobar et al 2003 ⁵¹	Prosp/mc	10	50	50	3	3	93.0	93.0
Total		51	274	234		9		

Prosp = prospective; cont = controlled; mc = multicenter.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

pain, etc). The survival and success rates of the implants as well as of the prostheses was 100%.

During a 5-year period (1996 to 2001), Degidi and Piattelli⁴¹ treated 152 patients presenting both partially and completely edentulous jaws (see first section for further details). Of the treated patients, 14 with an edentulous maxilla received 133 implants that were immediately loaded. The follow-up ranged between 2 and 60 months. Two of 133 implants were lost. Therefore the overall survival rate was 98.5%, while the prosthesis survival rate was 100%.

Conclusions Regarding the Immediate Loading of Implant-Supported Fixed Protheses in the Edentulous Maxilla

Seven articles addressing this topic were found, but only 5 met the criteria of this review. Of these articles, 3 were prospective case series and 2 were retrospective case series. No randomized controlled clinical trials were found in the literature. The total number of patients treated in the selected articles was 30 and the total number of implants placed was 294, which represents a large number of implants per patient. Of these implants, 276 were immediately loaded with fixed implant-supported prostheses. The follow-up ranged from 1 to 5 years. Survival rates ranged from 87.5% to 100%, while success rates ranged from 96.5% to 100%, although it must be considered that some articles did not present well-defined success criteria (Table 5). From the analysis of these data, it appears that survival rates of implants immediately loaded with full-arch fixed prostheses compare favorably with those obtained with conventional loading.^{40,66-69} However, several factors have to be considered: (1) The number of patients and implants is very limited; (2) well-defined inclusion and exclusion criteria are lacking; and (3) the articles do not present homogeneous and thorough information regarding success

criteria concerning implants, but only rough data about the survival rates of implants. It is therefore difficult to draw any significant conclusions.

The majority of the authors suggest the following:

1. A greater number of implants are necessary in the maxilla than in the mandible to support immediately loaded full-arch prostheses.
2. Primary stability is suggested to be an important factor for long-term survival of these implants.
3. Good bone quality (classes 1 to 3 according to the Lekholm and Zarb³⁸ classification) is an important factor, but there is generally a lack of objective measurements to evaluate implant stability, such as insertion torque measurements, RFA, and/or Periotest.

Some of the authors also suggested that obtaining an insertion torque of at least 35 Ncm is an important factor for loading decisions.

EARLY LOADING OF IMPLANT-SUPPORTED FIXED PROTHESES IN THE EDENTULOUS MAXILLA

As part of a case series of 41 patients, Glauser and coworkers⁴⁹ presented the results for 3 patients with edentulous maxillae who received 18 Brånemark System implants loaded within 1 week of implant placement with provisional cross-arch fixed prostheses. The follow-up after the start of prosthetic loading was 1 year. Two implants failed, for a survival rate of 89%.

Olsson and associates⁷² presented the results for 10 patients with edentulous maxillae. Nine patients received 6 implants each, while 1 patient received 8

Table 5 Published Articles Relating to the Immediate Loading of Implant-Supported Fixed Protheses in the Edentulous Maxilla

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Tarnow et al 1997 ¹⁶	Prosp/cs	4	22	14	1 to 4	0	100.0	100.0
Horiuchi et al 2000 ²⁴	Prosp/cs	5	52	44	1 to 2	2	96.5	96.5
Grunder 2001 ⁵⁸	Retro/cs	5	48	48	1 to 5	6	87.5	No data
Misch/Degidi 2003 ⁶³	Prosp/mc	2	18	18	0 to 5	0	100.0	100.0
Degidi/Piattelli 2003 ⁴¹	Retro/cs	14	133	133	1	2	98.5	No data
Total		30	294	276		10		

Prosp = prospective; Retro = retrospective; cs = case series; mc = multicenter.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

implants. Provisional prostheses were delivered after 2.5 days on average (range, 1 to 9 days). After a mean of 4 months, the provisional prostheses were replaced with the definitive ones. All implants were tested at the time of placement and loading with RFA. The mean follow-up was 12 months. Four of 61 implants were lost because of early infection. The mean RFA value at the time of implant placement was 60.1 ISQ (implant stability quotient). A survival rate of 93.4% after 1 year of prosthetic loading was reported.

Misch and Degidi⁶³ presented the long-term results of a 2-center study performed on 31 edentulous patients, 19 with edentulous mandibles and 12 with edentulous maxillae. In the edentulous maxilla group, 10 patients received a total of 90 implants (range, 8 to 10 implants each), which were loaded within 2 weeks with a provisional acrylic resin prosthesis. Four to 7 months afterward, definitive prostheses were fabricated. The follow-up ranged from 1 to 5 years after the start of prosthetic loading. No implants were lost and no implants presented signs of failure (excessive peri-implant bone loss, paresthesia, pain, etc). The survival and success rates of the implants and the prostheses were 100%.

Van den Bogaerde and colleagues⁷³ reported their experience with early loading of Brånemark System implants in partially or completely edentulous jaws. Three of the 31 treated patients had an edentulous maxilla. These patients received 23 implants, which were rigidly connected with a provisional prosthesis within 20 days of implant placement. Patients were followed up to 18 months with clinical and radiographic evaluations. The survival rate of the implants was 100%, but no success criteria were considered because of the relatively brief follow-up.

Conclusions Regarding the Early Loading of Implant-Supported Fixed Protheses in the Edentulous Maxilla

A total of 4 prospective articles were reviewed. All articles were represented by case series. No randomized controlled studies were found. Twenty-six patients received 192 implants that were loaded within 3 weeks of implant placement. The follow-up ranged from 1 to 5 years. The survival rate of implants ranged from 89% to 100% (mean, 95.6%; Table 6). Conclusions are similar to those for the previous section; however, the sample was too small to draw any meaningful conclusions.

GENERAL CONCLUSION

The analysis of the available publications demonstrated, on average, poor methodologic quality with regard to allocation concealment, completeness of follow-up, sample size, randomization, exclusion and inclusion criteria, type of opposing arch dentition, type of occlusion, and success criteria. A recent review published by Esposito and associates⁷⁴ demonstrated that only 2 articles presented sufficient methodologic quality (prospective, comparative randomized studies with at least 1 year of follow-up^{18,50}). Thus, the number of trials and patients was definitely too small to draw any reliable conclusions. More well-designed randomized controlled clinical trials are needed to understand how predictable the protocols are for immediate and early loading, as proposed by Esposito and associates.⁷⁴

Limited histologic data supporting the reliability of immediate loading under various clinical conditions further reduce the possibility, at present, of widespread use of immediate or early loading of implants in all clinical situations. Only sparse data are available.^{13,20-22,28,32,33} Data obtained by the analysis performed in this article and by the analysis of a

Table 6 Published Articles Relating to Early Loading of Implant-Supported Fixed Protheses in the Edentulous Maxilla

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Glauser et al 2001 ⁴⁹	Prosp/cs	3	18	18	1	2	89.0	No data
Olsson et al 2003 ⁷²	Prosp/cs	10	61	61	1	4	93.4	No data
Misch/Degidi 2003 ⁶³	Prosp/cs	10	90	90	1 to 5	0	100.0	100.0
Van den Bogaerde et al 2003 ⁷³	Prosp/cs	3	23	23	1.5	0	100.0	100.0
Total		23	169	169		8		

Prosp = prospective; cs = case series;

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

recent review concerning immediate loading of dental implants⁷⁵ seem to indicate the following aspects:

1. The majority of articles indicate that good bone quality, primary implant stability, and splinting of implants in cases of immediate and early loading are recommended, although no uniform criteria to evaluate these parameters have been used. Measurements have included insertion torque, RFA, and Periotest values.
2. Immediate loading of full-arch mandibular fixed protheses and overdentures supported by rigidly connected implants between the mental foramina is routine and has a base of clinical evidence.
3. Early loading of implants placed in the mandible, both with overdentures and fixed protheses, seems to be a reliable technique, but more data are needed before proposing this technique as routine.
4. No meaningful data are available about immediate or early loading of edentulous maxillae with implant-supported overdentures.
5. The use of immediate or early loading of fixed implant-supported protheses in the maxilla is not supported by sufficient data to consider this treatment modality as routine, although preliminary results seem to be encouraging.
6. On average, a greater number of implants is suggested by many authors for the rehabilitation of edentulous maxillae than edentulous mandibles.

REFERENCES

1. Schroeder A, Pohler O, Sutter F. Gewebsreaktion auf ein Titan-hohlzylinder-implantat mit Titan-Spritzschichtoberfläche. *Schweiz Monatsschr Zahnheilkd* 1976;86:713–727.
2. Brånemark P-I, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw: Experience from a 10-year period. *Scand J Plast Reconstr Surg* 1977;11:1–132.
3. Unthoff HK, Germain LP. The reversal of tissue differentiation around screws. *Clin Orthop* 1975;123:248–252.
4. Søballe K, Hansen ES, Brockstedt-Rasmussen H, Bünger C. Tissue ingrowth into titanium and hydroxyapatite-coated implants during stable and unstable mechanical conditions. *J Orthop Res* 1992;10:285–299.
5. Cameron H, Pilliar RM, Macnab I. The effect of movement on the bonding of porous metal to bone. *J Biomed Mater Res* 1973;7:301–311.
6. Schatzer J, Horne JG, Summer-Smith G. The effect of movement on the holding power of screws in bone. *Clin Orthop Relat Res* 1975;(III):257–262.
7. Brunski JB, Moccia AF, Pollock SR, Korostoff E, Trachtenberg DI. The influence of functional use of endosseous dental implants on the tissue implant interface: I. Histological aspects. *J Dent Res* 1979;58:1953–1969.
8. Akagawa Y, Hashimoto M, Kondo N, Satomi K, Tsuru H. Initial bone-implant interfaces of submergible and supramergible endosseous single-crystal sapphire implants. *J Prosthet Dent* 1986;55:96–101.
9. Ledermann PD. Stegprothetische Versorgung des zahnlosen Unterkiefers mit Hilfe von plasmabeschichteten Titan-schraubenimplantaten. *Dtsch Zahnärztl Z* 1979;34:907–911.
10. Ledermann PD. Sechsjährige klinische Erfahrung mit dem titanplasmabeschichteten ITI-Schraubenimplantat in der Regio Interforaminalis des Unterkiefers. *Schweiz Monatsschr Zahnmed* 1983;93:1080–1089.
11. Deporter DA, Watson PA, Pilliar RM, Howley TP, Winslow J. A histological evaluation of a functional endosseous, porous-surfaced titanium alloy dental implant system in the dog. *J Dent Res* 1988;67:1190–1195.
12. Hashimoto M, Akagawa Y, Hashimoto M, Nikai H, Tsuru H. Single crystal sapphire endosseous implant loaded with functional stress: Clinical and histological evaluation of peri-implant tissues. *J Oral Implantol* 1988;15:65–76.
13. Piattelli A, Ruggieri A, Franchi M, Romasco N, Trisi P. A 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.
14. Sagara M, Akagawa Y, Nikai H, Tsuru H. The effects of early occlusal loading on one-stage titanium implants in beagle dogs: A pilot study. *J Prosthet Dent* 1993;69:281–288.
15. Schnitman PA, Wohrle PS, Rubinstein JE, DaSilva JD, Wang NH. Ten-year results for Brånemark implants immediately loaded with fixed protheses at implant placement. *Int J Oral Maxillofac Implants* 1997;12:495–503.
16. Tarnow DP, Emtiaz 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.

17. Chiapasco M, Gatti C, Rossi E, Haefliger W, Markwalder T. Implant-retained mandibular overdentures with immediate loading: Results of 226 consecutive cases. *Clin Oral Implants Res* 1997;8:48–57.
18. Chiapasco M, Abati S, Romeo E, Vogel G. Implant-retained mandibular overdentures with Brånemark System MKII implants: A prospective comparative study between delayed and immediate loading. *Int J Oral Maxillofac Implants* 2001;16:537–546.
19. Chiapasco M, Gatti C. Implant-retained mandibular overdentures with immediate loading: A 3- to 8-year prospective study of 328 implants. *Clin Implant Dent Relat Res* 2003;4:51–61.
20. 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.
21. Piattelli A, Paolantonio M, Corigliano M, Scarano A. Immediate loading of titanium plasma-sprayed screw-shaped implants in man: A clinical and histological report of two cases. *J Periodontol* 1997;68:591–597.
22. Piattelli A, Corigliano M, Scarano A, Costigliola G, Paolantonio M. Immediate loading of titanium plasma-sprayed implants: A histologic analysis in monkeys. *J Periodontol* 1998;69:321–327.
23. Randow K, Ericsson I, Nilner K, Petersson 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.
24. 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.
25. Ganeles J, Rosenberg MM, Holt RL, Reichman LH. Immediate loading of implants with fixed restorations in the completely edentulous mandible: Report of 27 patients from a private practice. *Int J Oral Maxillofac Implants* 2001;16:418–426.
26. 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.
27. Cooper L, Rahman A, Moriarty J, Chaffee N, Sacco D. Immediate mandibular rehabilitation with endosseous implants: Simultaneous extraction, implant placement and loading. *Int J Oral Maxillofac Implants* 2002;17:517–525.
28. Romanos GE, Toh CG, Siar CH, Swaminathan D. Histologic and histo-morphometric evaluation of peri-implant bone subjected to immediate loading: An experimental study with *Macaca fascicularis*. *Int J Oral Maxillofac Implants* 2002;17:44–51.
29. Romeo E, Chiapasco M, Lazza A, et al. Implant-retained mandibular overdentures with ITI oral implants: A comparison of 2-year results between delayed and immediate loading. *Clin Oral Implants Res* 2002;13:495–501.
30. Gatti C, Chiapasco M. Immediate loading of Brånemark implants: A 24-month follow-up of a comparative prospective pilot study between mandibular overdentures supported by Conical transmucosal implants and standard MK II implants. *Clin Implant Dent Relat Res* 2002;4:190–199.
31. 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.
32. Rocci A, Martignoni M, Burgos PM, Gottlow J, Sennerby L. Histology of retrieved immediately and early loaded oxidized implants: Light microscopic observation after 5 to 9 months of loading in the posterior mandible. *Clin Implant Dent Relat Res* 2003;5:88–98.
33. Testori T, Szmuckler-Moncler S, Francetti L, Del Fabbro M, Trisi P, Weinstein R. 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;4:345–353.
34. Maniopoulos C, Pilliar RM, Smith D. Threaded versus porous-surfaced designs for implant stabilization in bone-endodontic implant model. *J Biomed Mater Res* 1986;20:1309–1333.
35. Pilliar RM, Lee GM, Maniopoulos C. Observations on the effect of movement on bone ingrowth into porous-surfaced implants. *Clin Orthop Relat Res* 1986;208:108–113.
36. Pilliar RM, Deporter D, Watson PA. Tissue-implant interface: Micromovement effects. In: Vincenzini P (ed). *Materials in Clinical Applications: Proceedings of Topical Symposium VIII on Materials in Clinical Applications of the 8th CIMTEC World Ceramics Congress and Forum on New Materials*, Florence, Italy, June 28 to July 4, 1994, vol 12, *Advances in Science and Technology*. Faenza, Italy: Techna, 1995:569–579.
37. Szmuckler-Moncler S, Salama H, Reingewirtz Y, Dubrulle JH. Timing of loading and effect of micromotion on bone-dental implant interface: Review of experimental literature. *J Biomed Mater Res* 1998;43:192–203.
38. Lekholm U, Zarb G. Patient selection and preparation. In: Brånemark P-I, Zarb G, Albrektsson T (eds). *Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry*. Chicago: Quintessence, 1985:199–209.
39. Albrektsson T, Zarb G, Worthington P, Eriksson RA. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986;1:11–25.
40. Gatti C, Haefliger W, Chiapasco M. Implant-retained mandibular overdentures with immediate loading. A prospective study of ITI implants. *Int J Oral Maxillofac Implants* 2000;15:383–388.
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. Naert I, De Clerq M, Theuniers G, Schepers E. Overdentures supported by osseointegrated fixtures for the edentulous mandible: A 2.5-year report. *Int J Oral Maxillofac Implants* 1988;3:191–196.
43. Mericske-Stern R. Clinical evaluation of overdenture restorations supported by osseointegrated titanium implants: A retrospective study. *Int J Oral Maxillofac Implants* 1990;5:375–383.
44. Johns RB, Jemt T, Heath MR, et al. A multicenter study of overdentures supported by Brånemark implants. *Int J Oral Maxillofac Implants* 1992;7:513–522.
45. Jemt T, Chai J, Harnett J, et al. A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. *Int J Oral Maxillofac Implants* 1996;11:291–298.
46. Payne AGT, Tawse-Smith A, Kumara R, Thomson M. One-year prospective evaluation of the early loading of unsplinted conical Brånemark fixtures with mandibular overdentures immediately following surgery. *Clin Implant Dent Relat Res* 2001;3:9–19.

47. Payne AGT, Tawse Smith A, Duncan WD, Kumara R. Conventional and early loading of unsplinted ITI implants supporting mandibular overdentures. Two-year results of a prospective randomized clinical trial. *Clin Oral Implants Res* 2002;13:603–609.
48. Roynesdal AK, Amundrud B, Hannaes H. A comparative clinical investigation of 2 early loaded ITI dental implants supporting an overdenture in the mandible. *Int J Oral Maxillofac Implants* 2001;16:246–251.
49. Glauser R, R e A, Lundgren AK, et al. Immediate occlusal loading of Br anemark implants in various jawbone regions: A prospective, 1-year clinical study. *Clin Implant Dent Relat Res* 2001;3:204–213.
50. Tawse-Smith A, Payne AGT, Kumara R, Thomson WM. Early loading of unsplinted implants supporting mandibular overdentures using a one-stage operative procedure with two different implant systems: A 2-year report. *Clin Implant Dent Relat Res* 2002;4:33–42.
51. Raghoobar 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.
52. 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.
53. Schnitman PA. Br anemark implants loaded with fixed provisional prostheses at fixture placement: Nine-year follow-up. *J Oral Implantol* 1995;21:235–245.
54. Balshi TJ, Wolfinger GJ. Immediate loading of Br anemark implants in edentulous mandibles: A preliminary report. *Implant Dent* 1997;6:83–88.
55. Br anemark P-I, Engstrand P, Ohnrell LO, et al. Br anemark 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.
56. Chow J, Hui E, Liu J. Immediate loading of Br anemark system fixtures in the mandible with a fixed provisional prosthesis. *Appl Osseointegration Res* 2001;1:30–35.
57. Chow J, Hui E, Liu J, et al. The Hong Kong bridge protocol. Immediate loading of mandibular Br anemark fixtures using a fixed provisional prosthesis: Preliminary results. *Clin Implant Dent Relat Res* 2001;3:166–174.
58. Grunder U. Immediate functional loading of immediate implants placed in edentulous arches: 2-year results. *Int J Periodontics Restorative Dent* 2001;21:545–551.
59. Testori T, Del Fabbro M, Szmuckler-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.
60. Testori T, Meltzer A, Del Fabbro M, et al. Immediate occlusal loading of Osseotite implants in the lower edentulous jaw. A multicenter prospective study. *Clin Oral Implants Res* 2004;15:278–284.
61. Mal  P, Rangert B, Eng M, Nobre M. “All-on-four” immediate function concept with Br anemark system implants for completely edentulous mandibles: A retrospective clinical study. *Clin Implant Dent Relat Res* 2003;5:2–9.
62. Engstrand P, Grondahl K, Ohnrell LO, Nilsson P, Nannmark U, Br anemark P-I. Prospective follow-up study of 95 patients with edentulous mandibles treated according to the Br anemark Novum concept. *Clin Implant Dent Relat Res* 2003;5:3–11.
63. 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.
64. Adell R, Lekholm U, Rockler B. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *J Oral Surg* 1981;10:387–416.
65. Lindquist LW, Carlsson GE, Jemt TA. 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.
66. Buser D, Mericske-Stern R, Bernard JP, et al. Long-term evaluation of non-submerged ITI implants. Part I: 8-year life table analysis of a prospective multicenter study with 2359 implants. *Clin Oral Implants Res* 1997;8:161–172.
67. Arvidson K, Bystedt H, Frykholm A, von Konow L, Lothigius E. Five-year prospective follow-up report of Astra Tech Implant System in the treatment of edentulous mandibles. *Clin Oral Implants Res* 1998;9:225–234.
68. Weber HP, Crohin CC, Fiorellini JP. A 5-year prospective clinical and radiographic study of non-submerged dental implants. *Clin Oral Implants Res* 2000;11:144–153.
69. Leonhardt A, Grondahl K, Bergstrom C, Lekholm U. Long-term follow-up of osseointegrated titanium implants using clinical, radiographic and microbiological parameters. *Clin Oral Implants Res* 2002;13:127–132.
70. Ericsson I, Randow K, Nilner K, Peterson A. Early functional loading of Br anemark dental implants: 5-year clinical follow-up study. *Clin Implant Dent Relat Res* 2000;2:70–77.
71. De Bruyn H, Kisch J, Collaert B, Linden U, Nilner K, Dvrsarter L. Fixed mandibular restorations on three early-loaded regular platform Br anemark implants. *Clin Implant Dent Relat Res* 2001;3:176–184.
72. 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: 81–87.
73. Van den Bogaerde R, Pedretti G, Dellacasa P, Mozzati M, Rangert B. Early function of splinted implants in maxillas and posterior mandibles using Br anemark System machined-surface implants: An 18-month prospective clinical multicenter study. *Clin Implant Dent Relat Res* 2003;5:1–9.
74. Esposito M, Worthington HV, Thomsen P, Coulthard P. Interventions for replacing missing teeth: Different times for loading dental implants. *Cochrane Database Syst Rev* 2004; 3:CD003878.
75. Aparicio C, Rangert B, Sennerby L. Immediate and early loading of dental implants: A report from the Societat Espanola de Implantantes—World Congress Consensus Meeting in Barcelona, Spain, 2002. *Clin Implant Dent Relat Res* 2003;4:57–60.