

Loading Protocols for Dental Implants in Edentulous Patients

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Purpose: The objective of this systematic review was to present the current scientific and clinical evidence related to implant-supported rehabilitations for the edentulous mandible and maxilla. **Materials and Methods:** An electronic search of several databases covered the period from January 1966 to August 2008. From a total of 2,371 publications identified from this search, 61 articles fulfilled the inclusion criteria set forth by the authors. It should be noted that only studies reporting on implants with rough surfaces were included in the final selection for this review. **Results:** Selected studies yielded data from 2,278 patients and 9,701 implants. Studies were grouped according to treatment protocol and prosthodontic design, and results on conventional, early, and immediate loading were assessed separately for fixed and removable dental prostheses. Clinical recommendations for implant loading in different edentulous indications were established using a special validation protocol of the published scientific and clinical evidence for different treatment modalities, which was based on the study design, sample size, and outcome homogeneity between studies. **Conclusions:** The highest level of scientific and clinical validation was found for conventional loading with mandibular overdentures and maxillary fixed dental prostheses. Insufficient scientific or clinical documentation/validation was found for immediate loading of maxillary overdentures, as well as for immediate loading of immediately placed implants combined with fixed or removable dental prostheses in either jaw. All other loading protocols for edentulous arches showed different degrees of clinical documentation. *Int J Oral Maxillofac Implants* 2009;24(SUPPL):132-146

Key words: dental implants, edentulism, fixed dental prosthesis, loading protocol, mandible, maxilla, removable prosthesis, systematic review

Loading protocols for the dental implant treatment of edentulous jaws have been widely discussed in the dental literature. Initial implant stability, implant surface characteristics, bone quality, bone healing, interim prosthesis design, and occlusion pattern dur-

ing the healing phase have been identified as influential factors in successfully achieving osseointegration with modified loading protocols.¹

While several randomized controlled trials (RCTs) and reviews have demonstrated clinical efficiency in shortening the time of loading for edentulous patients,²⁻⁵ the related scientific evidence is mostly presented from the perspective of implant survival or success, and with only limited information about the prosthodontic treatment outcome. In order to accurately assess the impact of modified loading protocols in edentulous patients, data should ideally be analyzed separately according to: (1) maxillary and mandibular protocols, (2) fixed and removable rehabilitations, (3) machined and rough-surfaced implants, and (4) implant placement into healed sites and extraction sockets that are not yet healed. These factors have often been presented as having a direct influence on the implant and prosthodontic survival rate.

In addition, special consideration should be given to the patient's initial clinical status. Here, two groups can be well differentiated: patients who have been edentulous for a certain period of time, and patients

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who will become edentulous due to a failing dentition. These different initial situations will have a direct influence on the treatment sequence.

The objective of this review on loading protocols in edentulous patients was to present well-structured scientific and clinical evidence related to implant-supported rehabilitations for the edentulous mandible and maxilla. The specific aim was to assess the survival outcome of various loading protocols according to their treatment sequence and prosthodontic design.

MATERIALS AND METHODS

Search Strategy and Data Analysis

An electronic search for clinical trials on edentulous patients was performed using MEDLINE, PubMed, the Cochrane Controlled Trials Register, and the Cochrane Health Group Specialized Register from 1966 through June 2008. The search terminology included:

- *complete edentulous AND implant*
- *complete edentulous AND full-arch*
- *complete implant prostheses OR complete implant bridge*
- *fixed complete prostheses AND implant*
- *edentulous jaws AND implant*
- *edentulous jaws AND immediate implant loading*
- *edentulous jaws AND delayed implant loading*
- *edentulous jaws AND early implant loading*
- *edentulous jaws AND staged approach*
- *edentulous jaws AND loading protocols*
- *complete implant overdentures OR complete implant removable prostheses*

Hand-searching of all offline journals and bibliographies of reviewed articles relevant to the topic completed the general search. References appraised in related systematic reviews were also considered.

The search strategy was limited to clinical trials investigating the compatibility of different loading protocols with the achievement of osseointegration. For prospective data, only studies reporting implant and prosthetic survival outcomes after 12 or more months were included. Only clinical trials using endosseous root-shaped implants with rough surfaces were considered for this review. All levels of the hierarchy of evidence, with the exception of expert opinions, were included. For case reports, only studies with a minimum of 10 patients and edentulous arches were accepted.

Selected publications were collected in reference management software, and duplicates were electronically discarded.

After title and abstract screening of 2,371 publications obtained from the electronic search, 295 were selected for full-text reading. Sixty-one articles including data from 2,278 patients and 9,701 implants appeared to fulfill the inclusion criteria. Selected studies on loading protocols for edentulous patients were broken down according to jaw location and prosthodontic design (Table 1).

Validation Criteria

To formulate conclusions and propose clinical recommendations for various loading protocols in combination with prosthodontic treatment options for the edentulous mandible and maxilla, the included studies were ranked according to their design, sample size, and outcome homogeneity (OH). The outcome homogeneity was considered positive (OH+) when the variation of implant survival rates for the same treatment protocol was 10% or less, and negative (OH-) when the variation was greater than 10%.

Using these criteria, scientific and/or clinical validation was determined as follows:

Scientifically and Clinically Validated (SCV):

- Systematic reviews of RCTs or
- Two or more RCTs + ≥ 100 patients + OH+ or
- One RCT and two or more prospective studies + ≥ 150 patients + OH+

Clinically Well Documented (CWD):

- One RCT and two or more prospective studies + ≥ 40 patients + OH+ or
- No RCTs but at least three prospective studies + ≥ 60 patients + OH+ or
- No RCTs but two or fewer prospective studies + ≥ 100 patients + OH+

Clinically Documented (CD):

- No RCTs, at least two prospective + any retrospective studies + ≤ 40 patients + OH- or
- No RCTs, retrospective studies + ≥ 60 patients + OH-/+

Clinically Insufficiently Documented (CID):

- None of the above, expert opinion only, case report only

Each treatment modality described in Table 1 was subsequently categorized according to the above validation criteria and presented in Table 2.

Table 1 Number of Selected Publications Broken Down by Loading Protocol and Prosthodontic Treatment Modality

	Removable		Fixed	
	Maxilla	Mandible	Maxilla	Mandible
Conventional loading	3 studies 0 (RCTs) 2 (Prosp) 1 (Retro) 110 Pts/530 Impls 94.8%–97.7% OH+	10 studies 4 (RCTs) 4 (Prosp) 2 (Retro) 671 Pts/1,396 Impls 97.1%–100% OH+	4 studies 1 (RCT) 3 (Prosp) 0 (Retro) 104 Pts/719 Impls 95.5%–97.9% OH+	4 studies 1 (RCT) 2 (Prosp) 1 (Retro) 207 Pts/1,254 Impls 97.2%–98.7% OH+
Early loading	2 studies 0 (RCTs) 2 (Prosp) 0 (Retro) 49 Pts/185 Impls 87.2%–95% OH-	4 studies 1 (RCT) 3 (Prosp) 0 (Retro) 68 Pts/136 Impls 97.1%–100% OH+	4 studies 1 (RCT) 1 (Prosp) 2 (Retro) 54 Pts/344 Impls 93.4%–99% OH+	3 studies 0 (RCTs) 2 (Prosp) 1 (Retro) 176 Pts/802 Impls 98.6%–100% OH+
Immediate loading	1 study 0 (RCTs) 1 (Prosp) 0 (Retro) 12 Pts/48 Impls 95.6% OH N/A	7 studies 0 (RCTs) 6 (Prosp) 1 (Retro) 329 Pts/1,161 Impls 96%–100% OH+	6 studies 0 (RCTs) 5 (Prosp) 1 (Retro) 153 Pts/893 Impls 95.4%–100% OH+	7 studies 0 (RCTs) 5 (Prosp) 2 (Retro) 181 Pts/942 Impls 98%–100% OH+
Immediate loading of immediately placed implants	N/A	N/A	4 studies 0 (RCTs) 1 (Prosp) 3 (Retro) 149 Pts/1,194 Impls 87.5%–98.4% OH-	2 studies 0 (RCTs) 0 (Prosp) 2 (Retro) 15 Pts/97 Impls 97.7%–100% OH+
Total subgroups	6	21	18	16
Total main groups	27		34	
Total	61			

RCT = randomized controlled trial; Prosp = prospective study; Retro = retrospective study; Pts = patients; Impls = implants; OH = outcome homogeneity (+ [less than 10% variation], – [more than 10% variation]).

Table 2 Validation of Loading Protocols for Different Prosthodontic Treatments in the Edentulous Mandible or Maxilla

	Removable		Fixed	
	Maxilla	Mandible	Maxilla	Mandible
Conventional loading	CWD	SCV	SCV	CWD
Early loading	CD	CWD	CD	CD
Immediate loading	CID	CWD	CWD	CWD
Immediate loading of immediately placed implants	CID	CID	CD	CID

SCV = scientifically and clinically validated; CWD = clinically well documented; CD = clinically documented; CID = clinically insufficiently documented (includes loading protocols that are not documented).

RESULTS: REMOVABLE IMPLANT PROSTHESES

Conventional Loading of Mandibular Implant Overdentures

This loading protocol describes the use of two to four implants placed in edentulous mandibles, to be connected to an overdenture after a healing period of 3 to 6 months. Several implant prosthetic designs have been proposed, such as two implants with single ball-shaped or locator attachments,^{6–10} two implants splinted with a rigid bar construction,^{8–17} four or more implants connected with a rigid bar construction,^{12,14–17} and four or more single implants with ball-shaped or locator attachments (Table 3).⁸

Mericske-Stern⁶ reported a clinical comparison of bar or single ball-shaped precision attachments placed onto two implants versus three or four

Table 3 Conventional Loading of Implant-Supported Mandibular Overdentures

Study	Study design	Implant type	No. of patients	No. of implants placed	Follow-up (y)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Mericske-Stern (1990) ⁶	Retro	Straumann	62	140	1 to 5.5	2	98.6	NR	NR
Naert et al (1999) ¹¹	RCT	Dyna/ Nobel Biocare	36	72	5	1	98.6	NR	NR
Ferrigno et al (2002) ¹²	Prosp	Straumann	129	348	10	7	97.1	2	97.7
Payne et al (2002) ⁷	RCT	Straumann	12	24	2	0	100	NR	NR
Karabuda et al (2002) ⁸	Retro	PittEasy Frialit 2	36	94	2-4	2	97.8	NR	NR
Heydenrijk et al (2002) ¹³	Prosp	IMZ	40	80	1	2	97.5	NR	NR
Behneke et al (2002) ¹⁷	Prosp	IMZ	100	340	5	4	98.8	NR	NR
Walton (2003) ⁹	RCT	Nobel Biocare	100	200	3	0	100	12	88
Visser et al (2005) ¹⁵	Prosp	IMZ	60	180	5	1	99.4	0	100
Stoker et al (2007) ¹⁶	RCT	Straumann	96	258	8	3	98.8	6	93.7

RCT = randomized controlled trial; Prosp = prospective study; Retro = retrospective study; NR = not reported.

Table 4 Conventional Loading of Implant-Supported Maxillary Overdentures

Study	Study design	Implant type	No. of patients	No. of implants placed	Follow-up (y)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Ferrigno et al (2002) ¹²	Prosp	Straumann	35	178	10	9	94.9	3	91.4
Mericske-Stern (2002) ²⁰	Retro	Straumann	41	173	1 to 9	9	94.8	NR	NR
Krennmair et al (2008) ²¹	Prosp	IMZ	34	179	5	4	97.7	NR	NR

Prosp = prospective study; Retro = retrospective study; NR = not reported.

implants splinted with a bar. The author suggested that two implants could adequately serve as retention for a mandibular overdenture. Naert et al,¹⁰ Karabuda et al,⁸ and Lachmann et al¹⁸ concluded in independent studies that the retention system for mandibular overdentures in splinted versus free-standing implants did not influence the peri-implant tissue outcome when using a conventional loading approach. However, prosthodontic considerations were not reported in these studies.

In a long-term prospective study, Visser and coworkers¹⁵ addressed the question of the number of implants required for ensuring a long-lasting outcome. The authors concluded that there was no difference in the clinical and radiographic status of patients treated with an overdenture on two or four implants during a 5-year evaluation period.

In summary, 10 articles were included in the group of mandibular implant overdentures: 4 RCTs, 4 prospective studies, and 2 retrospective studies indicating a high level of evidence. Results from 671 patients who received 1,396 implants showed an implant survival rate ranging from 97.1% to 100% during a mean follow-up period of 1 to 10 years. The prosthetic survival rate was reported in only 4 of 9 selected articles, and showed a mean survival rate of 95.7% (88% to 100%).

Conclusions for conventional loading of implant overdentures in the edentulous mandible:

- Conventional loading of mandibular implant overdentures is scientifically and clinically validated (SCV).
- Implant survival rates (1 to 10 years) range from 97.1% to 100%.
- Prosthodontic survival rates range from 88% to 100%.
- Two implants, single or splinted, will serve as effectively as four splinted implants.

Conventional Loading of Maxillary Implant Overdentures

This loading protocol describes the use of four to six implants placed in the edentulous maxilla and restored with an overdenture after a healing period of 3 to 6 months. The implant-prosthetic design includes four or more freestanding implants¹⁹ or four to six implants connected by a bar device (Table 4).^{12,20,21}

Ferrigno et al¹² conducted a multicenter study with a conventional loading approach and reported a 10-year outcome with a lower survival rate than mandibular implant overdentures.

Mericske-Stern and coworkers²⁰ stated that optimal survival rates of maxillary implants supporting an overdenture can be enhanced with well-planned

Table 5 Early Loading of Implant-Supported Mandibular Overdentures

Study	Study design	Implant type	No. of patients	No. of implants placed	Follow-up (y)	Time of loading (wk)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Roynesdal et al (2001) ²²	Prosp	Straumann	11	22	1	3	0	100	NR	NR
Payne et al (2002) ⁷	RCT	Straumann	12	24	2	6	0	100	0	100%
Attard and Zarb (2005) ⁴	Prosp	Nobel Biocare	35	70	1	1.5	2	97.1	6	82.6
Turkyilmaz and Tumer (2007) ²³	Prosp	Nobel Biocare	10	20	2	1	0	100	NR	NR

RCT = randomized controlled trial; Prosp = prospective study; NR = not reported.

treatment concepts including conventional loading. Recently, Cavallaro and Tarnow¹⁹ proposed using a minimum of four freestanding implants with locator abutments to support palate-free maxillary overdentures. After a conventional healing time, prostheses were attached to the implants, resulting in a 100% survival rate in a 12- to 48-month follow-up time. However, that article reports results from only five consecutive cases/arches, and for that reason was not part of this review.

In summary, three articles were included in the group of maxillary implant overdentures.^{12,20,21} The level of evidence was lower than for mandibular overdentures, since only prospective and retrospective studies were available for analysis. Results from 110 patients receiving 530 implants showed a mean implant survival rate ranging from 94.8% to 97.7% during a mean follow-up period of 5 years (range 1 to 10 years). Only one study reported a prosthetic survival rate, which was found to be 91.4%.

Conclusions for conventional loading of implant overdentures in the edentulous maxilla:

- Conventional loading of maxillary implant overdentures is clinically well documented (CWD).
- Implant survival rates (1 to 10 years) range from 94.8% to 97.7%.
- Prosthodontic survival rates were described in one prospective study (91.4%, 3-year follow-up).
- More clinical trials are needed to scientifically and clinically validate the use of freestanding implants supporting maxillary overdentures with or without palatal coverage.

Early Loading of Mandibular Implant Overdentures

This approach describes mandibular implant overdentures that were functionally loaded no earlier than 48 hours after implant placement and no later than 3 months afterward. Two implants combined with an

overdenture retained by single ball-shaped or locator abutments^{7,22-24} was the only prosthodontic design identified (Table 5).

Roynesdal et al²² compared conventional and early loading of two solid-screw dental implants supporting a mandibular overdenture. The authors concluded that the survival rate of rough-surfaced implants loaded 3 weeks after implant placement was similar to that of implants loaded in a conventional time frame, on the assumption that primary stability was achieved. Payne and coworkers,⁷ in a randomized controlled trial, reported that pairs of unsplinted SLA-surfaced implants can be successfully loaded with mandibular overdentures 6 weeks after surgery. Turkyilmaz and Tumer²³ concluded that the implant survival rate in the anterior mandible was not compromised when using a 1-week functional early loading protocol with unsplinted implants supporting an overdenture.

In summary, for the group of mandibular implant overdentures with an early loading approach, four publications reported results with rough-surfaced implants.^{7,22-24} An optimal level of evidence was supported by one RCT and three prospective controlled studies. While promising results were reported in the selected publications, this scientific evidence is based on 68 patients and 136 implants with a 2-year follow-up. The prosthodontic survival rate was reported in only two of the four selected articles.

Conclusions for early loading of implant overdentures in the edentulous mandible:

- Early loading (1 to 6 weeks) of mandibular implant overdentures is clinically well documented (CWD).
- Implant survival rates (1 to 2 years) range from 97.1% to 100%.
- Prosthodontic survival rates range from 82.6% to 100%.
- Two freestanding implants in the anterior mandible are sufficient for such a protocol.

Table 6 Early Loading of Implant-Supported Maxillary Overdentures

Study	Study design	Implant type	No. of patients	No. of implants placed	Follow-up (y)	Time of loading (wk)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Raghoobar et al (2003) ²⁵	Prosp	Biomet 3i	10	68	1	8	3	95.6	NR	NR
Payne et al (2004) ²⁶	Prosp	Nobel Biocare	39	117	2	12	15	87.2	NR	NR

Prosp = prospective study; NR = not reported.

Early Loading of Maxillary Implant Overdentures

This approach describes maxillary implant overdentures that were functionally loaded no earlier than 48 hours after implant placement and no later than 3 months afterward. Implant-prosthetic designs included four to six implants connected by a bar construction²⁵ and three freestanding implants with single ball or locator attachments (Table 6).²⁶

Raghoobar et al²⁵ reported on an early loading protocol with overdentures supported by splinted implants. The authors concluded that in selected cases early loading of implants could develop into a predictable treatment modality. In a different approach with early loading, Payne et al²⁶ investigated the use of freestanding narrow-diameter implants loaded at 12 weeks with maxillary overdentures. The implant survival rate after a 2-year follow-up was 87.2%.

During the 2004 ITI Consensus Meeting on edentulous patients,¹ no publications were available for early loading protocols with maxillary overdentures. Results from the actual search revealed two references with a publication date subsequent to Chiapasco's.¹ These prospective studies describe results from 49 patients who received 185 rough-surfaced implants. The time of loading varied from 8 to 12 weeks, with an implant survival rate ranging from 87.2% to 95.6%. No data related to the prosthodontic survival rate could be retrieved.

Conclusions for early loading of implant overdentures in the edentulous maxilla:

- Early loading (8 to 12 weeks) of maxillary implant overdentures is clinically documented (CD).
- Implant survival rates (1 to 2 years) range from 87.2% to 95.6%.
- No prosthodontic survival rates are reported.
- More clinical trials are needed to scientifically and clinically validate the use of freestanding implants supporting maxillary overdentures with or without palatal coverage.

Immediate Loading of Mandibular Implant Overdentures

Immediate loading with mandibular implant overdentures is a protocol in which implants are connected to the prosthesis and placed in occlusal contact within 48 hours after implant placement. Implant prosthetic designs included immediate prosthetic loading of a single implant in the anterior mandible,²⁷ two single implants with ball and locator attachments,²⁸ two immediately loaded and splinted implants,²⁹ three free-standing implants immediately loaded with a ball or locator attachment,³⁰ and four or more implants connected with a bar construction (Table 7).^{31–33}

Chiapasco and coworkers³¹ presented results for immediately loaded implants splinted by a bar construction. The authors concluded that four splinted implants showed survival rates similar to delayed loading. Similar results were later presented by Gatti et al³² and Romeo et al.³³ Stephan and coworkers³⁰ proposed an immediate loading protocol with 3 free-standing implants supporting a mandibular overdenture. It was concluded in this publication that the survival rate of three unsplinted immediately loaded implants with a mandibular overdenture was similar to rates of conventionally loaded implants. However, such a protocol is supported by a single publication reporting on 17 patients with no implant lost after a 2-year follow-up. Stricker et al²⁹ proposed a similar approach to Chiapasco et al,³¹ but using two splinted implants. The conclusions suggested that two splinted implants can be successfully used. Marzola et al²⁸ proposed the immediate loading of two implants by means of a ball attachment–retained mandibular complete denture and concluded that this approach may become a predictable treatment option. Lidellow and Henry²⁷ reported the use of immediate loading with a single implant supporting a mandibular overdenture. Based on a single publication, this protocol showed lower survival rates for both implants (89.3%) and prostheses (89.3%).

In summary, the use of mandibular overdentures in combination with an immediate loading approach

Table 7 Immediate Loading of Implant-Supported Mandibular Overdentures

Study	Study design	Implant type	No. of patients	No. of implants placed	Follow-up (y)	Time of loading (d)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Chiapasco et al (1997) ³¹	Retro	Straumann	226	904	2–13	1	24	96.9	3	98.5%
Gatti et al (2000) ³²	Prosp	Straumann	21	84	2–5	1	3	96.0	NR	NR
Romeo et al (2002) ³³	Prosp	Straumann	10	40	2	2	1	97.5	0	100%
Stricker et al (2004) ²⁹	Prosp	Straumann	10	20	2	1	0	100	1	90%
Stephan et al (2007) ³⁰	Prosp	Nobel Biocare	17	51	2	2	0	100	NR	NR
Liddelov and Henry (2007) ²⁷	Prosp	Nobel Biocare	28	28	1	1	3	89.3	3	89.3
Marzola et al (2007) ²⁸	Prosp	Nobel Biocare	17	34	1	1	0	100	2	88.3

Prosp = prospective study; Retro = retrospective study; NR = not reported.

Table 8 Immediate Loading of Implant-Supported Maxillary Overdentures

Study	Study design	Implant type	No. of patients	No. of implants placed	Follow-up (y)	Time of loading (d)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Cannizzaro et al (2007) ³⁴	Prosp	Zimmer	12	48	1	1	1	95.6	0	100

Prosp = prospective study.

on rough-surfaced implants was supported in seven publications. Six were prospective studies, and one was retrospective. Data were extracted from 329 patients receiving 1,161 implants. The scientific evidence can be divided between the well-documented immediate loading protocol using four splinted implants and the more recent proposals with immediate loading using fewer than four implants.

Conclusions for immediate loading of implant overdentures in the edentulous mandible:

- Immediate loading (1 to 2 days) of mandibular implant overdentures is scientifically and clinically validated (SCV).
- Implant survival rates (1 to 13 years) range from 96% to 100%.
- Prosthodontic survival rates range from 88.3% to 100%.
- The number of implants (two to four) and whether they are single or splinted has no effect on the implant survival.

Immediate Loading of Maxillary Implant Overdentures

Immediate loading with maxillary implant overdentures describes a protocol in which a removable prosthesis is attached to the implants and placed in

occlusal contact within 48 hours after implant placement (Table 8).

Use of four implants splinted by a bar construction and immediate loading was supported by one single publication.³⁴ Although the selected article for this category fulfilled the inclusion criteria, the small sample of the patient population and the number of implants precluded the drawing of any conclusions.

Conclusions for immediate loading of implant overdentures in the edentulous maxilla:

- Immediate loading (1 to 2 days) of maxillary implant overdentures is clinically insufficiently documented (CID).

RESULTS: FIXED IMPLANT PROSTHESES

Conventional Loading of Mandibular Fixed Implant Prostheses

This loading protocol describes the use of dental implants placed in an edentulous mandible to support a fixed dental prosthesis after a healing period of 3 to 6 months. Implant prosthetic designs included four to six implants with a one-piece full-arch fixed prosthesis^{35–37} and eight implants with a one-piece full-arch fixed prosthesis (Table 9).¹²

Table 9 Conventional Loading of Implant-Supported Fixed Protheses in the Edentulous Mandible

Study	Study design	Implant type	No. of patients	No. of implants placed	No. of implants per patient	Follow-up (y)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Arvidson et al (1998) ³⁵	Retro	Astra Tech	107	618	4–6	5	8	98.7	0	100
Ferrigno et al (2002) ¹²	Prosp	Straumann	40	320	8	10	5	98.5	0	100
Moberg et al (2001) ³⁶	RCT	Straumann/ Nobel Biocare	40	208	4–6	3	5	97.5	0	100
Rasmusson et al (2005) ³⁷	Prosp	Astra Tech	20	108	4–6	10	3	97.2	0	100

RCT = randomized controlled trial; Prosp = prospective study; Retro = retrospective study.

Table 10 Conventional Loading of Implant-Supported Fixed Protheses in the Edentulous Maxilla

Study	Study design	Implant type	No. of patients	No. of implants placed	No. of implants per patient	Follow-up (y)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Ferrigno et al (2002) ¹²	Prosp	Straumann	55	440	8	10	9	97.9	2	96.3
Bergkvist et al (2004) ³⁸	Prosp	Straumann	25	146	5–7	2	5	96.6	0	100
Rasmusson et al (2005) ³⁷	Prosp	Astra Tech	16	88	4–6	10	3	96.6	0	100
Fischer et al (2008) ²	RCT	Straumann	8*	45	5–6	3	2	95.5	NR	NR

*Patients belonging to a larger sample population of 32 patients with a different loading protocol.
RCT = randomized controlled trial; Prosp = prospective study; NR = not reported.

Arvidson et al,³⁵ Ferrigno et al,¹² Moberg et al,³⁶ and Rasmusson et al³⁷ concluded in similar clinical trials that the long-term clinical results of mandibular implant-supported fixed rehabilitations were highly successful in terms of prosthetic function and implant stability.

In summary, scientific evidence on fixed implant rehabilitations for the edentulous mandible with conventional loading and rough-surfaced implants was supported by one RCT, two prospective studies, and one retrospective study with follow-ups of 3 to 10 years. These clinical trials reported data from 207 patients and 1,254 rough-surfaced implants. The implant survival rate ranged from 97.2% to 98.7% and the prosthodontic survival rate was 100% for all four clinical trials.

Conclusions for conventional loading of fixed implant prostheses in the edentulous mandible:

- Conventional loading of mandibular fixed implant prostheses is scientifically and clinically validated (SCV).
- Implant survival rates (3 to 10 years) range from 97.2% to 98.7%.
- The prosthodontic survival rate is 100%.
- The prosthesis design was full arch, one piece, supported by four to eight implants.

Conventional Loading of Maxillary Fixed Implant Prostheses

This loading protocol describes implant-supported rehabilitations in edentulous maxillae that have been in occlusal function after a healing period of 3 to 6 months. Implant prosthetic designs included four to seven implants supporting a one-piece prosthesis^{2,37,38} and eight implants with a fixed full-arch rehabilitation (Table 10).¹²

In a longitudinal study, Ferrigno et al¹² concluded that a maxillary fixed full-arch prosthesis supported by eight implants with an anterior-posterior distribution allows for an optimal long-term implant survival rate. Accordingly, Bergkvist et al,³⁸ Rasmusson et al,³⁷ and Fischer et al² reported successful survival rates and concluded that rough-surfaced solid-screw implants in combination with fixed prostheses represent a viable treatment alternative in the edentulous maxilla.

In summary, scientific evidence on fixed implant rehabilitations in the edentulous maxilla was supported by three prospective studies and one RCT, with follow-up of up to 10 years. Implant survival rates were similar for all four independent publications, ranging from 95.5% to 97.9%, and included 719 rough-surfaced implants placed in 104 patients. Implant-prosthetic designs were exclusively found in

Table 11 Early Loading of Implant-Supported Fixed Protheses in the Edentulous Mandible

Study	Study design	Implant type	No. of patients	No. of implants placed	No. of implants per patient	Follow-up (y)	Time of loading (wk)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Collaert and De Bruyn (2002) ⁴¹	Retro	Astra Tech	25	108	4–5	2	4	0	100	0	100
Friberg and Jemt (2008) ⁴⁰	Prosp	Nobel Biocare	90	450	5	1	1	0	100	2	97.8
Arvidson et al (2008) ³⁹	Prosp	Straumann	61	244	4–5	3	1	3	98.6	0	100

Prosp = prospective study; Retro = retrospective study.

one-piece full-arch rehabilitations and varied in the number of implants and their distribution.

Conclusions for conventional loading of fixed implant protheses in the edentulous maxilla:

- Conventional loading of maxillary fixed implant protheses is scientifically and clinically validated (SCV).
- Implant survival rates (3 to 10 years) range from 95.5% to 97.9%.
- Prosthodontic survival rates range from 96.3% to 100%.
- The prosthesis design was generally full arch, one piece, and supported by four to eight implants.

Early Loading of Fixed Implant-Supported Protheses in the Edentulous Mandible

This loading protocol describes mandibular fixed implant rehabilitations that have been in functional loading 48 hours after implant placement, but no longer than 3 months. Implant prosthetic protocols were described as four to five implants supporting a fixed one-piece rehabilitation (Table 11).^{39–41}

In a 3-year follow-up, Collaert and De Bruyn⁴¹ reported that early loading of four to five implants in the edentulous mandible with cross-arch fixed protheses was a predictable procedure. Friberg and Jemt⁴⁰ compared the outcomes of early loading with rough- and machined-surface implants. In this 1-year follow-up study the authors concluded that the implant survival rate was significantly higher for rough-surfaced implants. In a similar clinical trial, Arvidson et al³⁹ reported that treatment outcomes for early loading in the edentulous mandible with fixed protheses are comparable with conventional protocols. In addition, no increase in the incidence of implant–prosthetic complications was reported when compared to conventional protocols. Patient benefits included reduced treatment time and improved quality of life.

In summary, one retrospective and two prospective studies supported the scientific evidence on early loading of implants in the edentulous mandible with fixed implant rehabilitations. They included data from 176 patients and 802 rough-surfaced implants with a 1- to 3-year follow-up. The time of loading varied from 1 to 4 weeks and the implant survival rate ranged from 98.6% to 100%.

Conclusions for early loading of mandibular fixed implant-supported rehabilitations:

- Early loading of mandibular fixed implant protheses is clinically documented (CD).
- Implant survival rates (1 to 3 years) range from 98.6% to 100%.
- Prosthodontic survival rates range from 97.8% to 100%.
- Prosthesis design was full arch, one piece, supported by four to five implants.

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

Early implant loading with fixed rehabilitations describes a protocol in which implants have been in occlusal contact no earlier than 48 hours and no later than 3 months. Implant prosthetic protocols included five to eight implants supporting maxillary fixed implant rehabilitations (Table 12).^{2,42–44}

Olsson et al⁴⁴ and Nordin et al⁴³ concluded that early loading protocols can be applied with predictable results using rough-surfaced implants for the rehabilitation of the edentulous maxilla with fixed protheses. In an RCT, Fischer et al² showed no important differences between early and delayed loading of implants in the edentulous maxilla after 5 years of function.

In summary, the sample population for early loading with fixed implant-supported rehabilitation in the edentulous maxilla included 54 patients and 344 rough-surfaced implants. One RCT, one prospective,

Table 12 Early Loading of Implant-Supported Fixed Protheses in the Edentulous Maxilla

Study	Study design	Implant type	No. of patients	No. of implants placed	No. of implants per patient	Follow-up (y)	Time of loading (wk)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Olsson et al (2003) ⁴⁴	Retro	Nobel Biocare	10	61	6–8	1	2	4	93.4	NR	NR
Nordin et al (2004) ⁴³	Retro	Straumann	16	98	6	1	2	1	99.0	NR	NR
Fischer et al (2008) ²	RCT	Straumann	16	94	5–6	5	2	5	94.7	NR	NR
Lai et al (2008) ⁴²	Prosp	Straumann	12	91	6–8	3	6	1	98.9	0	100%

RCT = randomized controlled trial; Prosp = prospective study; Retro = retrospective study; NR = not reported.

Table 13 Immediate Loading of Implant-Supported Fixed Protheses in the Edentulous Mandible

Study	Study design	Implant type	No. of patients	No. of implants placed	No. of implants per patient	Follow-up (y)	Time of loading (wk)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Ganeles et al (2001) ⁴⁵	Retro	Straumann, Astra, Frialit-2	27	161	5–8	2	1	1	99.4	NR	NR
Gallucci et al (2004) ⁴⁷	Prosp	Straumann	6*	34	6	1	1	0	100	0	100
Testori et al (2004) ⁴⁸	Prosp	Biomet 3i	62	325	5–6	1	2	2	99.4	NR	NR
Drago and Lazzara (2006) ⁴⁶	Prosp	Biomet 3i	27	151	5–6	1	1	3	98	0	100
Degidi et al (2006) ⁵¹	Retro	Nobel Biocare	9	50	4–5	3	1	0	100	?	?
Capelli et al (2007) ⁴⁹	Prosp	Biomet 3i	24	96	4	3	2	0	100	0	100
De Bruyn et al (2008) ⁵⁰	Prosp	Astra Tech	25	125	5	3	1	0	100	0	100

*Patients belonging to a larger sample population of 11 edentulous arches. Prosp = prospective study; Retro = retrospective study; NR = not reported.

and two retrospective studies with a follow-up time of 1 to 5 years yielded implant survival rates ranging from 93% to 99%.

Conclusions for early loading of maxillary fixed implant-supported rehabilitations:

- Early loading of maxillary fixed implant protheses is clinically documented (CD).
- Implant survival rates (1 to 3 years) range from 93.4% to 99%.
- Prosthodontic survival rates are not reported.
- The prosthesis designs were full-arch one-piece or segmented supported by five to eight implants.

Immediate Loading of Fixed Implant-Supported Protheses in the Edentulous Mandible

Immediate loading with mandibular implant overdentures describes a protocol in which a fixed provisional contact is attached to the implants and placed in occlusal function within 48 hours after implant placement. Implant-prosthetic protocols were

described as cross-arch fixed rehabilitations with anterior-posterior distribution of five to eight implants,^{45,46} segmented rehabilitations with anterior-posterior distribution of six implants,⁴⁷ and full-arch protheses with anterior implants and distal cantilevers (Table 13).^{48–51}

Ganeles and coworkers⁴⁵ reported that with appropriate stabilization and distribution of occlusal load, mandibular implants can be immediately loaded in a complete-arch configuration with no apparent detrimental effect on the rate of osseointegration. In a similar clinical trial but with a smaller sample population, Gallucci et al⁴⁷ concluded that osseointegration with immediate implant loading via fixed provisional restorations can be successfully achieved. Furthermore, the authors suggested that neither the metal-free design of the provisional protheses nor the removal of the provisional protheses during the healing phase adversely affected osseointegration. Testori et al,⁴⁸ Drago and Lazzara,⁴⁶ Degidi et al,⁵¹ and De Bruyn et al,⁵⁰ each using different implant systems, stated that the rehabilitation of the

Table 14 Immediate Loading of Implant-Supported Fixed Prosthesis in the Edentulous Maxilla

Study	Study design	Implant type	No. of patients	No. of implants placed	No. of implants per patient	Follow-up (y)	Time of loading (d)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Gallucci et al (2004) ⁴⁷	Prosp	Straumann	5*	40	8	1	1	2	95.4	0	100
Malo et al (2005) ⁵²	Retro	Nobel Biocare	32	128	4	1	1	3	97.6	4	87.5
Ostman et al (2005) ⁵³	Prosp	Nobel Biocare	20	123	6–7	1	1	1	99.2	NR	NR
van Steenberghe et al (2005) ⁵⁴	Prosp	Nobel Biocare	27	184	6–8	1	1	0	100	0	100
Capelli et al (2007) ⁴⁹	Prosp	Biomet 3i	41	246	4–6	3	2	5	97.9	0	100
Bergkvist et al (2009) ⁵⁵	Prosp	Straumann	28	168	6	2	1	3	98.2	NR	NR

*Patients belonging to a larger sample population of 11 edentulous arches.
Prosp = prospective study; Retro = retrospective study; NR = not reported.

edentulous mandible with an immediate, occlusally loaded provisional hybrid prosthesis is a viable treatment alternative to the classical delayed protocols. Capelli and coworkers⁴⁹ presented similar results for immediate loading using only four implants (two straight and two tilted).

In summary, immediate loading of rough-surfaced implants with a fixed provisional restoration was well supported by seven publications, mostly prospective studies. With a sample population of 181 patients and 942 implants and a follow-up of 1 to 3 years, the implant survival rate ranged from 99.4% to 100%. One interesting finding with this protocol is that there were no prosthetic failures during the follow-up period.

Conclusions for immediate loading of fixed mandibular implant-supported rehabilitations:

- Immediate loading of mandibular fixed implant prostheses is scientifically and clinically validated (SCV).
- Implant survival rates (1 to 3 years) range from 98% to 100%.
- The prosthodontic survival rate is 100%.
- Prosthesis designs were full-arch one-piece or segmented supported by four to eight implants.

Immediate Loading of Fixed Implant-Supported Prosthesis in the Edentulous Maxilla

This loading protocol describes maxillary implants that have been placed in occlusal function via fixed prostheses no later than 48 hours after surgery. Implant prosthetic designs have been proposed as four to six implants with full-arch prostheses and distal cantilevers,^{49–52} five to eight implants with a one-piece full-arch prosthesis,^{53–55} and eight implants

distributed along the edentulous maxilla to support a segmented rehabilitation (Table 14).⁴⁷

Various implant-prosthetic protocols have been proposed for immediate implant loading in the edentulous maxilla. Gallucci and coworkers⁴⁷ loaded maxillary implants immediately via a full-arch fixed interim prosthesis that was later replaced by a segmented final rehabilitation, as first described by Belser et al.⁵⁶ The authors concluded that this approach was compatible with the achievement of osseointegration, although the sample population was considered small. In a similar clinical trial, Ostman et al⁵³ and Bergkvist et al⁵⁵ concluded that six to seven implants for immediate loading of a fixed provisional prosthesis is a viable option for implant treatment of the edentulous maxilla, at least when good primary implant stability can be ensured. Malo et al,⁵² using a protocol of four immediately loaded implants and some rescue ones left unloaded, presented comparable implant survival rates. Similar results were found by Capelli et al⁴⁹ when using four to six implants. Van Steenberghe et al⁵⁴ reported on immediate loading using models derived from three-dimensional oral implant planning software. The authors concluded that this protocol is a reliable treatment option. On the other hand, this was the sole publication yielded by the search on such a protocol.

In summary, scientific background for immediate loading with fixed interim prostheses in the edentulous maxilla was supported by one retrospective and five prospective studies. No RCTs were available at the time of the search. Only one study had a follow-up of 3 years, one had a 2-year follow-up, and four had 1-year follow-ups. The sample population included 153 patients receiving 893 immediately loaded rough-surfaced implants. The implant survival rate ranged from 95.4% to 100%, and the prosthodontic survival rate ranged from 87.5% to 100%. One notable finding

Table 15 Immediate Implant Placement and Loading with Fixed Protheses in the Mandible

Study	Study design	Implant type	No. of patients	No. of implants placed	No. of implants per patient	Mean follow-up (y)	Time of loading (d)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Grunder (2001) ⁵⁸	Retro	Biomet 3i	5*	43	8–10	2	1	1	97.7	NR	NR
Cooper et al (2002) ⁵⁷	Retro	Astra Tech	10	54	4–6	1.5	1	0	100	0	100

*Patients belonging to a larger sample population of 10 edentulous patients. Retro = retrospective study; NR = not reported.

was that most of the failed implants were located in the posterior maxilla.

Conclusions for immediate loading of maxillary implant-supported rehabilitations:

- Immediate loading of maxillary fixed implant prostheses is scientifically and clinically validated (SCV).
- Implant survival rates (1 to 3 years) range from 95.4% to 100%.
- Prosthodontic survival rates range from 87.5% to 100%.
- Prosthesis designs were full-arch one-piece or segmented supported by four to eight implants.

Immediate Loading of Immediately Placed Implants with Fixed Protheses in the Edentulous Mandible

This loading protocol describes maxillary implants that have been immediately placed into extraction sockets and into occlusal function with fixed prostheses no later than 48 hours after surgery. The implant-prosthetic protocol included 4 to 6 immediately placed implants supporting fixed prostheses with distal cantilevers⁵⁷ and 8 to 10 implants splinted by a one-piece full-arch fixed rehabilitation (Table 15).⁵⁸

Grunder⁵⁸ reported on the immediate placement and loading of rough-surfaced implants supporting a fixed rehabilitation. The authors showed that the immediate functional loading of immediate implants without the use of any bone substitutes or barrier membranes for fixed full-arch reconstructions can be successful over a 2-year period. In a similar loading protocol but with a different prosthetic design, Cooper et al⁵⁷ concluded that in selected healthy patients, significant time and clinical visits may be saved by simultaneous extraction, implant placement, and restoration with a simple acrylic-resin provisional prosthesis.

In summary, two retrospective studies were identified from the electronic search. They reported data from 15 patients and 97 immediately placed and

loaded implants with a follow-up ranging from 1.5 to 2 years. The implant survival rate ranged from 97.7% to 100%. One article reported no prosthodontic failures.

Conclusions for immediate loading of immediately placed implants with fixed protheses in the edentulous mandible:

- Immediate loading of immediately placed implants with fixed implant prostheses is clinically insufficiently documented (CID).
- Implant survival rates (1.5 to 2 years) range from 97.7% to 100% (15 patients only).
- The prosthodontic survival rate is 100%.
- The prosthesis design was full-arch one-piece supported by 4 to 10 implants.

Immediate Loading of Immediately Placed Implants with Fixed Protheses in the Edentulous Maxilla

This protocol describes maxillary implants that have been inserted immediately into extraction sockets and placed in occlusal function no later than 48 hours with a fixed prostheses. Implant-prosthetic designs were described as 6 to 8 implants splinted by a full-arch prosthesis⁵⁹ and 8 to 12 implants splinted by a one-piece full-arch fixed rehabilitation (Table 16).^{58,60,61}

The reliability of this loading protocol has been supported by Degidi et al⁶⁰ with the conclusion that wider implants had a higher risk of failure. Grunder⁵⁸ and Jaffin et al⁵⁹ reported similar results, concluding that immediate loading of immediately placed implants in the edentulous maxilla was a viable treatment alternative. Balshi et al,⁶¹ in a prospective study of full-arch maxillary immediate loading, suggested that this protocol was suitable for most patients in need of full maxillary implant reconstruction to provide long-term stability of screw-retained fixed prostheses.

In summary, data for immediate placement and loading of rough-surfaced implants in the edentulous maxilla were supported by one prospective and three retrospective studies. In 2 to 5 years of follow-up, the sample population consisted of 149 patients receiving

Table 16 Immediate Implant Placement and Loading with Fixed Prosthesis in the Maxilla

Study	Study design	Implant type	No. of patients	No. of implants placed	No. of implants per patient	Mean follow-up (y)	Time of loading (d)	Implant failures	Implant survival rate (%)	Prosthodontic failures	Prosthodontic survival rate (%)
Grunder (2001) ⁵⁸	Retro	Biomet 3i	5*	48	8–11	2	1	6	87.5	NR	NR
Jaffin et al (2004) ⁵⁹	Retro	Straumann	34	236	6–8	2	2	16	93.2	NR	NR
Degidi et al (2005) ⁶⁰	Retro	Several	55	388	6–12	5	2	6	98.4	NR	NR
Balshi et al (2005) ⁶¹	Prosp	Nobel Biocare	55	522	8–11	3	1	8	98.4	0	100

*Patients belonging to a larger sample population of 10 edentulous patients. Prosp = prospective study; Retro = retrospective study; NR = not reported.

1,194 implants. Thirty-six failures were recorded, yielding an implant survival rate ranging from 87.5% to 98.3%. Implant-prosthetic designs were diverse, particularly in terms of the number of implants per patient (8 to 12). The prosthodontic outcomes were rarely described.

Conclusions for immediate loading of immediately placed implants with fixed prostheses in the edentulous maxilla:

- Immediate loading of immediately placed implants with fixed prostheses is clinically documented (CD).
- Implant survival rates (2 to 5 years) range from 87.5% to 98.4%.
- The prosthodontic survival rate, reported in only one study, is 100%.
- The prosthesis design was full-arch one-piece supported by 6 to 12 implants.

Staged Approach for Fixed Implant Rehabilitations in Edentulous Jaws

This approach describes a treatment sequence for patients who present a failing dentition and are receiving fixed implant rehabilitation. According to Cordaro et al,⁶² the main advantage of this protocol is the avoidance of a removable provisional phase. In addition, the protocol was presented as an alternative to immediate implant placement and loading.^{62,63}

The electronic search performed for this review failed to show any relevant clinical trials for this treatment modality.

Conclusions for staged approach for fixed implant rehabilitations in edentulous jaws:

- More clinical trials are needed to scientifically and clinically validate this protocol.

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