Treatment of Adult Patients with Edentulous Arches: A Systematic Review

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Purpose: This study aimed to evaluate the outcomes of treatment methods used to rehabilitate adult patients with maxillary and/or mandibular edentulism after at least 5 years of follow-up. The risks, adverse effects, and cost effectiveness of these methods were also evaluated. ***Materials and Methods:*** Three databases as well as the reference lists of included publications were searched using specified indexing terms. Publications that met the inclusion criteria were read and interpreted using pre-established protocols. Quality of evidence was classified according to the GRADE system (high, moderate, low, or very low). ***Results:*** The search yielded 2,130 titles and abstracts. Of these, the full-text versions of 488 publications were obtained. After data extraction and interpretation, 10 studies with moderate study quality of evidence and 1 study with low quality of evidence regarding outcomes, risks, and adverse effects remained. Three studies on the economic aspects of treatment were also included (1 with moderate quality and 2 with low quality). Low-quality evidence showed that the survival rate of implant-supported fixed prostheses is 95% after 5 years in patients with maxillary edentulism and 97% after 10 years in patients with mandibular edentulism. The survival rate of implant-supported overdentures is 93% after 5 years (low-quality evidence). In implant-supported fixed prostheses, 70 of every 1,000 implants are at risk of failing in the maxilla after 5 years and 17 of every 1,000 implants in the mandible are at risk after 10 years. Regarding economic aspects, the evidence was insufficient to provide reliable results. ***Conclusions:*** Due to the low quality of evidence found in the included studies, further research with a higher quality of evidence is recommended to better understand the outcomes of treatment for patients with maxillary and/or mandibular edentulism. *Int J Prosthodont 2012;25:553–567.*

During the last five decades, improvements in oral health care have led to a decreased number of lost teeth in the general population. Despite a lack of reliable statistics, it is evident that in the industrialized world today, the prevalence of edentulism in patients between 65 and 74 years of age is only a fraction of what it was 40 to 50 years ago.[1] For example, in Sweden in the 1950s, the frequency of edentulism in people aged 20 to 66 years was 24%; this number decreased to 9.5% percent in the 1970s[2] and to 3% in 2005.[3] It is also evident that the elderly population and lower socioeconomic groups are overrepresented among patients who have experienced tooth loss.

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The modalities available to treat edentulism have changed over the years, from the relatively simple vulcanized dentures of the early 20th century to the implant-retained constructions of today. Until well into the last century, most improvements were based on material and/or procedural modifications. It is only in the last three or four decades that an alternative to complete dentures has become available, ie, reconstructions supported by osseointegrated titanium implants.[4] Initially, selected patients with mandibular edentulism were treated with an implant-supported fixed prosthesis[4] or an implant-supported overdenture.[5,6] Eventually, these treatment modalities became available to treat maxillary edentulism as well.[7,8]

The current lack of consensus regarding the treatment of choice for edentulism has been attributed to pronounced variations in treatment approaches and a lack of scientific stringency in published studies.[9] Thus, the aim of this systematic review was to analyze studies of the treatment of maxillary, mandibular, or complete edentulism, with special attention paid to the quality of the evidence used to assess the outcomes, risks, adverse effects, and cost effectiveness of a given treatment method.

Materials and Methods

To ensure a systematic approach, the literature review was conducted and adapted to Goodman's model,[10] which consists of the following steps: *(1)* problem specification, *(2)* formulation of a plan for the literature search, *(3)* literature search and retrieval of publications, and *(4)* data extraction, interpretation of data, and evaluation of evidence from the included literature.

Problem Specification

This study aimed to assess the following factors regarding the prosthetic treatment methods used to rehabilitate adult patients with maxillary and/or mandibular edentulism:

- Treatment outcomes after at least 5 years
- Risks and adverse effects of the assessed methods after at least 5 years
- Cost effectiveness of the assessed methods after at least 5 years

The following terms were defined on the basis of the United States National Library of Medicine's Medical Subject Headings (MeSH) prior to the literature search:

- Jaw, edentulous: The total absence of teeth from either the mandible or maxilla, but not both. Total absence of teeth from both jaws is *Mouth, edentulous*. Partial absence of teeth in either is *Jaw, edentulous, partially*. Year introduced: 1980.
- Mouth, edentulous: Total lack of teeth due to disease or extraction. Year introduced: 1965.
- Treatment outcome: Evaluation of the results or consequences of treatment and the procedures used in combating disease to determine the efficacy, effectiveness, safety, practicability, etc of these interventions in individual cases or series. Year introduced: 1992. In the present study, treatment outcome includes success and/or survival rates of the prosthetic reconstruction at the patient level.
- Risk: The probability that an event will occur. It encompasses a variety of measures of the probability of a generally unfavorable outcome. Year introduced: 1988.
- Adverse effects: A term used with drugs, chemicals, or biologic agents in accepted dosage—or with physical agents or manufactured products in normal usage—when intended for diagnostic, therapeutic, prophylactic, or anesthetic purposes. The term is also used for adverse effects or complications of diagnostic, therapeutic, prophylactic, anesthetic, surgical, or other procedures, but excludes contraindications (for which *Contraindications* is used). Year introduced: 1966.
- Cost effectiveness: Included in the MeSH term *Cost-benefit analysis*, ie, a method of comparing the cost of a program with its expected benefits in dollars (or other currency). The benefit-to-cost ratio is a measure of total return expected per unit of money spent. This analysis generally excludes consideration of factors that are not measured ultimately in economic terms. *Cost effectiveness* compares alternative ways to achieve a specific set of results. Year introduced: 1976.

Formulation of a Plan for the Literature Search

Three databases were searched in consultation with a specialist in informatics at the Swedish Council on Health Technology Assessment, Stockholm, Sweden, for relevant studies regarding outcomes, risks, and adverse effects of treatment: PubMed, The Cochrane Central Registry of Controlled Trials, and Embase. For publications on health economics, three databases were searched: PubMed, the National Health Service Economic Evaluation Database, and the Health Economic Evaluation Database. The PubMed searches were based on MeSH terms. The entrez date was 01/01/1950 to 1/4/2010. To ensure the widest possible

Table 1 Example of Search Strategy in PubMed*

		Dental implants (NoExp)		
		Dental implantation, endosseous (NoExp)		
Edentulous (TiAb)		Blade implantation (MeSH)		Denture, overlay (MeSH)
Jaw, edentulous (NoExp)				Denture, complete (MeSH)
Mouth, edentulous (NoExp)		Dentistry (MeSH)		Denture, partial, removable (MeSH)
Edentulism (TiAb)	AND	OR Dental (TiAb)	AND	Dental prosthesis, implant-supported (MeSH)
		AND Osseointegration (MeSH, TiAb)		Denture, partial, fixed (NoExp)
NOT Partially edentulous (TiAb)				Denture (TiAb)
		Dental (TiAb)		Prosthesis (TiAb)
		AND Implant/s (TiAb)		
		OR Implantation (TiAb)		

MeSH = medical subject headings; NoExp = no expansion; TiAb = titles/abstracts.
*("Dental implants"[MeSH:NoExp] OR "Dental implantation, endosseous"[MeSH:NoExp] OR "Blade implantation"[MeSH] OR (("Dentistry"[MeSH] OR "Dental"[Ti/Ab]) AND ("Osseointegration"[MeSH] OR "Osseointegration"[TiAb])) OR ("Dental"[TiAb] AND ("Implant"[TiAb] OR "Implants"[TiAb] OR "Implantation"[TiAb]))) AND ("Denture, overlay"[MeSH] OR "Denture, complete"[MeSH] OR "Denture, partial, removable"[MeSH] OR "Dental prosthesis, implant-supported"[MeSH] OR "Denture, partial, fixed"[MeSH:NoExp] OR "Denture"[TiAb] OR "Prosthesis"[TiAb]) AND ("Edentulous"[TiAb] OR "Jaw, edentulous"[MeSH:NoExp] OR "Mouth, edentulous"[MeSH:NoExp] OR "Edentulism"[TiAb]) NOT "Partially edentulous"[TiAb]).

search, no limits on language were applied, and the indexing terms were used as MeSH terms and as free text in the PubMed search. The truncation symbol (*) was used in the Cochrane and Embase searches. Publications on primary materials and systematic reviews that shed light on the problem specification were included. The reference lists of included studies were searched for additional publications.

Literature Search and Retrieval of Publications

Table 1 shows an example of the first step of the PubMed search. Inclusion and exclusion criteria were discussed and determined (Table 2) prior to reading the retrieved abstracts. Two assessors independently read all retrieved titles and abstracts. If one assessor regarded a publication as having met the inclusion criteria, the full-text article was obtained.

In the second step of the search, titles of studies in the reference lists of the included publications were searched for any of *(1)* the term *treatment* together with *edentulous jaw, edentulous maxilla,* or *edentulous mandibles* and *(2)* words indicating an analysis of the following treatment methods: complete dentures, implant-supported overdentures, implant-supported fixed prostheses, or their equivalents. No limitations regarding publication date were specified in this step. Book chapters and reviews were excluded. Abstracts of the selected references were obtained. The full-text version of the publication was obtained if *(1)* there was no abstract or *(2)* at least one assessor considered the abstract relevant.

Data Extraction, Interpretation of Data, and Evaluation of Evidence

Two assessors independently read the articles to include or exclude a publication using a protocol (appendix 1, www.sbu.se/204_appendix). The assessor did not participate in the appraisal of any publications of which he or she was a coauthor. Publications deemed eligible for inclusion were appraised with the aid of another protocol (appendix 2, www.sbu.se/204_appendix), and the relevant data were extracted. Therefore, only publications considered to be relevant according to both protocols were ultimately included. When data were incomplete but other publications were referenced, the missing data were obtained, if possible, in the cited publications. The quality of each included study was assessed as high, moderate, or low according to criteria based on the CONSORT and STROBE statements (Table 3).[11,12] Risks and adverse effects were listed as either biologic or technical complications (Tables 4 and 5). Two health economists independently assessed the publications regarding economic aspects using a protocol based on criteria by Drummond et al.[13] The dental relevance and quality of these studies were assessed together by two specialists in prosthodontics.

Quality of evidence was rated according to GRADE guidelines[14] as high, moderate, low, or very low.

Table 2 Inclusion and Exclusion Criteria for Studies on Prosthetic Treatment of Adults with at Least One Edentulous Arch

	Comparison of treatment methods	Risks and adverse effects (prospective)	Risks and adverse effects (retrospective)
Inclusion criteria			
Study design	Prospective RCT Prospective CCT	Prospective observational study without comparison group	Retrospective observational study without comparison group
Observation period	≥ 5 y	≥ 5 y	≥ 10 y
Participants (age)	≥ 20 in each group (≥ 18 y)	≥ 50 (≥ 18 y)	≥ 50 (≥ 18 y)
Attrition	≤ 25% and described	≤ 25% and described	≤ 50% and described (minimum: 25 patients remaining)
Exclusion criteria			
Problem specification	Problem specification not addressed Primary outcome not analyzed	Problem specification not addressed Primary outcome not analyzed	Problem specification not addressed Primary outcome not analyzed
Sample	Advanced sample, not treated in GDP	Advanced sample, not treated in GDP	Advanced sample, not treated in GDP
	Sample characteristics unclear	Sample characteristics unclear	Sample characteristics unclear
	< 20 subjects in each group	< 50 subjects	< 50 subjects
	Impossible to analyze no. of subjects followed for ≥ 5 y	Impossible to analyze no. of subjects followed for ≥ 5 y	Impossible to analyze no. of subjects followed for ≥ 10 y
	Attrition > 25% or not described	Attrition > 25% or not described	Attrition > 50% or not described
	Not original research (editorial, review, etc)	Not original research (editorial, review, etc)	Not original research (editorial, review, etc)
	Case report	Case report	Case report
	Inclusion time of sample > 5 y or not reported	Inclusion time of sample > 5 y or not reported	Inclusion time of sample > 5 y or not reported
Observation period	< 5 y	< 5 y	< 10 y

RCT = randomized controlled trial; CCT = clinical controlled trial; GDP = general dental practice.

Results

Literature Identification

Figure 1 summarizes the process of literature identification and selection. The searches yielded 1,813 abstracts on outcomes, of which 472 met the inclusion criteria. Assessment of the full-text articles reduced this number to 39 original studies, of which 28 were systematic reviews. The second step of the search, ie, the search of the reference lists of the included publications, yielded 84 abstracts. Forty-five of these articles were read in full-text, but none were included in the final analysis. The principal reasons for exclusion were as follows: *(1)* the outcome of the treatment method was not patient-related and only the outcome at the implant level was analyzed (approximately one-quarter of excluded studies), *(2)* insufficient number of participants, and *(3)* inadequate observation time. The included publications on the outcomes of treatment of the maxilla and mandible are listed in Table 4[15,17,19,20] and Table 5,[19–23,25–28] respectively, together with publications[16,18,24,29] needed to provide complete data for the included studies. The problem specifications and thus the results of the systematic reviews[30–57] were not relevant to the present review. Excluded publications on outcomes of treatment methods and the reasons for exclusion are available online (appendix 3, www.sbu.se/204_appendix).

The searches on studies evaluating economic aspects yielded 317 abstracts on the rehabilitation of partially dentate or edentulous patients (Fig 1). Of these, the full-text articles of 16 publications on edentulous patients were obtained. Thirteen of these were excluded. Table 6 presents the remaining 3 studies (1 with moderate study quality of evidence[58] and 2 with low quality[30,59]). Excluded publications on economic aspects and the reasons for exclusion are online (appendix 4, www.sbu.se/204_appendix).

Interpretation of Data

All included studies were performed in specialist and/or university clinics. Some of the included studies were conducted in the same clinic.

Treatment of completely edentulous patients. No study fulfilling the inclusion criteria was identified.

Treatment of patients edentulous in the maxilla. No study comparing different treatment

Table 3 Assessment of Study Quality*

High quality	Moderate quality	Low quality
▪ Well-defined research question/hypothesis	▪ Research question/hypothesis ambiguous	▪ Research question vaguely defined
▪ Well-described trial design, inclusion criteria for participants, settings where data were collected, and period of recruitment	▪ Some ambiguities in trial design, inclusion criteria for participants, settings where data were collected, and period of recruitment	▪ Trial design, inclusion criteria for participants, settings where data were collected, and period of recruitment not clearly described
▪ Intervention described with sufficient detail to allow replication	▪ Some ambiguities in description of intervention	▪ Unclear description of intervention
▪ Well-defined pre-established primary and secondary outcomes measures, including how and when they were assessed; blinding of assessors	▪ Incomplete description of pre-established primary and secondary outcomes measures, including how and when they were assessed; assessors not blinded	▪ Unclear pre-established primary and secondary outcomes measures, including how and when they were assessed; assessors not blinded
▪ Systematic, stringent presentation of each primary and secondary outcome and estimated effect size and its precision	▪ Systematic presentation of primary and secondary outcomes; incomplete data on estimated effect size and its precision	▪ Ambiguous presentation of primary and secondary outcomes; incomplete data on estimated effect size and its precision
▪ Stringent presentation of risks and adverse effects	▪ Ambiguous presentation of risks and adverse effects	▪ Ambiguous presentation of risks and adverse effects
▪ Discussion of trial limitations, addressing sources of potential bias and imprecision	▪ Ambiguous discussion of trial limitations	▪ Trial limitations not discussed
▪ Clearly demonstrated that interpretation is consistent with results, balancing benefits and adverse effects, and considering other relevant evidence	▪ Some ambiguity in interpreting the results, balancing benefits and adverse effects, and contextualizing the results in relation to previous research	▪ Unclear how interpretation is based on results; contextualizing of the results in relation to previous research poorly developed
▪ Well-described generalizability (external validity, applicability) of results	▪ Proposed generalizability (external validity, applicability) of results is ambiguous	▪ Generalizability of results not presented or unclear

*Based on the CONSORT[11] and STROBE[12] statements.

methods fulfilled the inclusion criteria. As presented in Table 4, four studies of moderate quality were included: three with a 5-year follow-up[15,17,19] and one with a 10-year follow-up.[20] All studies presented outcomes of patients treated with implant-supported fixed dental prostheses (ISFDPs). Three studies[17,19,20] were designed as randomized controlled trials (RCTs), but the randomization of the patients was based on the material used and not on the treatment method. After observation periods of 5 and 10 years, the ISFDPs had high cumulative survival rates (93% to 97%). In two patients, the prosthetic reconstruction failed due to loss of all supporting implants.

Most complications occurred during the first year after treatment and were mainly of a technical nature, such as fractures of the denture teeth, veneering material, or metal framework (Table 4). After an observation period of 5 years, the survival rate of implants ranged from 90% to 97%. No implant loss was reported between 5 and 10 years.[20] After 10 years, the mean alveolar bone loss around implants was 0.5 to 0.7 mm but exceeded 2.5 mm in 8% to 20% of the implants.[20]

Treatment of patients edentulous in the mandible. Table 5 presents nine included studies,[19–23,25–28] all but one of which showed moderate quality of evidence. In one study,[23] patients were asked to rate the function of their overdentures after 8 years. In another study,[28] patient satisfaction with the treatment was analyzed. Implant-retained overdentures and complete dentures were compared in an RCT of treatment methods.[26] At baseline, patients to be treated with complete dentures were offered the option of an implant-retained overdenture at a later date. At the 10-year follow-up, almost half of these patients had chosen implant-retained overdentures. Satisfaction was greater among patients treated with implant-retained overdentures than among patients treated with complete dentures.

In the other RCTs, randomization was based on differences in either the anchoring/attachment systems[23,27,28] or the prosthetic construction material (titanium versus gold alloy).[19,20,25] The survival rate of implant-supported overdentures was 93% in one study with a 5-year observation period[22] and 94% in another study with an 8-year observation period.[27] In two studies with 5-year observation periods, the survival rates of ISFDPs were 100%.[19,21] In two studies with a 10-year follow-up, the survival rates of ISFDPs ranged from 93% to 100%.[20,25]

Table 4 Included Studies on Prosthetic Treatment of Patients with Edentulous Maxillae

Study	Study design	Intervention	Control
Jemt, 1994 (Sweden)[15]	Prospective observational Consecutive patients treated at specialist clinic Inclusion period: 2 y (1986–1987) Follow-up: 5 y	10- to 12-unit implant-supported fixed prosthesis on standard implants (two-stage surgery, Brånemark) Mean: 5.9 implants (cast type III alloy framework with resin teeth) 76 patients (mean age: 60.1 y [SD: 11.6 y]; range: 32–75 y) 28 women 48 men Lost to follow-up: 16%	–
Jemt et al, 2002 (Sweden)[17]	Prospective multicenter (6 centers) RCT 10 consecutive patients per center Fixed implants or natural dentition with or without removable partial dentures in mandible Inclusion period: 1 y (1994–1995)* Follow-up: 5 y	Fixed full-arch prostheses with laser-welded titanium framework supported ≥ 5 implants (two-stage surgery, Brånemark) 28 patients (mean age: 59 y; range: 40–73 y) 12 women 16 men Lost to follow-up: < 14%	Fixed full-arch prostheses with conventional cast gold alloy framework supported by ≥ 5 implants (two-stage surgery, Brånemark) 30 patients (mean age: 61 y; range: 38–74 y) 13 women 17 men Lost to follow-up: < 14%
Örtorp and Jemt, 2004 (Sweden)[19]	RCT Consecutive patients treated at specialist clinic Inclusion period: 1.5 y Follow-up: 5 y	Milled titanium framework supported by 6 to 8 implants (two-stage surgery, Brånemark) 23 patients (mean age: 66.9 y [SD: 8.9 y]) 10 women (mean age: 70.6 y [SD: 6.9 y]) 13 men (mean age: 64.1 y [SD: 9.4 y]) Lost to follow-up: 19% (mean)	Conventional cast gold alloy framework supported by 4 to 8 implants (two-stage surgery, Brånemark) 31 patients (mean age: 67.0 y [SD: 10.8 y]) 19 women (mean age: 67.2 y [SD: 12.1 y]) 12 men (mean age: 66.7 y [SD: 8.8 y]) Lost to follow-up: 25% (mean)
Örtorp and Jemt, 2012 (Sweden)[20]	RCT Consecutive patients treated at specialist clinic Inclusion period: 1.5 y Follow-up: 10 y	Milled titanium framework supported by 6 to 8 implants (two-stage surgery, Brånemark) 23 patients (mean age: 66.9 y [SD: 8.9 y]) 10 women (mean age: 70.6 y [SD: 6.9 y]) 13 men (mean age: 64.1 y [SD: 9.4 y]) Lost to follow-up: 45% (mean)	Conventional cast gold alloy framework supported by 4 to 8 implants (two-stage surgery, Brånemark) 31 patients (mean age: 67.0 y [SD: 10.8 y]) 19 women (mean age: 67.2 y [SD: 12.1 y]) 12 men (mean age: 66.7 y [SD 8.8 y]) Lost to follow-up: 38% (mean)

†Fracture adjusted chairside.
‡Fracture required laboratory adjustment.
CSR = cumulative survival rate; RCT = randomized controlled trial; SD = standard deviation.

More aftercare was needed for patients with implant-retained overdentures than for patients with complete dentures.[26] Most complications were technical in nature, such as fracture of the overdenture and lost retention of the anchoring system.[27] In ISFDPs, fractures were more frequent in laser-welded titanium frameworks than in gold alloy frameworks after 10 years.[25] The survival rate of implants after 5 and 10 years ranged between 92% and 100%. After 10 years, the mean alveolar bone loss around implants was 0.6 to 0.8 mm[20, 25] but exceeded 2.5 mm in 8% of implants.[20] No serious complications such as nerve damage or jaw fractures were reported.

Cost effectiveness of assessed methods. As presented in Table 6, two controlled clinical trials were included.[58,59] In the study by Attard et al,[58] a per protocol analysis was undertaken to compare the costs of mandibular fixed prostheses and mandibular overdentures over a period of 9 years. The authors reported that the costs associated with the overdentures were significantly lower. In another study by Attard et al,[59] the observation period was longer but varied

Intervention outcome and complications	Control outcome	Comparison	Study quality	Comments
CSR prostheses: 96% (3 failures) CSR implants: 92% Biologic: bone loss (mean: 1.2 mm [SD: 0.58 mm]), lost implants (n = 34, 8.9%), soft tissue problems (n = 44), phonetic problems (n = 30) Technical: problems with resin veneers (n = 73), framework fracture (n = 1), prosthesis redesign (n = 20), loose abutment screw/new prostheses/ resoldered prostheses (n = 7)	–	–	Moderate	Status of mandible: see Jemt et al[16]
CSR prostheses: 96% CSR implants: 91% Biologic: all implants and prosthesis lost (n = 1 patient), bone loss > 2 mm (n = 13 sites, 0.05%), soft tissue problems (n = 1) Technical: material fracture or mobile/ unstable prostheses (n = 21 in 12 patients)	CSR prostheses: 93% CSR implants: 94% Biologic: all implants and prosthesis lost (n = 1 patient), bone loss > 2 mm (n = 17 sites, 0.06%), soft tissue problems (n = 6 patients) Technical: new prosthesis due to veneering material problems (n = 1 patient), material fracture or mobile/unstable prostheses (n = 24 in 12 patients)	Similar cumulative survival and success rates	Moderate	Randomized by material, not treatment method *See Jemt et al[18]
CSR prostheses: 95% (1 failure) CSR implants: 90% Biologic: soft tissue problems (n = 3 in 3 patients), bone loss (mean: 0.5 mm [SD: 0.41 mm]), implant loss (n = 13 in 6 patients after insertion and connection) Technical: resin veneer fracture (n = 10 in 8 patients)	CSR prostheses: 97% (1 failure) CSR implants: 97% Biologic: soft tissue problems (n = 5 in 5 patients), bone loss (mean: 0.4 mm [SD: 0.45 mm]), implant loss (n = 5 in 5 patients after insertion and connection) Technical: resin veneer fracture (n = 23 in 10 patients)	More loaded implants were lost in intervention group than in control group Difference not significant at patient level	Moderate	Randomized by material, not treatment method
CSR prostheses: 95% CSR implants: 90% Biologic: soft tissue problems (n = 3 in 3 patients), bone loss (mean: 0.7 mm [SD: 0.61 mm]; > 2.5 mm in 20% of implants), implant loss (n = 13 in 6 patients after insertion and connection) Technical: resin veneer fracture (uncomplicated†: n = 7 in 6 patients; severe‡: n = 26 in 11 patients)	CSR prostheses: 97% CSR implants: 97% Biologic: soft tissue problems (n = 5 in 5 patients), bone loss (mean: 0.5 mm [SD 0.63 mm]; > 2.5 mm in 8% of implants), implant loss (n = 4 in 4 patients after insertion and connection) Technical: resin veneer fracture (uncomplicated†: n = 9 in 6 patients; severe‡: n = 37 in 13 patients)	Not relevant	Moderate	Randomized by material, not treatment method Same sample as Örtorp et al[19]

among the included groups. Maintenance and costs were calculated, and overdentures again showed the lowest costs per patient. A follow-up study of an RCT[27] that evaluated costs of maintenance of three different implant strategies showed no significant differences between any of the treatments.

Evaluation of evidence. For patients edentulous in the maxilla, low-quality evidence showed that after 5 years of observation, ISFDPs have a survival rate of 95% (Table 7). Low-quality evidence also showed that 70 of every 1,000 implants used to support ISFDPs will be lost after 5 years. For patients edentulous in the mandible (Table 7), low-quality evidence showed that implant-supported overdentures have a survival rate of 93% at 5 years. For ISFDPs in the mandible, the survival rate was 97% at 10 years. Additionally, there is low-quality evidence that 44 of every 1,000 implants used to support implant-supported overdentures will be lost after 5 to 10 years. In ISFDPs, 2 of 1,000 implants will be lost after 10 years (Table 7). There was insufficient evidence to draw any conclusions about the cost effectiveness of the assessed methods.

Table 5 Included Studies on Prosthetic Treatment of Patients with Edentulous Mandibles

Study	Study design	Intervention	Control
Arvidson et al, 1998 (Sweden)[21]	Prospective observational Patients treated at specialist clinic Inclusion period: 3 y (1985–1987) and 4 y (1988–1991)* Follow-up: 5 y	4 to 6 implants (two-stage surgery, Astra Tech) with fixed detachable prostheses (type III gold framework and acrylic resin artificial teeth) 107 patients 64 women (age range: 40–81 y) 43 men (age range: 41–81 y) Lost to follow-up: 15%	–
Behneke et al, 2002 (Germany)[22]	Prospective observational Patients treated at specialist clinic Inclusion period: 4 y (1988–1992) Follow-up: 5 y	Implant-retained overdenture on 2 to 5 implants (single-stage surgery, ITT) with straight bar and complete denture in maxilla 100 patients (mean age: 62.2 y) 57 women 43 men Lost to follow-up: 17%	–
Örtorp and Jemt, 2004 (Sweden)[19]	RCT Consecutive patients treated at specialist clinic Inclusion period: 1.5 y Follow-up: 5 y	Milled titanium framework supported by 4 to 5 implants (two-stage surgery in 37 patients and single-stage surgery in 7 patients, Brånemark) 44 patients 22 women (mean age: 70.4 y [SD: 11.6 y]) 22 men (mean age: 63.1 y [SD: 9.6 y]) Lost to follow-up: 19% (mean)	Conventional cast gold alloy framework supported by 5 to 6 implants (two-stage surgery, Brånemark) 31 patients 18 women (mean age: 66.8 y [SD: 9.7 y]) 13 men (mean age: 65.5 y [SD: 12.3 y]) Lost to follow-up: 25% (mean)
Timmerman et al, 2004 (The Netherlands)[23]	RCT (3 groups) Patients with persistent problems with their complete denture referred to specialist and teaching hospital Inclusion period: 3 y (1991–1993) Follow-up: 8 y	Implant-retained overdenture on 2 implants (single-stage surgery, ITT) and complete denture in maxilla Group A: ball attachments and Dalla Bona matrices 36 patients (mean age: 50 y; range: 33–80 y) 22 women 14 men Lost to follow-up: 11% Group B: single egg-shaped Dolder bar 37 patients (mean age: 51.3 y; range: 35–76 y) 29 women 8 men Lost to follow-up: 3%	Group C: implant-retained overdenture on 4 implants (single-stage surgery, ITT) with triple bar and complete denture in maxilla 37 patients (mean age: 53.1 y; range: 35–81 y) 25 women 12 men Lost to follow-up: 5%
Örtorp and Jemt, 2006 (Sweden)[25]	Retrospective RCT Consecutive patients treated with titanium framework at specialist clinic Inclusion period: 4 y (1987–1991) Follow-up: 10 y	Fixed full-arch prostheses (10 to 12 teeth) with laser-welded titanium framework on 4 to 6 implants (two-stage surgery, Brånemark) 155 patients (mean age: 64 y [SD: 10.4 y]; range: 35–87 y) 77 women 78 men Lost to follow-up: 46% (84 patients remaining at 10-y follow-up)	Fixed full-arch prostheses (10 to 12 teeth) with cast gold alloy framework on 4 to 6 implants (two-stage surgery, Brånemark) 53 patients (mean age: 67 y [SD: 9.7 y]; range: 39–86 y) 27 women 26 men Lost to follow-up: 47% (28 patients remaining at 10-y follow-up)
Visser et al, 2006 (Netherlands)[26]	RCT (5 groups, but only 4 included*) Patients referred to university clinic Inclusion period: 2 y (1991–1992) Follow-up: 10 y	Implant-retained overdenture on 2 implants (two-stage surgery, IMZ or Brånemark) and new denture in maxilla Overdenture on round-shaped bar with Ackermann clip retention system Group 1: bone height = 8 to 15 mm 30 patients (mean age: 56 y; range: 46–83 y) Lost to follow-up: 3% Group 3: bone height = 16 to 25 mm 32 patients (mean age: 59 y; range: 41–90 y) Lost to follow-up: 6%	Complete dentures Group 2: bone height = 8 to 15 mm 30 patients (mean age: 60 y; range: 53–82 y) Lost to follow-up: 16% Group 5: bone height = 16 to 25 mm 29 patients (mean age: 55 y; range: 44–88 y) Lost to follow-up: 17%

Intervention outcome and complications	Control outcome	Comparison	Study quality	Comments
CSR prostheses: 100% (criteria for failure: prostheses could not function after loss of implants) CSR implants: 98.7%	–	–	Low	No description of patient recruitment Criteria for CSR not well defined *2 patient groups
Overdenture fracture rate ranged between 1% and 15.8% per year CSR implants: 98.8% Biologic: bone loss (median: 1 mm), lost implants (n = 0 after loading and n = 4 before loading), soft tissue problems (mucosiitis, peri-implantitis, or mucosal enlargement; n = 93) Technical: bar fracture (n = 36)	–	–	Moderate	Percent fractured overdentures in relation to restorations at risk: 7%
CSR prostheses: 100% CSR implants: 99.5% Biologic: soft tissue problems (n = 3 in 2 patients), bone loss (mean: 0.4 mm [SD: 0.5 mm]), implant failure (n = 1 before insertion) Technical: resin veneer fracture (n = 2 in 2 patients)	CSR prostheses: 100% CSR implants: 100% Biologic: soft tissue problems (n = 2 in 2 patients), bone loss (mean: 0.7 mm [SD: 0.54 mm]), implant failure (n = 0) Technical: resin veneer fracture (n = 3 in 3 patients)	Difference not significant at patient level	Moderate	Randomized by material, not by treatment method
Score 1 to 5* Group A: function general = 1.95 ± 0.61, mandibular denture function = 1.88 ± 0.78, speech = 3.70 ± 0.93, social functioning = 1.34 ± 0.65, chewing soft food = 1.03 ± 0.12, chewing hard food = 1.37 ± 0.38 Group B: function general = 1.81 ± 0.61, mandibular denture function = 1.91 ± 0.78, speech = 4.02 ± 0.93, social functioning = 1.36 ± 0.65, chewing soft food = 1.00 ± 0.12, chewing hard food = 1.31 ± 0.38	Score: 1 to 5* Group C: Function general = 1.99 ± 0.61, mandibular denture function = 2.22 ± 0.78, speech = 3.82 ± 0.93, social functioning = 1.47 ± 0.65, chewing soft food = 1.36 ± 0.12, chewing hard food = 1.36 ± 0.38	No difference between the groups for 9 satisfaction scores	Moderate	Randomized by number of implants and retention elements, not by treatment method Participants were less satisfied after 8 y than at 19 mo Same sample as Stoker et al[27] *See Wismeijer et al[24]
CSR prostheses: 92.8% (n = 9 new prosthesis for 9 patients) CSR implants: 99.5% Clinical appointments during 10 y: n = 100 (98 during year 1; mean per patient and year: 1.4) Biologic: lost implants (n = 4 in 3 patients), soft tissue problems (n = 39 in 29 patients), bone loss (mean: 0.56 mm [SD 0.45 mm]) Technical: framework fracture (n = 30 in 20 patients), resin veneer fracture (n = 43 in 22 patients)	CSR prostheses: 100% CSR implants: 99.6% Clinical appointments during 10 y: n = 100 (98 during year 1; mean per patient and year: 1.4) Biologic: lost implants (n = 1), soft tissue problems (n = 12 in 8 patients), bone loss (mean: 0.77 mm [SD: 0.36 mm]) Technical: framework fracture (n = 2 in 2 patients), resin veneer fracture (n = 10 in 7 patients), screw retightened (n = 1)	Fractures of metal frameworks and remade prostheses more common for laser-welded titanium framework First generation titanium frameworks worked poorly compared to gold alloy frameworks (P <.05)	Moderate	Randomized by material, not by treatment method Two different fabrication modes of titanium frameworks combined as one test group in this table
CSR implants: 92% Biologic: implant loss (n = 17) Technical: Ackermann clip frequently broke and was replaced by Dolder bars	21 patients (43%) with complete dentures switched to implant-retained overdentures (group 2: 10 of 25 patients; group 5: 11 of 24 patients)	More treatment failures in complete denture group than in implant-retained overdenture group Compared with complete dentures, implant-retained overdentures needed more prosthetic care (P < .05) and more routine inspections (P < .05)	Moderate	*One group (group 4) treated with preprosthetic surgery not included here CSR of prostheses not presented Patients changing from complete denture to overdenture could be considered as failures

Table 5 Included Studies on Prosthetic Treatment of Patients with Edentulous Mandibles (continued)

Study	Study design	Intervention	Control
Stoker et al, 2007 (The Netherlands)[27]	RCT (3 groups) Patients with persistent problems with their complete denture referred to specialist and teaching hospital Inclusion period: 3 y (1991–1993) Follow-up: 8 y	Implant-retained overdenture on 2 implants (single-stage surgery, ITT) with new complete denture in maxilla Group A: ball attachments and Dalla Bona matrices 30 patients Lost to follow-up: 13%* Group B: single egg-shaped Dolder bar 33 patients Lost to follow-up: 3%*	Group C: implant-retained overdenture on 4 implants (single-stage surgery, ITI) with Dolder triple bar and new complete denture in maxilla 33 patients Lost to follow-up: 6%*
Meijer et al, 2009 (The Netherlands)[28]	RCT (3 groups) Patients with insufficient retention of mandibular denture referred to specialist and teaching hospital Inclusion period: 3.5 y (1992–1995)* Follow-up: 10 y	Implant-retained overdenture on 2 implants (two-stage surgery, ITI) and new denture in maxilla Overdenture on round bar and clip attachments 30 patients (mean age: 52.8 y; range: 38–74 y) 18 women 12 men Lost to follow-up: 10%	Implant-retained overdenture on 2 implants (two-stage surgery, Brånemark) and new denture in maxilla Overdenture on round bar and clip attachments 30 patients (mean age: 56.6 y; range: 35–79 y) 24 women 6 men Lost to follow-up: 10%
Örtorp and Jemt, 2012 (Sweden)[20]	RCT Consecutive patients treated at specialist clinic Inclusion period: 1.5 y Follow-up: 10 y	Milled titanium framework supported by 6 to 8 implants (two-stage surgery, Brånemark) 44 patients (mean age: 66.8 y [SD: 11.1 y]) 22 women (mean age: 70.4 y [SD: 11.6 y]) 22 men (mean age: 63.1 y [SD: 9.6 y]) Lost to follow-up: 45% (mean)	Conventional cast gold alloy framework supported by 4 to 8 implants (two-stage surgery, Brånemark) 31 patients (mean age: 66.0 y [SD: 11.1 y]) 13 women (mean age: 66.0 y [SD: 11.1 y]) 18 men (mean age: 65.5 y [SD: 12.3 y]) Lost to follow-up: 38% (mean)

†Requiring laboratory adjustment.
‡Adjusted chairside.
CSR = cumulative success rate of prosthesis or cumulative survival rate of implants; RCT = randomized controlled trial; SD = standard deviation.

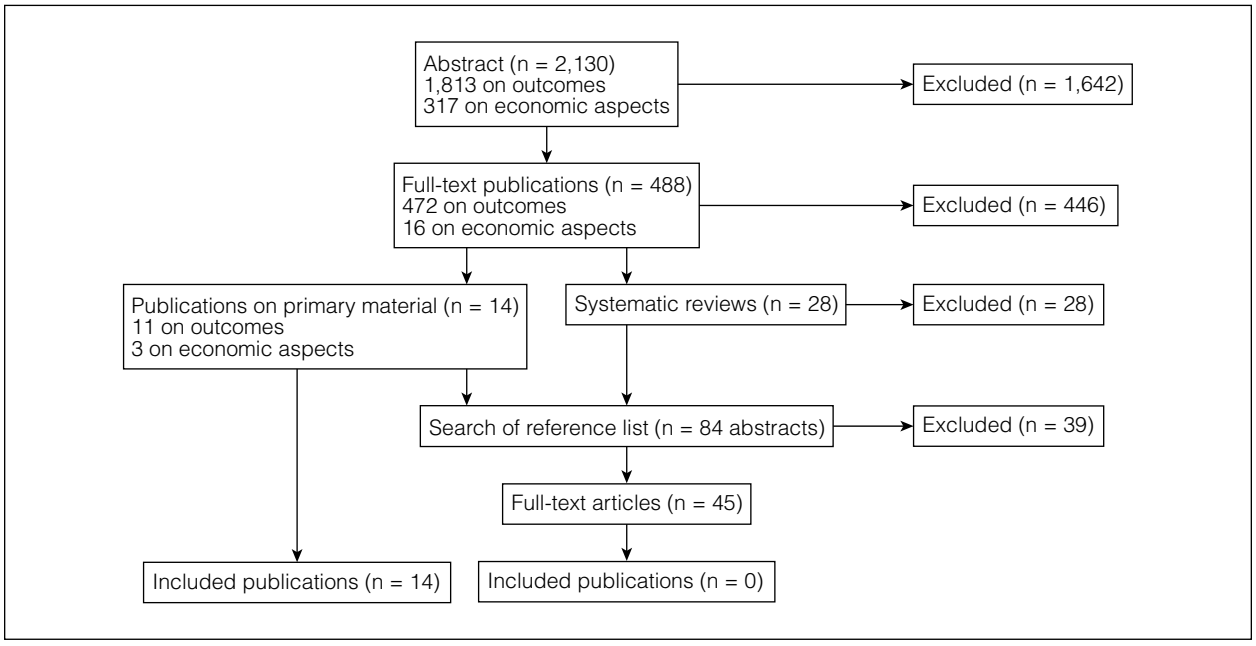

Fig 1 Flowchart showing the number of publications identified, retrieved, extracted, and included in the final analysis.

Intervention outcome and complications	Control outcome	Comparison	Study quality	Comments
Group A: Biologic: lost implants (n = 3 in 2 patients) Technical: overdenture fracture (n = 2), remake (n = 1), rebasing (n = 15), fractured/worn retention elements (n = 10) Group B: Biologic: lost implants (n = 0) Technical: overdenture fracture (n = 3), remake (n = 3), rebasing (n = 10), fractured/worn retention elements (n = 10)	Group C: Biologic: lost implants (n = 0) Technical: overdenture fracture (n = 0), remake (n = 2), rebasing (n = 7), fractured/worn retention elements (n = 5)	No differences in total number of checkups or mean total treatment time Group with ball attachment needed more appointments for simple readjustment of retentive system (eg, reactivating matrices)	Moderate	Randomized by of number of implants and retention elements, not by treatment method Remake of overdenture: 6% of total patient population Calculated CSR of prostheses in group A: 95% *See Timmerman et al[23]
Patients were satisfied with treatment Mean evaluation score in 6 domains ranged between 0.2 and 0.3 (4-point scale: 0 = no complaint; 3 = severe complaints)	Patients were satisfied with treatment Mean evaluation score in 6 domains ranged between 0.1 and 0.7 (4-point scale: 0 = no complaint; 3 = severe complaints)	No differences between implant system with respect to patients' perception of denture function or esthetics	Moderate	Randomized by implant system, not by treatment method One group was treated with IMZ implants that are no longer available *See Batenburg et al[29]
CSR prostheses: 96% CSR implants: 100% Biologic: soft tissue problems (n = 7 in 6 patients), bone loss (mean: 0.7 mm [SD: 0.85 mm]), implant loss (n = 0) Technical: resin veneer fracture (severe†: n = 1; uncomplicated‡: n = 1)	CSR prostheses: 100% CSR implants: 100% Biologic: soft tissue problems (n = 4 in 4 patients), bone loss (mean: 0.6 mm [SD: 0.52 mm]), implant loss (n = 0) Technical: resin veneer fracture (severe†: n = 1; uncomplicated‡: n = 2 in 2 patients)	Not relevant	Moderate	Randomized by material, not by treatment method Same sample as in Örtorp and Jemt[19]

Discussion

Methodologic Considerations

The strength of this review and the validity of its findings lie in the strength of the methodology. The extensive literature searches of several databases without language restrictions complied with AMSTAR guidelines, a measurement tool to assess the methodologic quality of systematic reviews.[60] Despite the comprehensive nature of the search strategy, it is unlikely that all relevant publications were identified. The authors carefully assessed the quality of each included article's study design and reporting. The pre-established inclusion and exclusion criteria may be debatable; therefore, some discussion of these aspects is warranted.

Both RCT and observational studies were included. Randomization to intervention and the presence of a control group are regarded as an important determinant of quality in treatment studies because the risk of systematic errors and biased results is reduced compared to in cohort studies. Since the outcomes of different treatment methods for edentulous patients are based on a close interplay between the patient and clinician, it is conceivable that for this research, it is difficult to maintain true randomization. The ethical barrier may become insurmountable in such studies. Out of six RCTs retrieved, five were based on randomization of the prosthesis material and anchoring system rather than on the treatment method. Only one study randomized patients according to treatment method.[26] However, although the formal part of the randomization via a computerized balancing method was correct, it is questionable whether the randomization was justified because the subjects allotted to the control group were informed at the start of the study that they would be offered the other treatment option at a later date. This could have raised expectations with respect to the other treatment option. A systematic review of the results of randomized and nonrandomized prospective studies evaluating 45 medical

Table 6 Included Studies on Economic Aspects of Prosthetic Treatment of Patients with Edentulous Mandibles

Study	Study design	Intervention	Control	Attrition
Attard et al, 2003 (Canada)[58]	CCT Follow-up: 9 y Cost minimization analysis	Fixed prostheses (n = 25)	Overdentures (n = 25)	I: NA C: NA
Attard et al, 2005 (Canada)[59]	CCT Follow-up: 15.6 and 20.7 y Cost analysis	Fixed prostheses (n = 45)	Overdentures (n = 45)	I: NA C: NA
Stoker et al, 2007 (Netherlands)[27]	RCT Follow-up: 8 y	A: 2 implants, ball attachments (n = 36) B: 2 implants, single bar (n = 36) C: 4 implants, triple bar (n = 37)	NA	I: 7, all deceased (A: n = 4; B: n = 0; C: n = 3) C: NA

NA = not applicable; I = intervention group; C = control group.

Table 7 Primary and Secondary Treatment Outcomes and Quality of Evidence After 5 and 10 Years

	No. of patients (no. of studies)	Mean survival rate (range)	Risk per 1,000 prostheses/implants	Quality	References
Primary outcome (prosthesis survival rate)					
Maxillary ISFDP (5 y)	188 (3)	95.40% (93%–97%)	46	Low	15, 17, 19
Mandibular overdenture (5 y)	196 (2)	93.5% (93%–94%)	65	Low	22, 27
Mandibular ISFDP (10 y)	283 (2)	97.3% (92.8%–100%)	27	Low	20, 25
Secondary outcome (implant survival rate)					
Maxillary ISFDP (5 y)	188 (3)	93% (90%–97%)	70	Low	15, 17, 19
Mandibular overdenture (5 y)	258 (3)	95.6% (92%–99%)	44	Low	22, 26, 27
Mandibular ISFDP (10 y)	283 (2)	99.8% (99.5%–100%)	2	Low	20, 25

ISFDP = implant-supported fixed dental prosthesis.

interventions showed that evidence from nonrandomized studies is important.[61] The authors found good correlation between the results of randomized and prospective nonrandomized studies, as long as the study quality of the latter was high.

A 5-year follow-up time was selected in accordance with studies of medical interventions such as hip implants, in which follow-up times of 5 to 9 years are regarded as short or moderate observation periods.[62–65] As with hip replacement surgery, oral prosthetic rehabilitations should be expected to last for many years. The pre-established criterion for studies with a 5-year follow-up time was that the study design must be prospective. After some deliberation, the authors decided to include retrospective studies with an observation period of 10 years because the definitions of "prospective" and "retrospective" were found to be ambiguous. This decision was supported by a systematic review of treatment outcomes of surgical interventions,[66] which concluded that results from "retro-pro" studies are an important source of information at the patient level.

The inclusion criteria with respect to the number of patients were set to at least 20 in both the intervention and control groups of RCTs, for a total of 40 patients. The study by Feine et al,[67] for example, in which one group of 8 edentulous patients was treated with a fixed construction and another group of 8 patients with a removable construction, could not be included. The minimum number of patients in observational studies was set at 50. Another inclusion criterion was that the data on patient attrition must be presented along with the reasons why such patients did not attend the follow-up examinations. Based on previous analyses of the influence of attrition on outcomes of implant treatment,[68,69] an attrition rate of less than 25% after an observation period of 5 years was selected. For observation periods of more than 10 years, a higher rate of attrition (less than 50%) was considered acceptable. Most edentulous subjects are elderly; thus, there are considerable difficulties in obtaining a representative patient sample.

Limitations of the Evidence

No meta-analysis could be performed because of the heterogeneity of the included studies. Study design and outcome variables differed between studies, as

Results	Comparison	Study quality
I: fixed prostheses = 10,748 $CAD (more severe hardware damage) C: overdenture = 3,665 $CAD	$P = .01$ for costs	Low due to follow-up based on per protocol data
I: fixed prostheses = 20.7 y of follow-up, average of 11,492 $CAD C: overdentures = 15.6 y of follow-up, average of 9,660 $CAD	$P < .05$	Low due to different lengths of follow-up
I: cost of follow-up during 8 y = 997 Euro (A), 961 Euro (B), 984 Euro (C) C: NA	Not significant regarding costs	Moderate

did the examination methods for outcome assessment. The most obvious shortcomings were insufficient descriptions of the sample, variables applied to define the outcomes, and assessment methods. According to Sanderson et al,[70] the three most fundamental domains to be considered in observational studies are appropriate selection of participants, appropriate measurement of variables, and appropriate control of confounding factors. These considerations are all relevant to studies of oral rehabilitation.

Evidence was available only for implant-retained treatments; such studies are more recent and presumably comply with more recent criteria for proper conduct of clinical studies. However, considering the global acceptance and application of implant-retained constructions, a higher quality of evidence might have been expected. Patient-perceived outcomes were studied in only two publications.[23,28] There should be greater emphasis on patient satisfaction and perception of function, ie, outcomes assessed by the patients and not only by the clinician.

It is interesting to note that the 10-year success rate of mandibular ISFDPs was higher than the 5-year maxillary rate. With respect to different treatment methods for mandibular edentulism, low-quality evidence indicates higher survival rates and lower risks for fixed prostheses than for overdentures. The McGill consensus statement on overdentures[71] concluded that there is "now overwhelming evidence that a two-implant overdenture should be the first choice of treatment." In this review, only one study eligible for inclusion compared conventional dentures and overdentures. According to GRADE guidelines,[14] the results of one study are inadmissible as evidence. However, the results of the study in question[26] did support the conclusion of the McGill consensus statement.

Treatment with respect to implant-supported reconstructions differs from country to country, as reflected in the design of the included studies. For example, studies carried out in The Netherlands and Germany analyzed the outcome of implant-supported overdentures, while the Swedish studies were concerned with the outcomes of fixed prostheses. The differences in study design probably reflect the preferred or advocated treatment methods in these countries, which is likely affected by each country's system for financing oral health care. The present literature search failed to identify any relevant study that analyzed the financial aspects of rehabilitation of patients with tooth loss. Moreover, the included publications provided insufficient evidence regarding the cost effectiveness of the assessed treatment methods. Thus, there is a need for both economic and financial studies in this field.

Conclusions

Considering the lack of high-quality evidence regarding the treatment of edentulism in adults, the GRADE guidelines state that "further research is likely to have an important effect on our confidence in the estimate of effect and is likely to change the estimate."[14] Since RCTs have limited applicability and are difficult to carry out for patients requiring prosthetic rehabilitation, future research should be in the form of well-designed observational studies. Such studies should comply with the STROBE statement. Moreover, little is known about the cost effectiveness of the methods used to treat patients with edentulism or about the potential influence on treatment preferences of different systems of financing dental care. There is an urgent need for studies of these factors.

Acknowledgment

The authors thank the Swedish Council on Health Technology Assessment for providing the opportunity and resources to accomplish the systematic review.

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