Treatment of Adult Patients with Partial Edentulism: A Systematic Review

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Purpose: The purpose of this systematic review was to identify and critically appraise published studies of treatment methods used in general practice to rehabilitate adult patients with single tooth loss or partial edentulism, with special emphasis on outcomes reported after at least 5 years of follow-up. ***Materials and Methods:*** Three databases were searched using specified indexing terms. Publications were included if the study design, research questions, and sample size satisfied pre-established criteria. Reference lists of relevant publications and systematic reviews were also searched. The quality of evidence was classified according to the GRADE system as high, moderate, low, or very low. ***Results:*** The search yielded 7,675 titles, of which 1,130 were read in full text. A final total of 15 publications were deemed eligible for inclusion: 5 of moderate quality and 10 of low quality. The five studies of moderate quality were all related to implant-based treatment. The 5-year survival rates for implant-supported single crowns and prostheses were 91% and 94.7%, respectively (implant survival rates: 98.5% and 94.9%, respectively). The underlying scientific evidence was low in quality. No relevant publications were identified regarding the economic aspects of treatment. ***Conclusion:*** Due to the low scientific evidence of the included studies, it was not possible to compare various treatment methods used for rehabilitation of single tooth loss or partial edentulism. *Int J Prosthodont 2012;25:568–581.*

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Tooth loss can vary in severity based on the number and location of missing teeth. Oral rehabilitation is usually performed when it becomes necessary to correct problems arising from lost teeth, such as impaired function (mastication and speech), esthetics, and self-perceived oral health–related quality of life. In prosthetic rehabilitation, the location of missing teeth is a major determinant of treatment; not every lost tooth needs to be replaced.[1,2]

Treatment modalities for single tooth loss and partial edentulism have evolved over time to include multiple options using either tooth-supported removable prostheses or tooth- or implant-supported fixed crowns and prostheses. These procedures involve a series of intricate clinical steps. For example, the metal framework of a removable partial denture must be carefully adapted to the natural teeth to allow for insertion, removal, and function without damaging the remaining teeth and supporting mucosa. Likewise, a fixed crown or prosthesis comprises a cemented or screw-retained metal or ceramic framework attached to abutment teeth or implants. Complex decision making and careful treatment planning are required to ensure long-term restoration of function.[3–5]

It is reasonable to assume that today's treatment options are generally successful in restoring oral function in patients with single tooth loss or partial edentulism. However, to select the most appropriate treatment for each patient, the clinician must be skilled in the various treatment methods available, have a thorough understanding of the patient's preferences, and be well versed in the advantages and disadvantages associated with each treatment option. Therefore, systematically collected data from studies evaluating and comparing the outcomes of different treatment modalities are crucial for clinical decision making.

Over the past decade, systematic reviews have been increasingly acknowledged as an important resource for evidence-based decision making in dentistry. Additionally, there is now a need for broader approaches to the evaluation of different treatment options, ie, evaluation not only of clinical outcomes but also of additional factors such as quality of life and economic consequences. The conclusions drawn from these evaluations should be based on the highest level of scientific evidence, which requires randomized studies or well-designed cohort studies with appropriate long-term follow-up periods.

Since its inception in 1987, the Swedish Council of Health Technology Assessment (SBU) has undertaken the critical appraisal of scientific evidence in support of clinical treatment methods used in medicine and dentistry. An assessment of the scientific support for different methods of prosthetic rehabilitation of missing teeth began in November 2007. The resulting systematic review reported the 5- and 10-year treatment outcomes of various methods for rehabilitating dentitions with a wide range of conditions, from a single missing tooth to complete edentulism.[6,7]

The present study reviewed treatment methods used to restore single lost teeth and partially edentulous dentitions (defined as dentitions with multiple missing teeth but not completely edentulous arches). The aim was twofold: *(1)* to evaluate the evidence with respect to treatment outcomes after an observation period of at least 5 years, and *(2)* to evaluate the evidence with respect to the cost effectiveness of the methods used.

Materials and Methods

The literature review was conducted using an adaptation of Goodman's model,[8] which comprises four steps: *(1)* problem specification, *(2)* formulation of the literature search, *(3)* retrieval of publications and extraction of data, and *(4)* interpretation and evaluation of evidence from the literature retrieved.

Problem Specification

This study aimed to answer the following questions regarding the prosthodontic methods used to rehabilitate adult patients with single missing teeth or partial edentulism:

- What are the treatment outcomes after at least 5 years?
- How strong is the scientific support for the treatment methods used?
- What risks and adverse effects are associated with the treatment methods used?
- How cost effective are the treatment methods used?

The following terms were defined on the basis of Medical Subject Headings (MeSH) prior to the literature search:

- Tooth loss: Failure to retain teeth as a result of disease or injury. Year introduced: 1991.
- 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 survival rates of prostheses 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 applied to drugs, chemicals, or biologic agents in accepted dosage—or to physical agents or manufactured products under conditions of normal usage—for diagnostic, therapeutic, prophylactic, or anesthetic purposes. This 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-benefit analysis: 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 ultimately measured in economic terms. *Cost effectiveness* compares alternative ways of achieving a specific set of results. Year introduced: 1976.

Table 1 PICO (Population, Intervention, Control, and Outcome) Criteria for Inclusion of Studies

Population	Adults (> 18 years of age) with single tooth loss or partial maxillary or mandibular edentulism
Intervention	Implant-supported single crowns Implant-supported fixed prostheses Tooth-supported fixed prostheses Resin-bonded fixed prostheses Removable partial dentures Implant-supported fixed partial dentures
Control	Implant-supported single crowns Implant-supported fixed prostheses Tooth-supported fixed prostheses Resin-bonded fixed prostheses Removable partial dentures Implant-supported fixed partial dentures
Outcome	Survival and success rates of prostheses Risks and adverse effects

Formulation of the Literature Search

The following databases were searched: PubMed, the Cochrane Central Registry of Controlled Trials, and Embase. The publication dates covered were 01/01/1950 to 1/4/2010, with no language restrictions. For studies regarding economic factors of treatment, three databases were searched: PubMed, the National Health Service Economic Evaluation Database, and the Health Economic Evaluations Database. To ensure the widest possible search, the indexing terms were used as MeSH terms and as free text in the PubMed search, and the truncation symbol (*) was used in the Cochrane and Embase searches. Systematic reviews were included. Searches were performed in combination with health-economic terms and in consultation with an SBU specialist in informatics.

Retrieval of Publications and Extraction of Data

The retrieved literature was divided into two sections (single tooth loss and partial edentulism) and assessed by two separate teams, each comprising two examiners. Prior to reading the titles and abstracts of the retrieved articles, the study requirements and inclusion and exclusion criteria were thoroughly discussed and determined by the authors, in accordance with SBU guidelines (Tables 1 and 2). Since this study focused on treatment methods used in general practice, the review excluded studies of advanced patient cases, such as those in which limited bone volume for implantation required regenerative or augmentation procedures. Also excluded were articles that did not adequately address the study questions. Book chapters and nonsystematic reviews were excluded. The electronic search was complemented by a manual search of the reference lists of all included publications as well as the 57 systematic reviews identified during the search process. Titles were searched for *(1)* the term *treatment* together with *single tooth loss*, *partial tooth loss*, *partially edentulous jaw*, and *partially edentulous maxilla or mandible* and *(2)* terms suggesting an analysis of the following treatment methods: single implant, single implant crown, resin-bonded bridge, three-unit fixed bridge, partial fixed prosthesis, partial denture, partial removable denture, implant-supported fixed partial prosthesis, or their equivalents. When at least one examiner considered the title or abstract to meet the inclusion criteria, the full-text version was obtained and read by both authors on the team. The article was then included or excluded according to the criteria shown in Table 2.

Interpretation and Evaluation of Evidence

Included full-text articles were interpreted based on guidelines designed to highlight problem specifications, experience of the research field, and study quality (Table 3).[9,10] Studies covering economic aspects were assessed using a checklist based on Drummond et al[11]; the odontologic relevance and study quality were appraised by two dental experts. Scientific evidence was classified according to the GRADE system[12] as high, moderate, low, or very low. The quality of the scientific evidence was downgraded if there were shortcomings in the study design, study limitations, inconsistent results, imprecision, or reporting bias.

Results

Literature Identification

A total of 7,675 titles were retrieved: 2,475 related to single tooth loss and 5,200 to partial edentulism (Fig 1). Of these, 15 publications were deemed eligible for inclusion. The reasons for exclusion of the 1,060 articles obtained in full-text format (original research) were shortcomings in study design (29%), limited sample size or sample characteristics (27%), inadequate follow-up period (22%), and failure to address this review's research questions (22%). The search for studies evaluating economic aspects yielded 317 abstracts on the rehabilitation of partially dentate or edentulous patients. Of these, the full-text articles of 8 publications regarding patients with single or partial tooth loss were obtained; all were excluded.

Table 2 Inclusion and Exclusion Criteria for Studies on Prosthetic Treatment of Adults with Single Tooth Loss or Partial Edentulism

	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
Study design	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.

Interpretation of Data

Of the 15 included studies, most were conducted at a specialist and/or university clinic. No study with a high quality of evidence was identified. Five were of moderate quality[13–17] and 10 were of low quality.[18–27] Seven studies were retrospective in design.[15,17,21–24,27]

Treatment outcomes of patients with single tooth loss. No studies of tooth-supported fixed prostheses using full- or partial-crown retention or the acid-etch technique were identified. Accordingly, comparison of different treatment methods was not possible. Four studies[13–15,18] on the treatment of single tooth loss using implant-supported single crowns were identified (Table 4).[13–15,18] Three of these studies were prospective in design and reported 5-year treatment outcomes.[13,14,18] The fourth study[15] was retrospective and presented data after 18 years of follow-up of subjects from an earlier prospective study that is also included in this review.[14] After 18 years, it was reported that 5% (3 of 65) of the implant-supported single crowns were infrapositioned in the maxillary esthetic zone,[15] necessitating remake of the crown. Henry et al[13] reported a failure rate of 8% (9 of 107) for implant-supported single crowns because of poor esthetics; however, the authors did not include a description of the rating criteria. Risks and adverse effects were listed as biologic or technical complications (Table 4). Common complications reported by Henry et al[13] were related to either implant components (loosening of abutment screws) or marginal soft tissue infections (fistulae).

Treatment outcomes of patients with partial edentulism. The methods used to rehabilitate patients with partial edentulism included tooth-supported removable partial dentures, tooth-supported fixed partial dentures, and implant-supported fixed partial dentures. None of the studies included tooth-supported overdentures.

Removable partial dentures were evaluated in two randomized controlled trials (RCTs) and one retrospective study, all of low quality (Table 5).[19–21] Although they were designed as RCTs, two of the studies[19,20] were evaluated as prospective cohort studies because the control group was treated with a method no longer available to general practitioners. The survival rate of removable partial dentures after 5 years ranged from 63% to 70%. One retrospective study reported a 10-year survival rate of 71%.[21] Risks and adverse effects are presented in Table 5. The most common adverse effect was loss of supporting teeth (26%), usually due to periodontal disease.[21]

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	▪ Implications of study results not presented or unclear

*Based on the CONSORT[9] and STROBE[10] statements.

Table 4 Single Tooth Loss Treated with an Implant-Supported Single Crown

Study	Study design	Intervention
Henry et al, 1996 (Australia)[13]	Prospective observational multicenter study (7 centers) Setting: specialist practice Consecutive allocation of patients Inclusion period: 1 y (Jan 1987–May 1988) Examination points: 1, 6, 12 mo; annually up to 60 mo Selection criteria: 1 or 2 single-tooth replacements with adjacent natural teeth; natural tooth/partial denture antagonist; healed implant site (≥ 9 mo) Follow-up: 5 y	107 implant-supported single crowns (88 maxillary/19 mandibular) Turned Brånemark implants (two-stage surgery) Standard single-tooth abutments with titanium abutment screw 92 patients (age range: 14–70 y) 47 women 45 men Attrition: 18%
Andersson et al, 1998 (Sweden)[14]	Prospective observational study Setting: specialist practice Consecutive patients Inclusion period: 3 y (1989–1991) Examination points: 2 wk; 1, 3, and 6 mo; 1, 2, 3, and 5 y Selection criteria: single tooth loss in nonmolar sites with adjacent natural teeth Follow-up: 5 y	65 implant-supported single tooth crowns (Cera-One; 62 maxillary/3 mandibular; 62 all-ceramic/3 metal-ceramic) Turned Brånemark implants (two-stage surgery) 57 patients (mean age: 31.9 y [SD: 10.66 y]) 24 women 33 men Attrition: 9%
Vigolo and Givani, 2009 (Italy)[18]	Prospective observational study Setting: private dental office Consecutive patients Inclusion period: 2 y (2000–2002) Selection criteria: single tooth loss in maxillary and mandibular molar regions Follow-up: 5 y	182 implant-supported single molar crowns (42 maxillary left molars with matching wide-diameter prosthetic components, 50 maxillary right molars with platform-switched prosthetic components, 43 mandibular right molars with matching wide-diameter prosthetic components, 47 mandibular left molars with platform-switched prosthetic components) 5-mm-diameter turned 3i implants (two-stage surgery) 144 patients (mean age: 37 y; range: 25–55 y) Attrition: 0%
Bergenblock et al, 2010 (Sweden)[15]	Retrospective observational study Setting: specialist practice Consecutive patients Inclusion period: 3 y (1989–1991) Examination points: 2 wk; 1, 3, and 6 mo; 1, 2, 3, and 5 y Selection criteria: single tooth loss in nonmolar sites with adjacent natural teeth Follow-up: 17–19 y (mean: 18.4 y [SD: 0.9 y])	65 implant-supported single tooth crowns (Cera-One; 62 maxillary/3 mandibular; 62 all-ceramic/3 metal-ceramic) Turned Brånemark implants (two-stage surgery) 57 patients (mean age: 31.9 y [SD: 10.66]) 24 women 33 men Attrition: 9%

SD = standard deviation; CSR = cumulative survival rate.

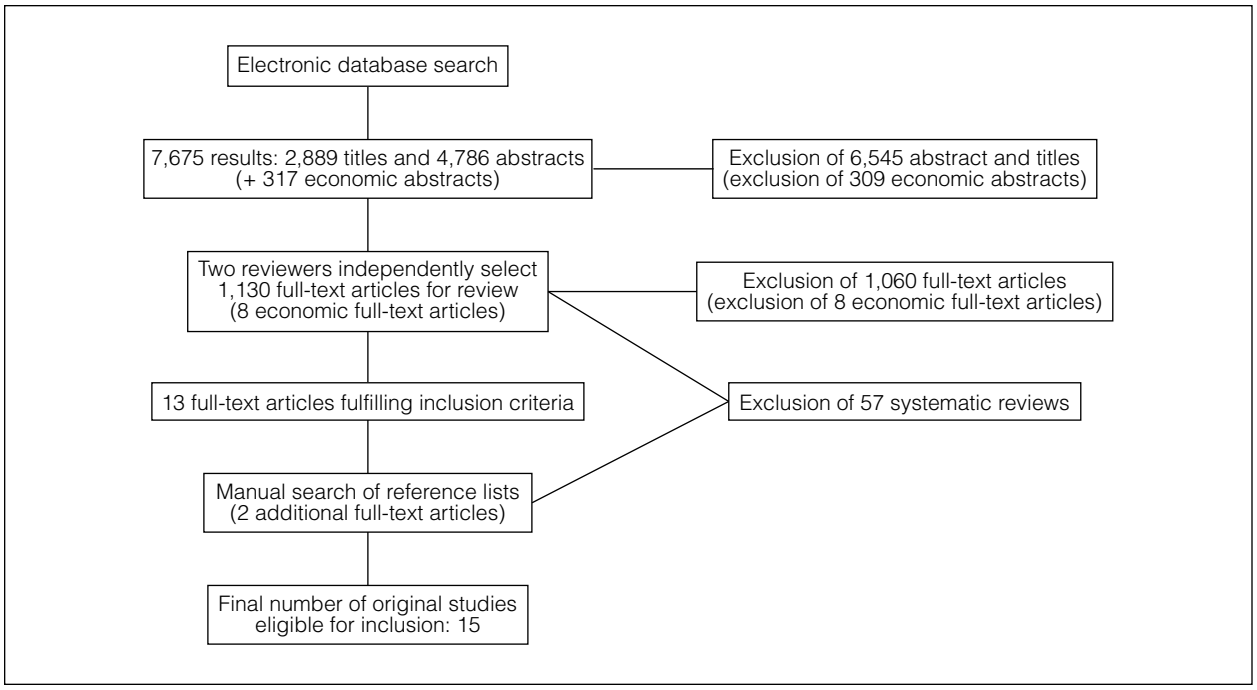

Fig 1 Flowchart of the literature search and retrieval process.

Results and complications	Study quality	Comments
CSR (crowns): 88% (13 remakes) CSR (implants): 98% (96.6% maxillary/100% mandibular) Biologic: implants lost = 3 (2.8%), marginal bone loss (maxillary: mean = 0.17 mm, mesial = 0.18 mm [SD: 0.75 mm], distal = 0.15 mm [SD: 0.74 mm]; mandibular: mean = 0.28 mm, mesial = 0.24 mm [SD: 0.57 mm], distal = 0.31 mm [SD: 0.60 mm]), soft tissue fistulation = 9 patients (9.8%) Technical: crown fracture = 4 (3.7%), esthetic failure = 9 (8.4%), crown/screw retightening = 28 occasions, titanium abutment screw replacement by gold screw = 13 (12%)	Moderate	See Jemt et al[28] and Laney et al[29] for description of sample Survival not reported at patient/crown level Mean age not reported; 6 patients below age of 20 No reliability testing
CSR (crowns): 93.7% CSR (implants): 98.5% Biologic: implants lost = 1, crowns lost = 4, marginal bone loss = 0.1 mm (SD: 0.5 mm) Technical: 1 titanium abutment screw loose after 1 y	Moderate	See Andersson et al[30,31] for description of sample No reliability testing Data reported at implant and crown level but not at patient level 1 patient < 15 y of age
CSR (crowns): 100% CSR (implants): 100% Biologic: implants lost = 0, crowns lost/replaced = 0, marginal bone loss (wide-diameter components [n = 85]) = 1.1 mm (SD: 0.3 mm), marginal bone loss (platform-switched components [n = 97]) = 0.6 mm (SD: 0.2 mm) Technical: none	Low	Confounding factors not reported (eg, smoking, reasons for tooth loss) Statistics (marginal bone loss) evaluated at implant level only and reported as mean values No frequency distribution of bone loss over 5 y
CSR (crowns) = 83.8% CSR (implants) = 96.8% Biologic: implants lost = 2, total crowns lost/replaced = 10, crowns lost due to implant failure = 2, crowns lost due to fistulation = 1, marginal bone loss = 0.2 mm (SD: 0.82 mm) Technical: 1 titanium abutment screw loose after 1 y, crowns lost/replaced due to infraposition = 3, crowns lost/replaced due to porcelain fracture = 3, crowns lost/replaced due to misfit = 2	Moderate	See Andersson et al[14,30,31] for description of sample Reliability testing Radiographic evaluation by blinded observer Data reported at implant and crown levels 1 patient < 15 y of age

Table 5 Treatment of Partial Edentulism with Tooth-Supported Removable Partial Dentures

Study	Study design	Intervention
Kapur, 1989 (USA)[19]	RCT* Setting: 5 VA dental centers** Inclusion period: 4 y (Oct 1977–Oct 1981) Follow-up: 5 y	122 RPDs (59 patients treated with bar design; 59 with circumferential design)*** 118 patients (100% men; mean age: 52 y; range: 25–77 y) Attrition: 18%
Kapur et al, 1994 (USA)[20]	RCT* Setting: 5 VA dental centers** Inclusion period: 4 y (Oct 1977–Oct 1981)** Follow-up: 5 y	59 RPDs (circumferential design) 59 patients (100% men; mean age: 53 y) Attrition: 10%
Wagner and Kern, 2000 (Germany)[21]	Retrospective cohort study Setting: university clinic Inclusion period: 1 y (1987–1988) Follow-up: 10 y	194 RPDs (113 conical crown-retained, 23 clasp-retained, 58 combination of clasp and conical crown retention) 147 patients (44% women; mean age: 55 y) Attrition: 49.7%

RCT = randomized controlled trial; VA = Veteran's Administration; RPD = removable partial denture; NR = not reported.

Remake was necessary in 13% of cases, and relining in 19% to 25%. Caries was more frequently reported in the retrospective study.

There were three retrospective studies of tooth-supported fixed partial dentures, all of low quality (Table 6).[22–24] Follow-up times ranged from 13 to 23 years. A 10-year survival rate of 90% was reported. After 18 to 23 years, survival rates ranged from 76% to 80%. Only 53% of the original superstructures were intact at the end of the follow-up period. In most cases, risks and adverse effects were reported as events and not related to the prostheses or patients. Palmqvist and Swartz[23] reported loss of supporting teeth in 14% of cases, primarily due to progressive periodontal breakdown; loss of end abutment teeth was significantly more frequent than loss of other teeth ($P < .01$). In contrast, Karlsson[22] and Valderhaug[24] reported that caries was the major reason for loosening of fixed prostheses. After 18 to 23 years, 15% of vital supporting teeth had developed endodontic complications.[23]

Three prospective[16,25,26] and two retrospective studies[17,27] assessed treatment outcomes of implant-supported fixed partial dentures (Table 7). Two of the prospective studies were of low quality,[25,26] and one was of moderate quality.[16] Two studies were designed as RCTs, but their aim was to compare different implant surfaces rather than prosthesis survival; therefore, these two studies were classified as prospective cohort studies in this review.[16,25] Two retrospective studies with 10-year follow-up periods were also identified: one of low quality[27] and one of moderate quality.[17] According to life table analysis or mean survival time at follow-up, survival of the implant-supported fixed partial dentures was reported to be 94% to 96% after 5 years and 87% to 94% after 10 years. The risk of implant loss was 3% to 7% at 5 years and 7% at 10 years; most losses occurred early. Common technical complications included functional wear of the veneers and fracture of implant/prosthetic components. Biologic complications, such as marginal bone loss around implants (0.4 to 0.7 mm after 5 to

Results and complications	Study quality	Comments
Prosthesis survival of original RPDs: 70% (including 7 remade RPDs) Loss of abutment teeth: n = 5 (% NR) Biologic: caries = NR, periodontitis = 5 teeth lost, marginal bone loss = NR Technical: fracture of abutments = 0, loss of retention = NR, veneer fracture = NR, fracture of frameworks or technical components = 9% (n = 11) Risks: permanent paresthesia = NR, allergic reactions = NR, severe infections = NR Maintenance: remake of prosthesis: = 12% (n = 15), relining = 19% (n = 23), extra appointments = NR, recementation = NR	Low	*See Kapur et al[32,33] (only one group is covered here) **Significant differences in success between centers ***See Kapur et al[20] No data reported at patient level
Prosthesis survival of original RPDs: 63% (including 5 remade RPDs) Lost abutment teeth: n = 4 (% NR) Biologic: caries = NR, periodontitis = 4 teeth lost, marginal bone loss = 0.0 mm Technical: fractures of abutments = NR, loss of retention = NR, veneer fractures = NR, fracture of framework or technical components = 7% (n = 4) Risks: permanent paresthesia = NR, allergic reactions = NR, severe infections = NR Maintenance: remake of prosthesis = 14% (n = 8), relining = 25% (n = 15), extra appointments = NR, recementation = NR	Low	*Only one group is covered here (attrition in the bar group > 25%); complementary information in Kapur et al[34] **Significant differences in success rates between centers No data reported at patient level
Prosthesis survival of original RPDs: 71% (original state [success]: 43%; modified [partially successful]: 29%; failures [replaced with complete dentures]: 29%) Biologic: caries = 13% (total: 6%) periodontitis = NR, marginal bone loss = NR Technical: fracture of abutments = NR, loss of retention = 18% (n = 13), veneer fractures = 39% (n = 28), fracture of frameworks or technical components = 11% (n = 8) Risks: permanent paresthesia = NR, allergic reactions = NR, severe infections = NR Maintenance: remake of prosthesis = NR, relining = NR, extra appointments = NR, recementation = NR	Low	No results presented at patient level

10 years), were limited. The risk of permanent nerve damage or paraesthesia of the lower lip was reported to be 2.5%.

Evaluation of Evidence

Single tooth loss. The scientific evidence to support a 90% survival rate of implant-supported single crowns after 5 years was of low quality (Table 8). Similarly, only low scientific evidence was available to support the finding that implant survival is close to 100%, and the risk of marginal bone loss (> 2 mm) is less than 5% after 5 years. Finally, the evidence available to assess methods of esthetic evaluation 5 years after treatment was also of low quality. No evidence was available regarding the cost effectiveness of treatment.

Partial edentulism. No further analysis of removable partial dentures or tooth-supported fixed partial dentures was undertaken due to the low quality of evidence found in the included studies. There was low-quality evidence to support survival rates of 94.7% and 89.7% for implant-supported fixed partial dentures after 5 and 10 years of function, respectively. The corresponding survival rates for the implant abutments were 94.9% and 92.8%, respectively (Table 8). The scientific evidence regarding the assessment of risks and adverse effects was of low quality. No study on the economic aspects of treatment fulfilled the inclusion criteria.

Discussion

Systematic reviews used to identify the cumulative evidence on prosthetic treatment methods may be of questionable value to the clinician, depending on the scientific quality of the evidence.[4,5,43–47] The aim of this systematic review was to draw scientifically validated conclusions regarding the 5- and 10-year outcomes of various clinical methods for restoring lost single teeth and partial edentulism. However, such conclusions were limited by the lack of studies with acceptable scientific quality.

Table 6 Treatment of Partial Edentulism with Tooth-Supported Fixed Partial Dentures

Study	Study design	Intervention
Karlsson, 1989 (Sweden)[22]	Retrospective cohort study (register) Setting: unknown number of private practices Inclusion period: 1 y (1974–1975) Follow-up: 13–14 y and 20 y*	164 TFPDs (> 4 units with [26%] and without [74%] extensions) 97 (72*) patients (55% women; mean age: 64 y; range: 54–75 y) Recalled: 41% (57%*)** Eligible: 85% (89%*)**
Palmqvist and Swartz, 1993 (Sweden)[23]	Retrospective cohort study Setting: 1 specialist center Inclusion period: 5 y (1968–1972) Follow-up: 18–23 y	103 TFPDs (> 4 units with gold-resin [67%] or metal-ceramic [31%] prostheses in either arch) 487 abutments (365 vital [75%]) 122 patients (55% women; 29 [24%] younger than 30 y, 43 [35%] older than 49 y) Attrition: 46%
Valderhaug, 1991 (Norway)[24]	Retrospective cohort study Setting: 1 university clinic Inclusion period: 1 y (Sept 1967–June 1968) Follow-up: 15 y	108 TFPDs (gold-acryilic resin; 89 maxillary/19 mandibular) 343 abutment teeth 102 patients (72% women; mean age: 48 y; range: 25–69) Attrition: 46% (30% after 10 y)

TFPD = tooth-supported fixed partial denture; CSR = cumulative survival rate; NR = not reported.

A systematic review requires expert knowledge not only of the research question being addressed, but also of statistics, methodology, study design, and science in general. These requirements were taken into account when establishing the research group, which comprised authors with specific scientific and/or clinical knowledge. In an attempt to maintain an objective approach to the research questions, the sequence of steps involved in this review was thoroughly planned, and the opinions of all members of the study group were calibrated via repetitive and comprehensive discussions regarding inclusion/exclusion criteria and quality appraisal. The inclusion/exclusion criteria were therefore clearly defined before the search to allow proper grading of the immense number of titles retrieved and to minimize the reviewers' preconceptions, which may otherwise influence the assessment. Other measures taken to avoid bias included a restriction on authors evaluating studies from their own research group and the decision to work in assessment teams, which guaranteed that all studies were read and evaluated by two separate assessors.

A systematic review can be regarded as a tool for condensing enormous amounts of information and transforming this information into accepted knowledge. As the amount of information stored in databases such as PubMed or Embase continues to increase, it becomes practically impossible for one individual to survey every study on a given topic. Therefore, the systematic review will become even more common over time.

Thorough scrutiny of all studies included in a systematic review is essential for proper evaluation of the results. This requires specific methodologic skills. If all systematic reviews graded their conclusions in terms of the quality of scientific evidence, the results could be more readily applied in a clinical context.[45]

Several systematic reviews of prosthetic treatment methods have been carried out, but none met the

	Results and complications	Study quality	Comments
	CSR (TFPDs): 80% (14 y),* 65% (20 y)* Loss of abutment teeth: NR Biologic (causing prosthesis failure): caries = 9%, periodontitis = 2%, endodontic = 1%, marginal bone loss = NR Technical: fractures of abutments = NR, loss of retention = 9% (caries), veneer fractures = NR, fracture of frameworks or technical components = 1% Risks: permanent paresthesia = NR, allergic reactions = NR, severe infections = NR Maintenance: remake of prosthesis = NR, relining = NR, extra appointments = NR, recementation = NR	Low	High no. of patients lost to study in relation to eligible numbers of patients (n = 642) *See Lindquist and Karlsson[35] for complementary information **Register study: no attrition, no baseline data
	Prosthesis survival of original TFPDs: 77% (original/unchanged = 53%, repaired = 10%, partly remaining = 12%, failed = 23% [3% metal-ceramic/33% gold-resin; $P < .01$]) Loss of abutment teeth: 14% (n = 67) (vital/nonvital = 10%/24%, $P < .001$; terminal/intermediate: 13%/6%, $P < .01$) Biologic: caries = 2% (n = 10 abutment teeth requiring extraction), periodontitis = 6% (n = 28 abutment teeth requiring extraction), endodontic problems = 15% (n = 49 loss of vitality), marginal bone loss = NR Technical: fracture of abutments = 2% (n = 9 abutment teeth requiring extraction), loss of retention = 6% (n = 6), veneer fracture = NR, fracture of framework or technical components = 3% (n = 3) Risks: permanent paresthesia = NR, allergic reactions = NR, severe infections = NR Maintenance: remakes of prostheses = NR, relining = NR, extra appointments = NR, recementation = NR	Low	Cluster patterns for abutment loss were noted See Palmqvist et al[36] for complementary information Inclusion criteria unclear (some single crown patients?)
	Prosthesis survival of original TFPDs: 76% (90% after 10 y) Failure rates: 0–5 y = 4%; 5–10 y = 7%; 10–15 y = 14% Loss of abutment teeth: NR Biologic (leading to prosthesis failure): caries = 5% (n = 5 prostheses), periodontitis = 2% (n = 2 prostheses), endodontic = NR, marginal bone loss = NR Technical (leading to prosthesis failure): fracture of abutments = 3% (n = 3 prostheses), loss of retention = 7% (n = 7 prostheses), fracture of framework or technical components = 1% (n = 1 prosthesis) Risks: permanent paresthesia = NR, allergic reactions = NR, severe infections = NR Maintenance: remake of prosthesis = NR; relining = NR, extra appointments = NR, recementation = NR	Low	No data at patient level See Valderhaug et al[37–39] for complementary information

inclusion criteria for the present review, mainly because of its stringent inclusion and exclusion criteria. The results of this literature search, which yielded only 15 original studies deemed eligible for inclusion, are open to debate. It could be argued that the inclusion criteria were unreasonably stringent, showed a lack of understanding regarding the problems associated with clinical research, or were even degrading to odontologic research as a whole. The authors' response is that the results are legitimate; the research questions are highly relevant, and grading the level of scientific evidence is not intended to discount the contribution of previous research to the body of knowledge.

When grading scientific evidence, RCTs are often regarded as the gold standard. In contrast, retrospective studies are considered to have lower scientific value. However, a high-quality study design does not necessarily guarantee high-quality evidence.[48] An RCT can be carelessly conducted, leading to false conclusions (or no conclusions), while a well-conducted retrospective study can shed light on research questions that are difficult to measure in an RCT. The authors expected to find that a considerable number of prosthetic studies were retrospective in design, and this was taken into consideration when formulating the inclusion criteria. The goal was to embrace the literature of prosthetic research while maintaining scientific quality in the systematic review. The results of this literature search demonstrate that if the aim of prosthetic research is to provide the profession with new scientific knowledge in the area of prosthetic treatment, future clinical studies should be based on a more distinct study methodology that permits validated conclusions. Thus, to ensure studies of high clinical and scientific value, future research should require closer collaboration between clinicians and scientists.

It should be noted that the included publications with the highest study quality (moderate) were related to more recent treatment techniques, such as

Table 7 Treatment of Partial Edentulism with Implant-Supported Fixed Partial Dentures

Study	Study design	Intervention
Gotfredsen and Karlsson, 2001 (Denmark)[25]	Prospective multicenter (n = 6) cohort study* Inclusion period: 3 y (Nov 1990–Sept 1993) Follow-up: 5 y	52 freestanding IFPDs (17 maxillary/35 mandibular) 133 AstraTech implants (TiO_2: 64; turned: 64; regular surface/not accounted for: 5; two-stage surgery) 50 patients (50% women; mean age: 53 y) Attrition: 10%
Lekholm et al, 1994 (Sweden)[26]	Prospective multicenter (n = 9) cohort study Inclusion period: 2 y (July 1985–April 1987) Follow-up: 5 y	197 Freestanding IFPDs (68 mandibular/91 maxillary; gold–acrylic resin) 558 turned Brånemark implants (two-stage surgery) 159 patients (92 [58%] women; age range: 18–70 y) Attrition: 17%
Wennström et al, 2004 (Sweden)[16]	Prospective cohort study* Setting: 1 specialist center Inclusion period: 3 y Follow-up: 5 y	56 freestanding IFPDs (ceramic occlusal surface) 149 Astra Tech implants (TiO-blasted: 75; turned: 73; two-stage surgery) 51 patients (31 [61%] women; mean age: 60 y; range: 36–80 y) Attrition: 7.8%
Lekholm et al, 1999 (Sweden)[27]	Retrospective multicenter (n = 6) cohort study Inclusion period: 2 y (July 1985–April 1987) Follow-up: 10 y	163 freestanding IFPDs (65 maxillary/98 mandibular; gold–acrylic resin) 461 turned Brånemark implants (two-stage surgery) 127 patients (73 [57%] women; mean age: 50 y; range: 18–70 y) Attrition: 30%
Örtorp and Jemt, 2008 (Sweden)[17]	Retrospective cohort study Setting: 1 specialist center Inclusion period: 3 y (Nov 1990–11–Sept 1993) Follow-up: 10 y	120 freestanding IFPDs (all mandibular) Test: 60 laser-welded FPDs with titanium frameworks (49 veneered with low-fusing porcelain; 11 veneered with acrylic resin/composite resin teeth) Control: 60 cast gold alloy FPDs (8 with resin-veneered teeth; 52 with ceramic-veneered teeth) 351 turned Brånemark implants (174 titanium/177 gold; two-stage surgery) 104 patients (52 test [mean age: 58 y; range: 28–77 y]/52 control [mean age: 59 y; range: 27–78 y]) 63 women (30 test/33 control), 41 men (22 test/19 control) Attrition: 33.7%

IFPD = implant-supported fixed partial denture; NR = not reported; RCT = randomized controlled trial; CSR = cumulative survival rate; BoP= bleeding on probing.

implant treatment. The average 5- to 10-year survival rates of implant-supported fixed partial dentures were 95% and 90%, respectively. For mucosal and tooth-supported designs, which have a longer history of clinical use, the review failed to identify any studies offering evidence-based conclusions. However, the clinical data indicate a slightly lower survival rate for these treatment options (see Tables 5 and 6).

The review identified no studies of sufficient quality on the economic aspects of treatment. Further, there are very few studies of health economics in the field of dentistry. The more cost-effective treatment

Results and complications	Study quality	Comments
Prosthesis survival of original IFPDs: 96.1% (2/52) Loss of implant abutments: 2.3% (3 turned implants) Biologic: peri-implantitis = 6% for both implant groups, marginal bone loss = 0.5 mm (TiO_2) and 0.2 mm (turned), marginal bone loss > 2.4 mm = 3.1% (n = 2) TiO_2, 0% turned. Technical: fracture of implants = 0, fracture of retention components = 2, veneer fractures = 2, fracture of framework = 0 Risks: permanent paresthesia = 2.9% (1/35 mandibles), allergic reactions = NR, severe infections = NR Maintenance: remake of prosthesis = 3.9% (n = 2), relining = NR, extra appointments = NR, loss of retention = 17	Low	*RCT of implants, not primary endpoint Results not reported at patient level Marginal bone loss measured first from prosthesis attachment
CSR (original IFPDs): 94.3% (94.4% maxillary/94.1% mandibular) Loss of implant abutments: 6.7% (CSR: 92.0% maxillary/94.1% mandibular) Biologic: peri-implantitis = 0.1/0.1** (mean), marginal bone loss = 0.5 mm (mandibular) and 0.8 mm (maxillary) Technical***: fracture of implants = 0.4% (n = 2), fracture of retention components = 0.9% (n = 5), veneer fracture = 22 occasions, fracture of framework = 0 Risks***: permanent paresthesia = 2.2% (2 mandibles at 5 y), allergic reactions = NR, severe infections = NR Maintenance***: remake of prostheses = NR, relining = NR, extra appointments = NR, loss of retention = 7 occasions	Low	*See van Steenberghe et al[40] and Lekholm et al[27] **See Mühlemann and Son[41] ***Reported for 4th and 5th year only Results presented at prosthesis/implant levels, not at patient level Radiographic baseline at stage-two surgery
Prosthesis survival of original IFPDs: 94.7% IFPDs failed: 3/56 (5.3%); at subject level: 5.9% Loss of implant abutments: 2.7% (4/149) Biologic: BoP = 5% of surfaces, marginal bone loss = 0.4 mm (TiO-blasted = 0.5 mm, turned = 0.3 mm**), marginal bone loss > 2.0 mm = 10% (n = 15) Technical: fracture of implants = 2% (n = 3), fracture of retention components = NR, veneer fracture = 2% (n = 3), fracture of framework = 0 Risks: permanent paresthesia = NR, allergic reactions = NR, severe infections = NR Maintenance: remake of prosthesis = NR, relining = NR, extra appointments = NR, loss of retention = 2% (n = 3)	Moderate	*RCT of implants, not primary endpoint **Significant difference ($P > .05$) No information on paresthesia Radiographic baseline at prosthesis placement
CSR (original IFPDs): 86.5%; IFPDs replaced: 7.4%; continuous prosthesis function: 94.3% Loss of implant abutments: 7.4% (9.8% maxillary/6.3% mandibular) Biologic: BoP = 9% of implant sites, marginal bone loss = 0.7 mm for both arches, marginal bone loss > 2.0 mm = 7% Technical: fracture of implants = 2.7% (3 patients), fracture of retention components = 2.7% (3 patients), veneer fracture = 5.5% (7 patients), fracture of framework = 0 Risks: permanent paresthesia = 2.8% (2/71 mandibles), allergic reactions = NR, severe infections = NR Maintenance: remake of prosthesis = 7.4%, relining = NR, extra appointments = 14.2% (18 patients), loss of retention = 3.9% (5 patients)	Low	No report on reliability and deviation in radiographic readings Complications reported during the last 5 y only Results reported at prosthesis and implant levels, not at patient level
CSR (original IFPDs): 93.7%; CSR (test): 88.4%; CSR (control): 100% Loss of implant abutments: 7.0% (CSR [test]: 8.5%; CSR [control]: 5.3%)* Biologic: peri-implantis = 8 (test) and 11 (control) occasions, marginal bone loss = 0.5 mm (test) and 0.7 mm (control), marginal bone loss > 2.4 mm = 2%** Technical: fracture of implants = 0, fracture of retention components = 3 (test) and 4 (control) occurrences, veneer fracture = 26 (test) and 4 (control) occurrences,*** fracture of framework = 0 Risks: permanent paraesthesia = NR, allergic reactions = NR, severe infections = NR Maintenance: no event (prosthesis) = 50% (test) and 32% (control), remake of prosthesis = NR, relining = NR, extra appointments = NR, loss of retention = 7 (test) and 7 (control) occurrences	Moderate	See Örtorp and Jemt[42] for description of sample *Significantly more implants lost after loading in test group (at implant and patient levels) **Significantly more marginal bone loss over 10 y in control group (at patient level) ***Significantly more veneer chipping in test group

of two or more options is the one that provides additional health benefits at an acceptable cost.[11] Given comparable clinical effectiveness (such as survival time and quality of the prostheses), the most cost-effective treatment would be the one with the lowest cost. Because treatment of single tooth loss and partial edentulism is costly and of high priority for patients, there is a need for health economic data to guide patients and clinicians during the decision-making process. When there is a lack of empirical evidence, decision analysis modeling is a potential means of providing such information.

Table 8 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	Quality
Primary outcome (prosthesis survival rate)				
ISC, original	149 (2)	91% (88%–94%)	90	Low
IFPD (5 y)	260 (3)	94.7% (94%–96%)	53	Low
IFPD (10 y)	231 (2)	89.7% (86%–94%)	103	Low
Secondary outcome (implant survival rate)				
ISC, original	149 (2)	98.5% (98%–99%)	15	Low
ISC (bone loss: > 2 mm)	149 (2)	4.5% (2%–7%)	45	Low
IFPD (5 y)	260 (3)	94.9% (93%–98%)	51	Low
IFPD (10 y)	231 (2)	92.8% (92%–93%)	72	Low

ISC = implant-supported single crown restoration; IFPD = implant-supported fixed partial denture.

Conclusion

Due to the low scientific evidence of the included studies, it was not possible to compare various treatment methods used for rehabilitation of single tooth loss or partial edentulism.

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