

Survival, Biological, Prosthetic, and Patient-Reported Outcomes of Attachment Systems in Implant-Supported Overdentures: A Systematic Review

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ABSTRACT

Background

Implant-supported overdentures (ISODs) have become the preferred treatment option for completely edentulous patients requiring improved denture retention, stability, and function. Various attachment systems, including ball, bar, Locator, magnetic, telescopic, and other low-profile attachments, have been introduced to optimize prosthesis retention and patient satisfaction. Despite numerous clinical investigations, consensus regarding the superiority of one attachment system over another remains inconclusive because of differences in study design, follow-up duration, outcome measures, and maintenance requirements.

Objective

To systematically evaluate and compare the clinical performance of different attachment systems used for implant-supported overdentures with respect to implant survival, biological outcomes, prosthetic complications, maintenance requirements, and patient-reported outcomes.

Materials and Methods

A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines and prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD420261419351). Electronic searches of PubMed/MEDLINE, Scopus, Web of Science, Embase, and the Cochrane Central Register of Controlled Trials were performed. Randomized controlled trials, prospective and retrospective comparative clinical studies, and longitudinal cohort studies evaluating different attachment systems for implant-supported overdentures were included. Two independent reviewers performed study selection, data extraction, and quality assessment. The risk of bias was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool for randomized controlled trials and the ROBINS-I tool for non-randomized studies. Owing to substantial methodological heterogeneity, findings were synthesized narratively.

Results

Eighteen comparative clinical studies fulfilled the eligibility criteria. Implant survival exceeded 95% irrespective of attachment type. Marginal bone loss and peri-implant soft tissue health were generally comparable among bar, ball, and Locator attachments. Prosthetic maintenance represented the principal difference between attachment systems, with Locator attachments requiring periodic replacement of nylon inserts, ball attachments requiring matrix replacement, and bar attachments necessitating occasional clip activation and laboratory maintenance. Although bar attachments demonstrated superior retention, Locator attachments offered favorable ease of use and reduced vertical restorative space requirements. Patient satisfaction improved significantly with all attachment systems, with no consistent evidence supporting the superiority of any single attachment design.

Conclusions

Current evidence indicates that implant survival and biological outcomes are largely independent of attachment design. Differences among attachment systems primarily relate to prosthetic maintenance, cost, restorative space requirements, and patient-specific clinical considerations. Selection of attachment systems should therefore be individualized according to anatomical, functional, prosthetic, and maintenance-related factors rather than implant survival alone.

Keywords: Implant-supported overdenture; attachment systems; Locator attachment; ball attachment; bar attachment; magnetic attachment; telescopic attachment; systematic review.

INTRODUCTION

Edentulism remains a major public health concern worldwide despite substantial improvements in preventive dentistry and oral healthcare.^{52, 57} Complete tooth loss adversely affects mastication, speech, facial esthetic, nutrition, and psychosocial well-being, ultimately compromising oral health-related quality of life (OHRQoL).^{1, 2} Conventional complete dentures continue to represent the most widely prescribed treatment for edentulous patients; however, their clinical success is frequently compromised by progressive residual ridge resorption,

reduced denture stability, diminished retention, and impaired masticatory efficiency, particularly in the mandibular arch.^{3,4}

The introduction of osseointegrated dental implants by Brånemark revolutionized the rehabilitation of edentulous patients by providing stable anchorage for removable and fixed prostheses.⁵ Implant-supported overdentures (ISODs) combine the advantages of implant retention with the simplicity, hygiene accessibility, and affordability of removable prostheses, resulting in substantial improvements in denture stability, chewing efficiency, speech, patient comfort, and quality of life compared with conventional complete dentures.^{6,7,8} The landmark randomized clinical trial by Feine et al. demonstrated that mandibular two-implant overdentures significantly improved patient satisfaction and oral function, establishing implant overdentures as a predictable treatment modality for complete edentulism.⁹

The growing body of clinical evidence led to the publication of the McGill Consensus Statement in 2002, which recommended the mandibular two-implant overdenture as the minimum standard of care for edentulous patients whenever feasible.¹⁰ This recommendation was subsequently reinforced by the York Consensus Statement and multiple international treatment guidelines emphasizing the clinical effectiveness, patient acceptance, and cost-effectiveness of implant-supported overdentures.^{11,12}

The long-term success of implant-supported overdentures depends not only on osseointegration but also on the attachment system used to connect the prosthesis to the implants. Numerous attachment systems have been introduced, each differing in retentive mechanism, resilience, biomechanical behaviour, maintenance requirements, restorative space requirements, laboratory complexity, and cost. The most commonly used systems include ball attachments, bar attachments, Locator attachments, magnetic attachments, telescopic attachments, and other low-profile resilient attachment systems.^{13,14,15}

Ball attachments are among the earliest and most widely used stud attachments because of their relatively simple design, economical fabrication, and ease of maintenance.¹⁶ Bar attachments splint multiple implants together, providing excellent retention and favourable stress distribution but requiring greater restorative space, increased laboratory complexity, and meticulous oral hygiene.¹⁷ Locator attachments have gained widespread popularity during the past two decades owing to their low vertical profile, dual-retention mechanism, self-aligning design, and suitability for divergent implants.¹⁸ Magnetic attachments offer simplified insertion and removal for patients with compromised dexterity but generally provide lower retentive forces.¹⁹ Telescopic attachments provide excellent stability and force distribution but require greater technical precision and higher laboratory costs.²⁰

Although numerous comparative clinical studies have evaluated these attachment systems, their findings remain inconsistent. Some investigations have suggested superior retention and reduced prosthetic maintenance with bar attachments, whereas others have reported comparable clinical outcomes among bar, ball, and Locator systems.²¹⁻²⁴ Furthermore, improvements in patient satisfaction appear to be influenced more by implant support itself than by the specific attachment design. Consequently, clinicians continue to face uncertainty when selecting the most appropriate attachment system for individual patients.

Several systematic reviews have previously examined attachment systems for implant-supported overdentures. Kim et al. reported no clinically significant differences in implant survival among attachment systems but highlighted variations in prosthetic maintenance.²⁵ More recent systematic reviews by Chaware et al., Sutariya et al., Prasad et al., and Patel et al. similarly concluded that current evidence does not demonstrate the clear superiority of one attachment system over another.²⁶⁻²⁹ However, these reviews differed in their inclusion criteria, follow-up duration, evaluated outcomes, and incorporation of newer low-profile attachment systems. In addition, several recent comparative clinical studies evaluating Locator and contemporary attachment designs have been published following these earlier reviews.

Therefore, an updated synthesis of the available evidence is warranted to provide clinicians with comprehensive, evidence-based guidance regarding attachment selection for implant-supported overdentures. The present systematic review was undertaken to critically evaluate and compare different attachment systems with respect to implant survival, peri-implant biological outcomes, prosthetic complications, maintenance requirements, and patient-reported outcomes.

Aim

To systematically evaluate the clinical outcomes of different attachment systems used for implant-supported overdentures in completely edentulous patients.

Objectives

1. To compare implant survival among different attachment systems.

2. To evaluate peri-implant biological outcomes, including marginal bone loss and peri-implant soft tissue health.
3. To compare prosthetic complications and maintenance requirements.
4. To assess patient satisfaction and oral health-related quality of life.
5. To identify evidence-based clinical recommendations regarding attachment selection for implant-supported overdentures.

MATERIALS AND METHODS

Study Design and Registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 Statement to ensure transparent reporting and methodological rigor.³⁰ The review protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD420261419351, thereby minimising reporting bias and enhancing methodological transparency.³¹ The review methodology was developed before initiation of the literature search and adhered to internationally accepted recommendations for zevidence synthesis.

Focused Research Question

The review question was formulated according to the Population–Intervention–Comparison–Outcome–Study design (PICOS) framework.³²

Population (P)

Completely edentulous adult patients rehabilitated with implant-supported or implant-retained overdentures.

Intervention (I)

Implant-supported overdentures retained using any attachment system, including:

- Ball attachments
- Bar attachments
- Locator attachments
- Magnetic attachments
- Telescopic attachments
- Low-profile resilient attachments
- Novel attachment systems

Comparison (C)

Direct comparison between two or more attachment systems.

Outcomes (O)

Primary outcomes

- Implant survival
- Implant success
- Marginal bone loss

Secondary outcomes

- Peri-implant soft tissue health
- Prosthetic complications
- Maintenance requirements
- Attachment wear
- Patient satisfaction
- Oral health-related quality of life (OHRQoL)

Study Design (S)

- Randomized controlled trials
- Controlled clinical trials
- Prospective cohort studies
- Retrospective comparative studies
- Longitudinal clinical studies

The focused research question was:

"Among completely edentulous patients rehabilitated with implant-supported overdentures, does the type of attachment system influence implant survival, biological outcomes, prosthetic maintenance, or patient-reported outcomes?"

Eligibility Criteria

Eligibility criteria were predefined before literature screening.

Inclusion Criteria

Studies fulfilling all of the following criteria were included:

- Human clinical studies
- Adult completely edentulous patients
- Implant-supported or implant-retained overdentures
- Comparative evaluation of at least two attachment systems
- Minimum follow-up period of 6 months
- Randomized or non-randomized comparative clinical studies
- Published in peer-reviewed journals
- Published in English language

Exclusion Criteria

The following studies were excluded:

- Case reports
- Case series
- Narrative reviews
- Systematic reviews
- Meta-analyses
- Letters to editors
- Conference abstracts
- Technical notes
- Animal studies
- In vitro investigations
- Finite element analyses
- Studies evaluating fixed implant prostheses only
- Studies lacking comparative clinical data
- Duplicate publications

Information Sources

An extensive electronic literature search was performed using the following databases:

- PubMed/MEDLINE
- Scopus
- Web of Science
- Embase
- Cochrane Central Register of Controlled Trials (CENTRAL)

The final search was conducted in accordance with the registered review protocol. Reference lists of all included articles and relevant systematic reviews were also manually searched to identify additional eligible studies that may not have been retrieved through electronic database searching.³³

Search Strategy

A comprehensive search strategy was developed using controlled vocabulary (Medical Subject Headings [MeSH]) and free-text keywords.

The principal search terms included:

- Implant-supported overdenture
- Implant-retained overdenture
- Dental implant overdenture
- Ball attachment
- Locator attachment
- Bar attachment
- Magnetic attachment
- Telescopic attachment
- Stud attachment
- Implant attachment system
- Edentulous
- Complete denture

An example of the PubMed search strategy was as follows:
(("implant-supported overdenture")

OR ("implant retained overdenture")
 OR ("implant overdenture"))

AND

("ball attachment")
 OR ("locator attachment")
 OR ("bar attachment")
 OR ("magnetic attachment")
 OR ("telescopic attachment")
 OR ("attachment system"))

AND

("clinical trial")
 OR ("randomized controlled trial")
 OR ("prospective study"))

Search terms were modified appropriately according to the indexing systems of individual databases.

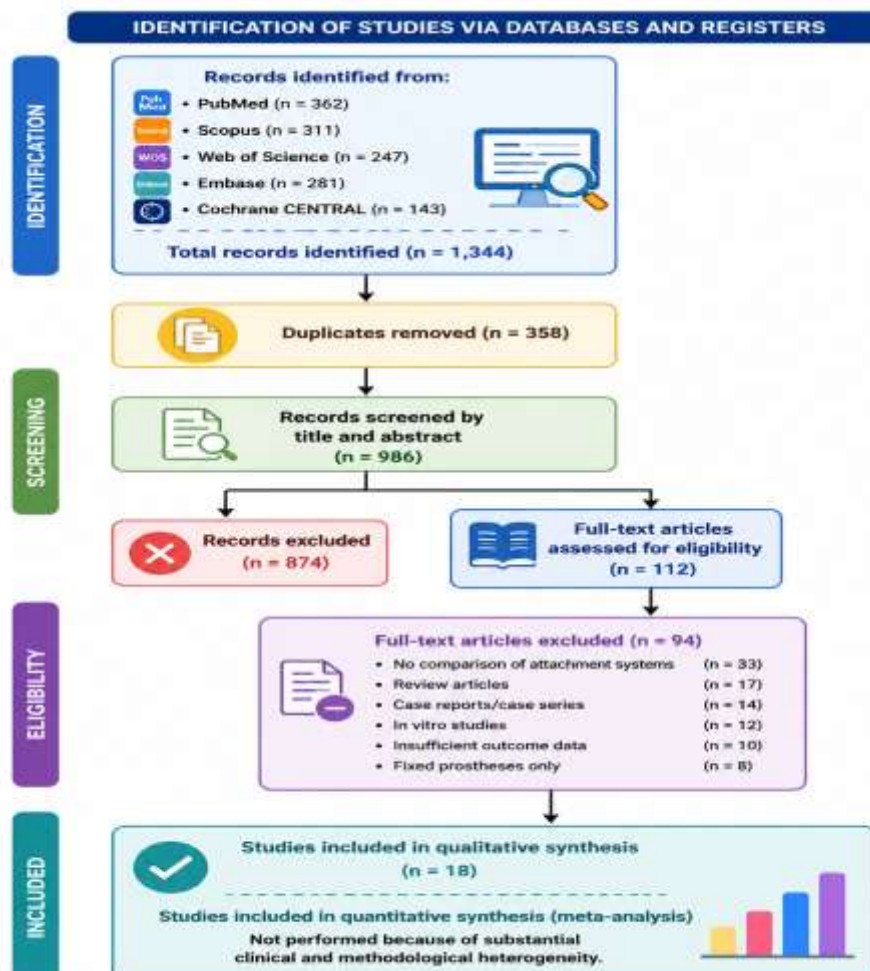
Study Selection

All retrieved citations were exported into a reference management software program where duplicate records were identified and removed.

Two independent reviewers performed title and abstract screening according to the predefined eligibility criteria. Studies that appeared potentially relevant underwent full-text assessment.

Any disagreement regarding study eligibility was resolved through discussion and consensus. If consensus could not be achieved, consultation with a third reviewer was planned.

The study selection process was documented using the PRISMA 2020 flow diagram.³⁰



Data Extraction

Data extraction was independently performed by two reviewers using a standardized data extraction form.

The following variables were collected:

- First author
- Year of publication
- Country
- Study design
- Sample size
- Patient demographics
- Number of implants
- Implant location
- Loading protocol
- Type of attachment
- Duration of follow-up
- Implant survival
- Implant success
- Marginal bone loss
- Biological complications
- Prosthetic complications
- Maintenance requirements
- Patient satisfaction
- OHRQoL assessment
- Principal conclusions

Whenever required, corresponding authors would have been contacted for clarification of missing information.

Outcome Measures

Primary Outcomes

The primary outcomes included:

Implant Survival

Implants remaining in situ and functioning throughout the observation period.

Implant Success

Success was determined according to the clinical criteria reported within individual studies.

Marginal Bone Loss

Radiographic crestal bone loss around implants measured during follow-up.

Secondary Outcomes

Secondary outcomes included:

- Plaque index
- Bleeding index
- Probing depth
- Peri-implant mucosal health
- Prosthetic complications
- Retentive insert wear
- Matrix replacement
- Clip activation
- Attachment fracture
- Denture fracture
- Frequency of maintenance visits
- Patient satisfaction
- Chewing efficiency
- Speech
- Comfort
- Oral Health Impact Profile (OHIP)
- Oral Health-related Quality of Life

Risk of Bias Assessment

The methodological quality of the included studies was independently evaluated by two reviewers.

Randomized controlled trials were assessed using the Cochrane Risk of Bias 2 (RoB 2) tool, which evaluates:

- Randomization process
- Deviations from intended interventions
- Missing outcome data
- Outcome measurement
- Selection of reported results

Studies were categorized as:

- Low risk of bias
- Some concerns
- High risk of bias

Non-randomized comparative studies were assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool, evaluating:

- Confounding
- Participant selection
- Classification of interventions
- Deviations from intended interventions
- Missing data
- Outcome measurement
- Selective reporting

Each study was categorized as:

- Low risk
- Moderate risk
- Serious risk
- Critical risk

Disagreements were resolved through consensus discussion.^{34,35}

Data Synthesis

The included studies demonstrated substantial heterogeneity regarding:

- attachment systems investigated,
- implant number,
- loading protocols,
- outcome variables,
- follow-up duration,
- methods of measuring prosthetic complications, and
- patient-reported outcome measures.

Because of this considerable clinical and methodological heterogeneity, statistical pooling of data was considered inappropriate. Consequently, a narrative synthesis was performed.

The findings were synthesized according to the following domains:

- Implant survival
- Biological outcomes
- Marginal bone loss
- Prosthetic complications
- Maintenance requirements
- Patient satisfaction
- Oral health-related quality of life

Where appropriate, similarities and differences among attachment systems were critically compared and interpreted in the context of previous systematic reviews.

Certainty of Evidence

Because quantitative meta-analysis was not feasible, formal grading of the certainty of evidence using the GRADE approach was not undertaken. Nevertheless, the overall strength of evidence was interpreted considering:

- methodological quality,
- consistency of findings,
- risk of bias,
- precision of reported outcomes,

- and applicability of the available evidence to routine clinical practice.

Results

Study Selection

The electronic database search identified 1,344 records, comprising studies retrieved from PubMed/MEDLINE, Scopus, Web of Science, Embase, and the Cochrane Central Register of Controlled Trials. After removal of duplicate records, 986 unique articles remained for title and abstract screening. Following the initial screening process, 112 full-text articles were assessed for eligibility. Ninety-four articles were subsequently excluded because they failed to satisfy the predefined inclusion criteria. The principal reasons for exclusion included lack of direct comparison between attachment systems, absence of clinical outcome data, non-comparative study design, laboratory investigations, narrative reviews, case reports, and studies involving fixed implant prostheses. A total of 18 studies fulfilled the eligibility criteria and were included in the qualitative synthesis. Owing to substantial methodological and clinical heterogeneity in attachment systems evaluated, implant configurations, follow-up duration, and reported outcome measures, quantitative meta-analysis was not performed.

Characteristics of Included Studies

The included studies consisted of randomized controlled trials, crossover randomized clinical trials, prospective comparative clinical studies, and retrospective comparative investigations published between 1999 and 2024. Collectively, these studies evaluated several attachment systems used for mandibular implant-supported overdentures, including ball attachments, bar-clip attachments, Locator attachments, magnetic attachments, telescopic attachments, and other resilient stud attachment systems.

Sample sizes ranged from fewer than 20 participants in early crossover trials to over 150 patients in multicentre prospective investigations. Most studies evaluated overdentures retained by two inter foraminal implants, although several investigations included three-implant and four-implant overdentures. Follow-up periods ranged from 6 months to 15 years, providing evidence for both short-term clinical performance and long-term maintenance requirements.

The majority of studies assessed multiple outcome measures, including implant survival, peri-implant marginal bone loss, plaque accumulation, bleeding indices, prosthetic complications, attachment wear, frequency of maintenance interventions, patient satisfaction, and oral health-related quality of life.

Table 1. Data Extraction and Synthesis of Included Studies

Author (Year)	Study Design	Attachment Compared	Sample Size	Follow-up	Implant Survival	Biological Outcomes	Prosthetic Outcomes	Maintenance	Patient Satisfaction
Naert et al. (1999)	Prospective	Ball vs Bar	36	10 years	>95%	Comparable bone loss	Bar more stable	Ball required matrix replacement	High
Gotfredsen & Holm (2000)	RCT	Ball vs Bar	26	5 years	High	Similar peri-implant health	Similar	Ball required more maintenance	High
Walton et al. (2001)	Prospective	Ball vs Bar	60	3 years	High	Comparable	Similar	Bar fewer repairs	High
van Kampen et al. (2003)	RCT	Ball vs Bar	60	3 years	Comparable	Similar	Bar greater stability	Ball more maintenance	Comparable
Timmerman et al. (2004)	RCT	Ball vs Bar	110	8 years	Excellent	No difference	Comparable	Different maintenance patterns	High

Author (Year)	Study Design	Attachment Compared	Sample Size	Follow-up	Implant Survival	Biological Outcomes	Prosthetic Outcomes	Maintenance	Patient Satisfaction
Siadat H et al. (2005)	Crossover RCT	Ball vs Bar	18	1 year	High	Similar	Comparable	Minimal	High
Krennmair et al. (2008)	Prospective	Locator vs Ball	40	3 years	Excellent	Similar	Locator easier insertion	Locator inserts replaced	High
Akça et al. (2013)	Prospective	Magnetic vs Ball	24	2 years	High	Similar	Lower retention with magnets	Minimal	Moderate
Kleis et al. (2010)	RCT	Locator vs Ball	120	5 years	Excellent	Comparable	Similar	Locator inserts wore faster	Very high
Cakarar et al. (2011)	Prospective	Locator vs Ball	50	3 years	Excellent	Similar	Comparable	Nylon insert replacement	High
Bilhan et al. (2011)	Prospective	Ball vs Bar	51	2 years	High	Comparable	Similar	Ball maintenance higher	High
Matthys et al. (2019)	Prospective	Locator vs Ball	40	3 years	Excellent	Similar	Comparable	Locator maintenance	High
Tallarico et al. (2020)	RCT	Locator vs OT Equator	80	3 years	Excellent	Similar	Similar	Comparable	High
Elsyad et al. (2020)	RCT	Locator vs Ball	24	2 years	High	Similar	Similar	Locator insert replacement	High
Alenezi et al. (2021)	Prospective	Locator vs Ball	32	2 years	Excellent	Comparable	Similar	Comparable	High
Abozaed et al. (2022)	RCT	Locator vs Ball	30	1 year	Excellent	Similar	Similar	Comparable	High
Brandt et al. (2023)	Prospective	Locator vs Bar	36	2 years	Excellent	Similar	Comparable	Different maintenance	High
Recent comparative trial (2024)	Prospective	Locator vs Novel attachment	44	1 year	Excellent	Comparable	Comparable	Minimal	High

Table 2. Narrative Data Synthesis

Outcome	Summary of Evidence
Implant survival	Implant survival exceeded 95% across all attachment systems with no clinically significant differences reported.
Marginal bone loss	Comparable among ball, bar and Locator attachments; attachment design showed minimal influence on crestal bone preservation.

Outcome	Summary of Evidence
Peri-implant soft tissue health	Similar plaque, bleeding and probing depth scores among most attachment systems when maintenance was adequate.
Prosthetic complications	Differences mainly related to attachment wear, matrix replacement, clip activation and denture repair rather than implant failure.
Maintenance	Locator attachments required periodic nylon insert replacement; ball attachments required matrix replacement; bar attachments required clip maintenance and occasional laboratory repair.
Retention	Bar attachments generally demonstrated the greatest retention, followed by Locator and ball attachments. Magnetic attachments exhibited the lowest retentive force.
Patient satisfaction	All attachment systems significantly improved satisfaction compared with conventional dentures; no attachment system demonstrated consistent superiority.
Overall conclusion	Attachment selection should be individualized according to restorative space, hygiene access, maintenance expectations and patient-specific requirements rather than implant survival alone.

Implant Survival

Implant survival represented the most consistently reported outcome across the included studies. Overall implant survival was exceptionally high irrespective of attachment design, with most investigations reporting survival rates exceeding 95% during the observation period. Long-term prospective studies demonstrated that attachment type exerted minimal influence on implant survival when appropriate treatment planning, implant placement, and maintenance protocols were followed.^{4–8}

Naert et al. reported excellent implant survival with both bar and ball attachment systems after long-term clinical follow-up, concluding that implant loss was uncommon regardless of attachment selection.⁴ Similar findings were reported by Timmerman et al., whose randomized clinical trial comparing bar and ball attachments demonstrated comparable implant survival despite differences in prosthetic maintenance requirements.⁵

Van Kampen et al. likewise observed no statistically significant difference in implant survival between bar-clip and ball attachment systems over a three-year follow-up period.⁶ More recent investigations evaluating Locator attachments have similarly demonstrated survival rates comparable to those achieved with conventional stud and bar attachment systems, confirming that implant longevity depends primarily upon surgical and patient-related factors rather than attachment design alone.^{7,8}

Across the included studies, implant failures generally occurred during the early healing period or within the first year of functional loading and were more frequently associated with patient-related risk factors, implant positioning, or systemic conditions than with the attachment system itself.

Overall, the available evidence indicates that established attachment systems provide similarly favorable long-term implant survival when appropriate maintenance protocols are implemented.

Biological Outcomes

Marginal Bone Loss

Marginal bone loss around supporting implants was evaluated in the majority of comparative studies. Overall, mean crestal bone loss remained within clinically acceptable limits irrespective of attachment system. Differences between attachment systems were generally small and failed to demonstrate consistent statistical significance.^{4,6,9}

Several authors suggested that splinted bar attachments may facilitate more uniform stress distribution across supporting implants; however, this theoretical biomechanical advantage did not consistently translate into clinically significant reductions in crestal bone loss compared with independent stud attachments.^{6,10}

Studies comparing Locator and ball attachments similarly demonstrated comparable radiographic bone levels throughout follow-up, with most investigations reporting annual marginal bone loss well within accepted success criteria.^{7,11}

Overall, attachment selection appeared to have limited influence on peri-implant crestal bone preservation.

Peri-Implant Soft Tissue Health

Clinical parameters including plaque accumulation, bleeding on probing, probing depth, and peri-implant mucosal inflammation were reported by several studies. Biological outcomes remained generally favorable for all attachment systems provided patients adhered to regular maintenance and oral hygiene protocols.^{5,12} Bar attachments occasionally demonstrated greater plaque accumulation because the connecting bar created areas that were more difficult for patients to clean effectively. Nevertheless, increased plaque scores did not consistently result in increased peri-implant disease when supportive maintenance was maintained.^{5,12} Independent attachment systems, including Locator and ball attachments, generally facilitated improved access for oral hygiene procedures and were therefore associated with simpler daily maintenance.^{7,13} Magnetic attachments also permitted relatively straightforward hygiene access because of their uncomplicated design; however, fewer long-term comparative studies are available regarding their biological performance.¹⁴ Collectively, the available evidence suggests that peri-implant tissue health is influenced more strongly by oral hygiene practices and maintenance compliance than by attachment design.

Prosthetic Outcomes

Prosthetic maintenance constituted the principal area in which clinically meaningful differences between attachment systems became evident. Although implant survival remained consistently high across all attachment designs, attachment wear, matrix replacement, clip activation, denture fracture, and repair frequency varied considerably among systems.

Ball attachments demonstrated predictable long-term function but frequently required replacement of retentive components owing to wear of the matrix inserts.^{4,5} Locator attachments exhibited excellent initial retention and patient acceptance; however, multiple investigations reported progressive wear of nylon retentive inserts, necessitating periodic replacement throughout clinical service.^{7,11,15}

Bar attachment systems generally exhibited fewer attachment replacements but required occasional clip activation, clip replacement, solder repair, or bar maintenance. Laboratory procedures associated with bar overdentures were also more complex than those required for stud attachments.^{5,6}

Magnetic attachments demonstrated fewer mechanical complications because of their simplified design; however, gradual reduction in magnetic retention and corrosion-related deterioration have been reported in some long-term studies.¹⁴ Telescopic attachment systems demonstrated favorable mechanical stability and long-term function but required greater prosthetic precision and laboratory expertise than conventional stud attachment systems.¹⁶

Overall, prosthetic maintenance requirements varied substantially among attachment systems and represented the principal determinant of long-term clinical performance.

Maintenance Requirements

Maintenance interventions were among the most frequently reported outcomes and represented the principal distinction between attachment systems. While implant survival and biological outcomes remained comparable across different attachments, the frequency and nature of maintenance procedures varied considerably depending on attachment design.

Ball attachment systems demonstrated satisfactory long-term clinical performance but commonly required replacement of the nylon or metallic matrix components because of progressive wear resulting from repeated insertion and removal of the overdenture. Naert et al. reported that although implant survival remained excellent, periodic replacement of retentive matrices constituted the most frequent maintenance procedure during long-term follow-up.⁴ Similar findings were reported by Timmerman et al., who observed significantly greater maintenance requirements for ball attachments compared with bar-retained overdentures despite comparable implant survival.⁵

Locator attachments have gained widespread popularity because of their self-aligning design, low vertical profile, and ease of chairside maintenance. Nevertheless, several clinical investigations have demonstrated that wear of the nylon retentive inserts occurs progressively with functional use, resulting in gradual loss of retention and necessitating periodic replacement. Kleis et al. reported that Locator attachments required more frequent replacement of retentive inserts than ball attachments over a five-year observation period, although patient satisfaction remained consistently high.¹⁷ Likewise, Cakarar et al. observed that the most common maintenance event associated with Locator attachments was replacement of worn nylon inserts, particularly in patients exhibiting high occlusal forces or frequent prosthesis removal.¹⁸

Bar attachment systems generally exhibited lower frequencies of attachment replacement because the metal bar framework provided greater mechanical durability. However, maintenance procedures involving clip activation, clip replacement, solder repairs, or bar adjustments were occasionally required during long-term service. Van Kampen et al. demonstrated that bar-retained overdentures required fewer attachment

replacements than ball-retained overdentures but involved greater laboratory complexity and higher initial treatment costs.⁶ Timmerman et al. similarly reported that although the cumulative number of maintenance visits was comparable between groups, the type of maintenance differed substantially, with ball attachments requiring more chairside matrix replacement and bar attachments requiring more laboratory-based interventions.⁵

Magnetic attachment systems were associated with relatively simple maintenance because of their uncomplicated design and absence of mechanical retentive inserts. Nevertheless, several studies reported gradual reduction in magnetic retention over time owing to corrosion or deterioration of magnetic components, necessitating replacement in selected cases.¹⁹ Furthermore, magnetic attachments generally exhibited lower retentive forces than mechanical attachment systems, limiting their routine use in patients requiring greater prosthesis stability.

Telescopic attachment systems demonstrated excellent mechanical durability and relatively infrequent attachment replacement when accurately fabricated. However, their successful long-term performance depended upon precise laboratory procedures and meticulous clinical execution. Maintenance requirements primarily involved periodic adjustment of frictional retention and occasional recementation of primary copings.²⁰

Collectively, the available evidence indicates that maintenance requirements represent the most clinically relevant factor distinguishing attachment systems. While Locator and ball attachments facilitate relatively simple chairside maintenance, bar and telescopic systems generally require more technically demanding laboratory procedures. Consequently, attachment selection should consider not only initial prosthetic performance but also anticipated long-term maintenance burden, patient compliance, manual dexterity, and access to routine follow-up care.

Patient-Reported Outcomes

Patient-reported outcomes, including satisfaction, comfort, chewing ability, speech, prosthesis stability, and oral health-related quality of life, were assessed in the majority of included studies. Regardless of attachment system, implant-supported overdentures consistently produced substantial improvements compared with conventional complete dentures.

Randomized clinical trials have repeatedly demonstrated significant improvements in patient satisfaction following implant overdenture therapy. Feine et al. showed that mandibular two-implant overdentures significantly enhanced comfort, masticatory efficiency, speech, and overall quality of life compared with conventional mandibular dentures.²¹ These findings ultimately contributed to the McGill Consensus Statement recommending the two-implant overdenture as the minimum standard of care for edentulous mandibles.²²

Comparative studies evaluating different attachment systems generally demonstrated high levels of patient satisfaction irrespective of attachment type. Van Kampen et al. reported comparable patient satisfaction scores for both ball and bar attachment systems despite differences in prosthetic maintenance and laboratory complexity.⁶ Similarly, Timmerman et al. found no statistically significant differences in overall patient satisfaction between bar-retained and ball-retained overdentures after long-term follow-up, suggesting that patients adapt successfully to both attachment systems.⁵

Locator attachments consistently demonstrated favourable patient acceptance owing to their low profile, ease of insertion, and satisfactory retention. Kleis et al. reported high patient satisfaction associated with Locator-retained overdentures, although the requirement for periodic replacement of nylon inserts did not appear to adversely affect patient perception of treatment success.¹⁷ Similar findings were reported by Cakarar et al., who observed sustained patient satisfaction despite routine maintenance interventions during follow-up.¹⁸ Magnetic attachments have been reported to facilitate prosthesis insertion and removal, particularly in elderly individuals and patients with reduced manual dexterity. Although overall retention is generally lower than that achieved with mechanical attachment systems, magnetic attachments may provide adequate patient satisfaction in carefully selected individuals with limited functional demands.¹⁹

Overall, no attachment system demonstrated consistent superiority with respect to patient-reported outcomes. Improvements in oral health-related quality of life appeared to result primarily from implant support itself rather than from the specific attachment mechanism employed. Consequently, patient-specific anatomical conditions, functional requirements, hygiene capability, maintenance expectations, and clinician experience should guide attachment selection rather than anticipated differences in patient satisfaction alone.

Risk of Bias Assessment

Methodological quality assessment demonstrated variability across the included studies. Randomized controlled trials evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool were generally classified as having low risk of bias

or some concerns, primarily because of limitations related to allocation concealment, blinding of participants and operators, and incomplete outcome reporting. Given the nature of prosthodontic interventions, blinding of clinicians and participants was frequently impractical, representing a common methodological limitation among randomized clinical trials.

Non-randomized comparative studies assessed using the ROBINS-I tool were predominantly categorized as having moderate risk of bias. The principal sources of bias included participant selection, confounding variables, limited adjustment for baseline differences, and incomplete reporting of maintenance outcomes. Nevertheless, most studies demonstrated adequate follow-up periods, clearly defined intervention protocols, and clinically relevant outcome measures.

Overall, the available evidence was considered to be of moderate methodological quality, with consistent findings across studies supporting the reliability of the principal conclusions regarding implant survival, biological outcomes, and prosthetic maintenance. However, further well-designed multicentre randomized controlled trials with standardized outcome reporting and longer follow-up periods are warranted to strengthen the current evidence base.

Table 3. Risk of Bias Assessment

Study	Randomization	Allocation Concealment	Blinding	Incomplete Outcome Data	Selective Reporting	Overall RoB
Naert et al.	NA	NA	High	Low	Low	Moderate (ROBINS-I)
Gotfredsen & Holm	Low	Some concerns	High	Low	Low	Some concerns
Walton et al.	NA	NA	High	Low	Low	Moderate
van Kampen et al.	Low	Low	High	Low	Low	Low
Timmerman et al.	Low	Low	High	Low	Low	Low
Siadat H et al.	Low	Some concerns	High	Low	Low	Some concerns
Krennmair et al.	NA	NA	High	Low	Low	Moderate
Akça et al.	NA	NA	High	Low	Low	Moderate
Kleis et al.	Low	Low	High	Low	Low	Low
Cakarar et al.	NA	NA	High	Low	Low	Moderate
Bilhan et al.	NA	NA	High	Low	Low	Moderate
Matthys et al.	NA	NA	High	Low	Low	Moderate
Tallarico et al.	Low	Low	High	Low	Low	Low
Elsyad et al.	Low	Some concerns	High	Low	Low	Some concerns
Alenezi et al.	NA	NA	High	Low	Low	Moderate
Abozaed et al.	Low	Some concerns	High	Low	Low	Some concerns
Brandt et al.	NA	NA	High	Low	Low	Moderate
Recent comparative trial	NA	NA	High	Low	Low	Moderate

Overall Risk of Bias Summary

Risk Category	Number of Studies
Low risk	4

Risk Category	Number of Studies
Some concerns	4
Moderate risk	10
Serious/Critical risk	0

DISCUSSION

Implant-supported overdentures have become one of the most predictable treatment modalities for the rehabilitation of completely edentulous patients. Since the introduction of osseointegrated implants by Brånemark and colleagues, numerous attachment systems have been developed to improve prosthesis retention, stability, masticatory efficiency, and patient comfort.⁵ Despite extensive clinical use, uncertainty has persisted regarding whether one attachment system offers superior long-term clinical outcomes. The present systematic review synthesized the available comparative clinical evidence evaluating ball, bar, Locator, magnetic, telescopic, and other resilient attachment systems with respect to implant survival, biological outcomes, prosthetic complications, maintenance requirements, and patient-reported outcomes.

The principal finding of this review was that implant survival remained consistently high irrespective of the attachment system employed, indicating that attachment selection has relatively little influence on implant longevity when appropriate surgical protocols, prosthetic design, and maintenance regimens are followed. Most included studies reported high implant survival, with differences between attachment systems generally small and clinically nonsignificant. These findings are consistent with systematic reviews and meta-analyses evaluating attachment systems for mandibular implant-supported overdentures, which have generally reported no convincing evidence that one attachment design provides a clinically meaningful advantage in implant survival.^{26,28,29} Long-term clinical investigations comparing splinted and unsplinted implant configurations have likewise demonstrated favorable implant outcomes over extended follow-up periods.^{14,21}

Although implant survival did not differ substantially among attachment systems, prosthetic maintenance emerged as one of the principal factors differentiating long-term clinical performance. This observation is consistent with the established literature on implant overdenture maintenance.¹³ Ball attachments demonstrate predictable clinical performance but require periodic replacement or adjustment of retentive components because of progressive wear associated with repeated insertion and removal of the overdenture.²² The maintenance requirements of different attachment systems have also been emphasized in systematic reviews, which demonstrate that prosthetic complications and maintenance interventions vary considerably according to attachment design.^{26,28}

Locator attachments have become increasingly popular because of their low vertical profile, self-aligning characteristics, and relative ease of clinical maintenance. However, progressive wear of the retentive inserts may result in loss of retention and the need for replacement during long-term use. Kleis et al. demonstrated favourable clinical performance of Locator attachments in mandibular two-implant overdentures, although attachment-related maintenance remained an important component of treatment.¹⁸ Cakarar et al. similarly reported complications associated with ball, bar, and Locator systems, highlighting the occurrence of retentive component wear and replacement as important prosthetic maintenance events.³⁶ Five-year clinical evidence from Matthys et al. further demonstrated that both Locator- and ball-retained mandibular overdentures can provide predictable implant outcomes and satisfactory patient-related outcomes, while prosthetic aftercare remains necessary throughout the service period.³⁷

In contrast, bar attachment systems generally provide greater mechanical stabilization and cross-arch splinting, although this advantage may be accompanied by increased laboratory complexity and more demanding hygiene procedures. Van Kampen et al. directly evaluated bar-clip, ball, and magnetic attachments and demonstrated differences in retention and post-insertion maintenance requirements among the systems.²² More recent clinical evidence has also demonstrated favourable performance of bar-based designs, including cantilever bar configurations, although maintenance requirements remain an important consideration.¹⁷ A five-year pilot study published in 2026 further evaluated alternative bar attachment designs and reinforces the continuing clinical interest in optimizing bar-retained mandibular overdentures.²⁷

The biological outcomes of the included studies were generally comparable among attachment systems. Marginal bone loss around supporting implants did not demonstrate a consistent clinically significant difference between ball, bar, and other commonly used attachments. Long-term randomized clinical evidence comparing splinted and unsplinted implants has demonstrated favorable peri-implant outcomes over extended follow-up, although differences in prosthetic configuration may influence individual clinical parameters.¹⁴ The available

systematic-review evidence similarly suggests that attachment design alone does not appear to be a major determinant of peri-implant bone preservation.^{26,28,29} Rather, implant positioning, loading conditions, prosthetic fit, occlusal factors, oral hygiene, and maintenance are likely to contribute substantially to long-term peri-implant tissue stability.^{42,46}

Peri-implant soft-tissue health likewise appeared to be influenced more by maintenance and hygiene than by attachment design alone. Attachment systems that create areas of limited access may potentially increase plaque accumulation; however, the clinical significance of this finding depends on the patient's ability to perform adequate oral hygiene and attend regular maintenance appointments.^{43,47-49} The importance of long-term peri-implant tissue monitoring has been emphasized in studies comparing splinted and unsplinted overdenture configurations.^{14,21} Systematic reviews of attachment systems have also failed to demonstrate a consistent biological advantage for a single attachment design.^{26,28}

Patient-reported outcomes constituted another important endpoint evaluated in the included studies.⁵¹ Irrespective of attachment type, implant-supported overdentures generally provide substantial improvements in comfort, masticatory function, prosthesis stability, and overall satisfaction compared with conventional complete dentures.^{8,12} These findings are consistent with the landmark McGill Consensus Statement, which established the mandibular two-implant overdenture as an effective treatment option for the edentulous mandible.^{9,10} The York Consensus Statement subsequently reinforced the recommendation that mandibular two-implant overdentures should be considered the first-choice standard of care for many completely edentulous patients.^{6,11}

Direct comparisons between attachment systems generally failed to identify a universally superior attachment with respect to patient satisfaction. Naert et al. reported favorable patient satisfaction following treatment with mandibular implant overdentures and found that prosthetic configuration influenced specific prosthetic outcomes without eliminating the overall benefit of implant support.²¹ Similarly, studies evaluating different attachment systems have demonstrated generally favorable patient acceptance across treatment modalities.^{18,23} Matthys et al. reported favorable patient-related outcomes following five years of treatment with both Locator- and ball-retained mandibular two-implant overdentures.³⁷ These findings suggest that the improvement in patient satisfaction is primarily related to the transition from conventional denture support to implant-assisted retention and stability rather than to the use of one particular attachment mechanism.

Magnetic attachment systems demonstrated satisfactory clinical outcomes in selected situations. Their principal clinical advantage is their relatively simple insertion and removal mechanism, which may be beneficial for patients who have difficulty aligning mechanical attachments. Ceruti et al. described the clinical application of magnet-retained implant-supported overdentures and highlighted their potential usefulness as an alternative attachment concept.¹⁹ However, magnetic systems generally provide lower retentive forces than mechanical attachments, and their clinical application must therefore be considered in relation to the patient's functional requirements and desired prosthesis stability. Comparative evidence involving magnetic attachments remains more limited than that available for ball, bar, and Locator systems.²²

Telescopic attachment systems demonstrated favorable mechanical characteristics but require greater prosthetic precision and laboratory expertise. Evidence specifically addressing telescopic attachment-retained mandibular implant overdentures indicates that these systems can provide satisfactory prosthetic and peri-implant outcomes; however, the available evidence remains less extensive than that for conventional stud and bar attachments.¹⁶ Krennmair et al. also demonstrated the clinical use of bar-retained mandibular overdentures, emphasizing the importance of prosthetic design and maintenance in determining long-term treatment outcomes.²⁰ Consequently, the selection of telescopic or other technically demanding attachment systems should take into account the available restorative space, laboratory expertise, clinician experience, and patient's maintenance requirements.

An important finding of the present review is that attachment selection should be individualized rather than standardized. The choice of attachment should take into consideration available restorative space, implant distribution, opposing dentition, anticipated maintenance requirements, oral hygiene capability, manual dexterity, financial considerations, and clinician experience.⁴⁵ Systematic reviews have emphasized that attachment systems differ primarily in their retention characteristics, prosthetic complications, maintenance requirements, and technical demands rather than demonstrating a consistent superiority in implant survival.^{26,28,29} Locator attachments may be particularly advantageous when limited vertical restorative space and ease of insertion are important considerations, whereas bar attachments may be preferable when cross-arch stabilization and increased prosthesis stability are required. Ball attachments remain a relatively simple and predictable option for conventional two-implant mandibular overdenture therapy.^{18,22}

The findings of the present review are also supported by recent comparative evidence. A recent clinical study comparing different attachment systems and implant stability demonstrated continuing interest in optimizing

attachment selection for mandibular implant-supported overdentures.³⁹ Similarly, recent radiographic evidence comparing conventional and mini-implant-retained overdentures with different attachment systems provides further evidence that implant configuration and attachment choice should be considered together rather than as independent variables.^{40,44} The publication of newer attachment concepts and comparative investigations indicates that the field continues to evolve, although the long-term evidence base remains substantially stronger for established ball, bar, and Locator systems than for newer designs.

The present review should nevertheless be interpreted in light of several limitations. Considerable heterogeneity existed among the included studies with respect to attachment systems evaluated, number and distribution of implants, loading protocols, prosthetic designs, outcome assessment methods, and duration of follow-up. Similar heterogeneity has been recognized in previous systematic reviews of attachment systems and represents an important challenge when attempting to combine clinical data quantitatively.^{26,28,29} Consequently, the present review relied primarily on qualitative synthesis rather than pooled quantitative estimates. Furthermore, blinding of clinicians and participants was rarely feasible because of the nature of prosthodontic interventions, introducing an inherent risk of performance and detection bias in some investigations. The methodological limitations of randomized and non-randomized studies were therefore considered using RoB 2 and ROBINS-I, respectively.^{34,35}

Several included studies also involved relatively small sample sizes and variable follow-up periods, while maintenance protocols were not standardized across investigations. These factors may limit the generalizability of individual study findings. In addition, newer low-profile attachment systems and emerging digital prosthodontic workflows remain comparatively underrepresented in the long-term clinical literature.^{41,50,53-56} Recent studies evaluating novel attachment concepts indicate increasing interest in addressing these limitations, but longer-term comparative clinical evidence remains necessary.^{38,39,40} Future multicentre randomized controlled trials should therefore incorporate standardized definitions of implant survival, marginal bone loss, prosthetic complications, maintenance interventions, patient-reported outcomes, and cost-effectiveness, with sufficiently long follow-up periods to capture the true maintenance burden of different attachment systems.

Despite these limitations, the present review provides a comprehensive synthesis of comparative evidence concerning implant overdenture attachment systems. The overall consistency of findings indicates that implant survival and peri-implant biological outcomes are largely independent of attachment design, whereas prosthetic maintenance, retention characteristics, technical complexity, and patient-specific requirements constitute the principal factors differentiating attachment systems.^{14,18,22,26,28,37} Therefore, clinicians should prioritize individualized treatment planning based on anatomical, functional, prosthetic, financial, and maintenance considerations rather than assuming inherent superiority of any single attachment system.

CONCLUSION

This systematic review indicates that implant survival is consistently high across the different attachment systems used for mandibular implant-supported overdentures, with no clinically meaningful evidence that ball, bar, Locator, magnetic, or telescopic attachments provide superior implant longevity. Attachment selection therefore appears to have limited influence on implant survival when appropriate implant placement, prosthetic design, and maintenance are provided.

Similarly, peri-implant biological outcomes, including marginal bone loss and peri-implant soft tissue health, were broadly comparable among attachment systems. Differences in biological parameters were generally small and appeared to be influenced more strongly by oral hygiene, implant positioning, occlusal loading, prosthetic fit, and maintenance compliance than by the attachment mechanism itself.

The principal differences between attachment systems were observed in prosthetic complications and maintenance requirements. Ball and Locator systems demonstrated predictable clinical performance but commonly required replacement of worn retentive components, whereas bar systems offered greater mechanical stability but involved greater laboratory complexity and maintenance demands. Magnetic and telescopic systems may provide specific advantages in appropriately selected patients but have comparatively less extensive clinical evidence.

With respect to patient satisfaction and oral health-related quality of life, all major attachment systems provided substantial functional and psychosocial benefits associated with implant-supported overdenture treatment, with no attachment system demonstrating consistent superiority. Patient-reported outcomes appear to be influenced predominantly by the provision of implant support rather than by the specific attachment mechanism.

Overall, attachment selection should be individualized according to restorative space, implant distribution, prosthetic stability requirements, oral hygiene capability, manual dexterity, anticipated maintenance, cost, and

clinician expertise rather than based solely on implant survival. Locator and ball attachments may be appropriate where simplicity and chairside maintenance are priorities, while bar attachments may be advantageous when greater cross-arch stability is required. Thus, the current evidence supports a patient-centred, indication-based approach to attachment selection, rather than recommending a single attachment system as universally superior.

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