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SYSTEMATIC REVIEW OPEN ACCESS

Patient- and Clinician-Reported Outcomes and Outcome Measures for Edentulous Maxilla Rehabilitated With Implant-Assisted Overdentures: A Systematic Review

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ABSTRACT

Aim: To identify patient- and clinician-reported outcomes (PROs and ClinROs) and methods of assessment in clinical trials involving short and/or standard-length and/or zygomatic implants supporting maxillary implant overdentures (IODs).

Materials and Methods: A systematic search was conducted in PubMed, EMBASE, Scopus, Web of Science CENTRAL, and National clinical trial register for articles published between January 1, 2014, and March 23, 2024. Studies that included PROs and ClinROs for implant therapy in patients with edentulous maxillae were eligible, and study quality was appraised using the Cochrane Risk of Bias 2 tool, Newcastle-Ottawa Scale, or Joanna Briggs Institute Critical tool.

Results: A total of 2331 articles were screened, resulting in 21 studies representing 14 patient cohorts with 462 participants and 2140 implants. Two studies used short implants (6 mm) with standard-length implants, while the remaining 19 studies focused exclusively on standard-length implants (7–14 mm); none included zygomatic implants. Patient-reported outcome measures (PROMs) varied widely: Oral Health Impact Profile questionnaires and visual analogue scales were each used in eight studies, and eleven studies relied on unstandardized questionnaires. Implant survival rate was the most frequently used ClinRO, included in all but one study. Subjective ClinROs based on clinician perception were absent in all studies.

Conclusions: Although PROMs were frequently employed in clinical trials, the lack of standardization hinders meaningful comparisons across studies. While objective ClinROs were commonly reported, subjective ClinROs reflecting clinicians' perceptions were notably absent.

1 | Introduction

Implant therapy, once considered to be a treatment for edentulous patients, has also been proven to be a highly successful treatment option for partially edentulous patients (Pjetursson et al. 2012; Velasco-Ortega et al. 2022). Despite research efforts to develop cost- and time-efficient implant protocols, implant therapy still remains a relatively high-cost treatment option in some nations, especially for fixed options (Ghiasi et al. 2022; Zhurakivska et al. 2023). Anatomical conditions required for the implant-supported fixed dental prostheses often lead to larger bone augmentations, which are more invasive and entail higher treatment costs and longer treatment times (Vazouras and Taylor 2021). Given this consideration, elderly patients who are

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in need of full-arch rehabilitation tend to seek treatment with removable rather than fixed implant-borne or supported solutions (Vazouras and Taylor 2021).

Removable treatment options in the maxilla predominantly differ in the number, the dimension, and the location of implants encompassing the use of standard-length implants, shorter dental implants mostly located in the posterior zone of the maxilla to avoid sinus elevation procedures, and even the placement of zygomatic implants in cases of a highly limited ridge height (Messias et al. 2021). From a clinician's and patient's perspective, a systematic approach listing the three treatment options (standard-length implant, short dental implant, and zygomatic implant) and the respectively recorded patient-reported outcomes (PROs) and clinician-reported outcomes (ClinROs) is considered crucial.

Traditionally, long-term outcomes of implant therapy using fixed full-arch prostheses have primarily relied on objective ClinROs such as survival rates and assessments of marginal bone levels through radiographic and clinical evaluations. However, objective ClinROs may not always align with what patients consider most important (Chalmers and Glasziou 2009). Recently, there has been a shift towards incorporating subjective parameters such as questionnaires to better understand aspects like procedural challenges (Thoma et al. 2024) and aesthetic outcomes in implant therapy (Bienz et al. 2022). This transition from traditional ClinROs focused on objective metrics (like survival and bone levels) to incorporating subjective ClinROs and PROs reflects a broader trend in clinical research over the last few years. PROs have significantly influenced treatment strategies by capturing patient experiences and preferences that are crucial for decision-making (Thoma and Strauss 2022), thereby reducing unnecessary treatment and enhancing quality of life. Generally, PROs are quicker, less burdensome, and more cost-effective to collect compared to traditional clinical measures (Feine et al. 2018).

The choice of implant placement protocols heavily relies on the clinician's preferences and expertise (Tonetti et al. 2019). This is critical because treatment options for the edentulous maxilla often involve invasive procedures that require a high level of clinical skill and experience, and clinical decisions are influenced by the clinician's knowledge, skills, and attitudes as much as by the patient's values and preferences (Sackett et al. 1996). While there is a growing emphasis on PROs in treatment decisions, the perspectives and preferences of clinicians remain underrepresented in clinical research (Thoma et al. 2024). The practice of evidence-based medicine inherently involves combining clinician's individual expertise with the available evidence (Sackett et al. 1996). Integrating subjective ClinROs reflecting clinicians' perception such as the choice of treatment options or surgical complexity with PROs could significantly improve the decision-making process.

Due to the continued focus on PROs and ClinROs in edentulous maxilla cases, it is essential to identify and consolidate the current and possibly new assessment methods. This approach aims to offer a comprehensive understanding of treatment effectiveness and patient satisfaction, ultimately enhancing informed clinical decisions and improving patient care. While previous studies have aimed to identify relevant PROs on edentulous patients undergoing implant therapy, these often included a broader scope covering maxillary, mandibular, or both edentulism (Messias et al. 2021). Therefore, the aim of the present systematic review was to identify PROs and ClinROs and methods of assessment in trials using short and/or standard-length and/or zygomatic implants for the rehabilitation of the edentulous maxilla with removable implant-supported prostheses.

2 | Materials and Methods

2.1 | Protocol and Registration

This systematic review is reported according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al. 2021). A detailed protocol has been designed before the start of this study, and it has been registered on PROSPERO (CRD42024523579).

2.2 | Terminology

Due to the heterogeneity in the terminology reported in the literature, the following definitions were employed to classify parameters:

2.2.1 | Patient-reported outcome (PRO)

"Any report of the status of a patient's health condition that comes directly from the patient without interpretation of the patient's response by a clinician or anyone else" (U.S. Food and Drug Administration 2021b).

2.2.2 | Patient-Reported Outcomes Measures (PROMs)

Instruments that are used to measure the PROs, most often self-reported questionnaires (Powers 3rd et al. 2017).

2.2.3 | Clinician-Reported Outcomes (ClinROs)

"A measurement based on a report that comes from a trained health-care professional after observation of a patient's health condition" (U.S. Food and Drug Administration 2021a). Most ClinRO measures involve a clinical judgment or interpretation of the observable signs, behaviors, or other manifestations related to a disease or condition (FDA-NIH Biomarker Working Group. BEST (Biomarkers, EndpointS, and other Tools)). ClinRO measures cannot directly assess symptoms that are known only to the patient. In the present systematic review, the scope of ClinRO was broadened to include *subjective* factors related to the clinician's perception such as the observable signs related to treatment (swelling), ease of performing surgical and restorative procedures with different implant options (short, standard-length and zygomatic implants) and their perceptions regarding the maintenance of the prosthesis. This expanded definition reflects the understanding that the terminology will be periodically updated to include additional terms and clarifications

from wide range stakeholders, including the scientific and medical communities, patients, providers, industry and regulators (FDA-NIH Biomarker Working Group. BEST (Biomarkers, EndpointS, and other Tools)).

2.3 | Eligibility Criteria

The eligibility criteria for this systematic review were organized using a modified PICO framework (PIOS), excluding the "comparison" element. The focused question was: "In adult patients with edentulous maxilla undergoing implant overdenture (IOD) therapy with short (≤6 mm) and/or standard-length (>6mm) and/or zygomatic implants, which types and methods of assessment are commonly used to report PROs and ClinROs?"

2.3.1 | Population (P)

Adult (≥18 years) patients with edentulous maxilla in need of implant therapy.

2.3.2 | Intervention (I)

Implant therapy with short (≤6 mm) and/or standard-length (>6 mm) and/or zygomatic implants supporting a removable dental prosthesis.

2.3.3 | Outcome (O)

PROs including pain, edema, hematoma, painkillers administrated, aesthetic satisfaction, treatment satisfaction, willingness to repeat the surgery, oral health impact profile, quality of life, surgery time, and adverse effects simultaneously with ClinROs including clinical outcomes (e.g., survival, marginal bone level changes) as well as ease of treatment, feasibility of treatment, and satisfaction.

2.3.4 | Study (S)

Randomized controlled trials (RCTs), non-randomized controlled trials (non-RCTs), prospective cohort studies, observational studies, and case series with a minimum of 10 subjects per study group or sample were eligible, since the aim of the present review was to assess outcome measures.

Studies eligibility criteria based on the PIOS elements were assessed (Table 1). All decisions regarding the eligibility criteria were made by the group of review authors, including dentists with professional experience in prosthetic and implant dentistry.

2.4 | Search Strategy

Four electronic databases and two trials registers were searched, namely National Library of Medicine (MEDLINE/PubMed), EMBASE, Scopus Web of Science, Cochrane Central Register of Controlled Trials (CENTRAL) and National clinical trial register using specific adapted strategies (Table 2). The electronic search was performed in duplicate by two review authors (S.S. and J.P.) and included articles published between January 1st, 2014, and March 23rd, 2024. No search filters were applied. The complete search strategies are reported in Table 1. The electronic search was supplemented by forward and backward reference checking from reviewed papers and relevant systematic reviews on the topic (Boven et al. 2015; Sadowsky and Zitzmann 2016; Di Francesco et al. 2021; Sáez-Alcaide et al. 2022; Messias et al. 2023).

2.5 | Study Selection

Based on the inclusion and exclusion criteria (Table 1), two calibrated reviewers (S.S. and S.P.) independently performed title and abstract screening using the Rayyan Online Software (Qatar Computing Research Institute). Inter-examiner calibration was achieved with the presence of another co-author (J.P.) by open discussion and comparison after independent assessment of the first 100 records. No restrictions were made in terms of the length of the follow-up period, but the language was restricted to English, German, Korean, Russian, and Spanish. Any disagreement between the two reviewers was discussed and resolved by a third reviewer (D.T.). Subsequently, the same authors read individually through the full-text version of the potentially eligible studies after the calibration of five articles. When disagreement regarding the inclusion of a specific article occurred, both reviewers had an open discussion. If no agreement was achieved, another co-author (D.T.) made the final decision. Following article selection, Cohen's kappa coefficient (k) was calculated to determine the degree of inter-examiner agreement.

2.6 | Data Extraction and Management

Data from the included studies were extracted using a pilot-tested data extraction table (Excel Microsoft Corporation) after calibration and validation by discussion of the first two articles. One reviewer (S.P.) performed data extraction, and another (S.S.) checked all the information. Final data accuracy and consistency was independently verified by another co-author (F.J.S.). Any missing information that could contribute to this project was kindly requested from the corresponding author(s) via email communication. In case of nonresponse, the corresponding article was ultimately excluded from the review.

For each of the eligible studies, the following data were recorded: bibliographic information; first author, publication year, and country of origin; (2) study design; (3) participants characteristics: gender and age; (4) implants characteristics: type, length, diameter, brand, location, type of attachment used, and number of implants overall and per patient; (5) PROs: utilized scale, range, number of evaluated questions, method of data interpretation, and key aspects; (6) ClinROs: evaluated time-points, objective (reported) parameters, subjective (clinician's perception-related) parameters; utilized scale, range, number of evaluated questions, method of data interpretation, and key

TABLE 1 | Summary of review search strategy and eligibility criteria.

Databases	1. National Library of Medicine (MEDLINE/PubMed) 2. Embase 3. Scopus 4. Web of Science
Registers	1. National clinical trial register 2. Cochrane Central Register of Controlled Trials (CENTRAL)
Other sources	Forward and backward reference checking from reviewed papers and relevant systematic reviews on the topic
Key terms	*Population*: (jaw, edentulous OR mouth, edentulous OR edentulous OR tooth loss) AND (maxilla OR upper jaw OR maxillary); *Intervention*: (dental implant OR Dental Prosthesis, Implant-Supported OR Denture, Partial OR full-arch OR Denture, Complete OR overdenture); *Outcome*: (visual analog scale OR quality of life OR patient satisfaction OR patient reported outcome measure* OR PROM* OR OHIP OR questionnaire* OR patient centered outcome OR patient-reported outcome OR patient related)
Limits	
Dates	January 1, 2014—March 23, 2024
Language	English, German, Spanish, Russian or Korean
Location	International
Article type	Academic
Eligibility criteria	
Types of studies	Randomized clinical trials, controlled clinical studies, prospective studies, observational studies and case-series
Inclusion	1. Systemically healthy adult patients with edentulous maxilla or both maxilla and mandible in case of 2 arms studies; 2. Patients with implant-supported removable prosthesis using mini dental implants, short (≤ 6 mm), standard-length (> 6 mm) or zygomatic conventional implants
Exclusion	1. Unsuitable population (not evaluating adult patients in need of implant overdenture therapy on the edentulous maxilla without prior maxillectomy or similar procedures); 2. Inadequate exposure (not evaluating implant therapy with mini-implants, short (≤ 6 mm), standard-length (> 6 mm) or zygomatic conventional implants and removable prosthesis); 3. Inadequate outcomes (the lack of PROMs and ClinROs); 4. Articles did not publish the implant length; 5. Inadequate study type (not RCT, controlled studies, prospective studies, observational studies and case-series with at least 10 patients per group or sample); 6. Articles reported not in English, German, Spanish, Russian or Korean; 7. Trial registered, not yet published; 8. Trial of published and included articles

aspects; and (7) complications: postoperative, technical, and biological complications and drop-outs.

2.7 | Quality Assessment

All included articles were independently evaluated by two reviewers (S.S. and F.J.S.) for overall risk of bias using the corresponding scale according to the study design. The RoB 2 tool (Cochrane Handbook of Systematic Reviews, version 5.1, (Higgins et al. 2011)) was used for RCTs; the Newcastle-Ottawa Scale (NOS) was utilized for non-randomized controlled/observational studies; and the Joanna Briggs Institute Critical Appraisal tool (Moola et al. 2017) for case series. Disagreement between reviewers was resolved by open discussion. In case no agreement could be achieved, the final decision was made by another co-author (D.T.).

2.8 | Data Synthesis

A narrative synthesis was employed for this review, as a meta-analysis was deemed inappropriate due to the significant heterogeneity among the studies and the aim of the present systematic review. The synthesis process started with a preliminary analysis, during which data were extracted and the outcomes organized into tabular form. This method provided a comprehensive summary of the findings and facilitated the identification of potential patterns within the data.

TABLE 2 | Search strategies.

Databases	
PubMed	#1 (jaw, edentulous OR mouth, edentulous OR edentulous OR tooth loss) AND (maxilla OR upper jaw OR maxillary) #2 (dental implant OR Dental Prosthesis, Implant-Supported OR Denture, Partial OR full-arch OR Denture, Complete OR overdenture) #3 (visual analog scale OR quality of life OR patient satisfaction OR patient reported outcome measure* OR PROM* OR OHIP OR questionnaire* OR patient centered outcome OR patient-reported OR patient related) #4 #1 AND #2 AND #3
Embase	#1 ("jaw, edentulous" OR "mouth, edentulous" OR edentulous OR "tooth loss") AND (maxilla OR "upper jaw" OR maxillary) #2 ("dental implant" OR "Dental Prosthesis, Implant-Supported" OR "Denture, Partial" OR "full mouth" OR "Denture, Complete" OR "overlay denture") #3 ("visual analog scale" OR "quality of life" OR "patient satisfaction" OR "patient reported outcome measure*" OR "PROM*" OR "OHIP" OR "questionnaire*" OR "patient centered outcome" OR "patient-reported outcome" OR "patient related") #4 #1 AND #2 AND #3
Scopus	#1 TITLE-ABS-KEY (("jaw, edentulous" OR "mouth, edentulous" OR edentulous OR "tooth loss") AND (maxilla OR "upper jaw" OR maxillary)) #2 TITLE-ABS-KEY (("dental implant" OR "dental prosthesis, implant-supported" OR "denture, partial" OR full-arch OR "denture, complete" OR overdenture)) #3 TITLE-ABS-KEY (("visual analog scale" OR "quality of life" OR "patient satisfaction" OR "patient reported outcome measure*" OR prom* OR ohip OR questionnaire* OR "patient centered outcome" OR "patient-reported outcome" OR "patient related")) #4 #1 AND #2 AND #3
Web of Science	#1 TS = (("jaw, edentulous" OR "mouth, edentulous" OR "edentulous" OR "tooth loss") AND ("maxilla" OR "upper jaw" OR "maxillary")) #2 TS = (("dental implant" OR "Dental Prosthesis, Implant-Supported" OR "Denture, Partial" OR full-arch OR "Denture, Complete" OR overdenture)) #3 TS = (("visual analog scale" OR "quality of life" OR "patient satisfaction" OR "patient reported outcome measure*" OR PROM* OR OHIP OR questionnaire* OR "patient centered outcome" OR "patient-reported outcome" OR "patient related")) #4 #1 AND #2 AND #3
Register	
Cochrane Central Register of Controlled Trials (CENTRAL)	#1 MeSH descriptor: [Jaw, Edentulous] explode all trees #2 MeSH descriptor: [Mouth, Edentulous] explode all trees #3 MeSH descriptor: [Tooth Loss] explode all trees #4 (jaw edentulous OR mouth edentulous OR edentulous OR tooth loss) #5 #1 OR #2 OR #3 OR #4 #6 MeSH descriptor: [Maxilla] explode all trees #7 (maxilla OR upper jaw OR maxillary) #8 #6 OR #7 #9 #5 AND #8 #10 MeSH descriptor: [Dental Implants] explode all trees #11 MeSH descriptor: [Dental Prosthesis, Implant-Supported] explode all trees #12 MeSH descriptor: [Denture, Partial] explode all trees #13 MeSH descriptor: [Denture, Complete] explode all trees #14 MeSH descriptor: [Denture, Overlay] explode all trees #15 (dental implant OR Dental Prosthesis Implant-Supported OR Denture Partial OR full-arch OR Denture Complete OR overdenture) #16 #10 OR #11 OR #12 OR #13 OR #14 OR #15 #17 MeSH descriptor: [Visual Analog Scale] explode all trees #18 ("visual analog scale" OR "quality of life" OR "patient satisfaction" OR ("patient reported outcome" NEXT measure*) OR PROM* OR OHIP OR questionnaire* OR "patient centered outcome" OR "patient-reported outcome" OR "patient related") #19 #17 OR #18 #20 #9 AND #16 AND #19
US National Institutes of Health database	Condition or disease: Jaw Edentulous AND Maxilla Intervention or treatment: Dental Implants OR Implant-supported denture OR implant overdenture

Abbreviation: MeSH, medical subject headings.

3 | Results

3.1 | Study Selection

The initial electronic search yielded a total of 2331 entries, of which 734 were retrieved in PubMed, 518 in EMBASE, 408 in Scopus, 377 in Web of Science, 271 in CENTRAL, and 23 in National clinical trial register. Following duplicate removal, 1191 articles remained. After title and abstract screening, 65 articles were selected for full-text analysis. Forty-seven of these articles were excluded after full-text review. The list of excluded articles and reasons for exclusion are displayed in Table S1. Inter-examiner agreement kappa score was kappa = 0.859 for screening phase, which demonstrated an almost perfect agreement, and kappa = 0.811 for full-text analysis, which showed a substantial agreement. No additional manuscripts were found through cross-reference checking. A flowchart illustrating the article selection process is displayed in Figure 1.

Finally, 21 articles reporting on 14 unique patient populations were included, and a total of 462 participants and 2140 implants were evaluated in this systematic review.

3.2 | Study Characteristics

Table 3 described general details, participant information, and implant characteristics of the included studies. Of the 21 selected articles, 2 were published in 2014 (Slot et al. 2014b, 2014a), 1 in 2015 (Eerdekens et al. 2015), 3 in 2016 (Ebinger et al. 2016; Pozzi et al. 2016; Slot et al. 2016), 1 in 2017 (Boven et al. 2017), 4 in 2019 (Bernard et al. 2019; Park et al. 2019; Romandini et al. 2019; Slot et al. 2019), 2 in 2020 (Bouhy et al. 2020; Van Doorne et al. 2020), 2 in 2021 (Fonteyne et al. 2021; Van Doorne et al. 2021), 3 in 2022 (Agustín-Panadero et al. 2022; Mo et al. 2022; Slot et al. 2022), and 3 in 2023 (Bouhy et al. 2023; Slot et al. 2023; Van Doorne et al. 2023). Seven of the included studies were RCTs (Slot et al. 2014a, 2016, 2019, 2022, 2023; Bernard et al. 2019; Park et al. 2019), nine were prospective cohort studies (Eerdekens et al. 2015; Ebinger et al. 2016; Pozzi et al. 2016; Boven et al. 2017; Van Doorne et al. 2020, 2021, 2023; Fonteyne et al. 2021; Mo et al. 2022), one was a cross-sectional study (Romandini et al. 2019), and four were case series (Slot et al. 2014b; Bouhy et al. 2020, 2023; Agustín-Panadero et al. 2022). The sample size ranged from 10 participants (60 implants) (Agustín-Panadero et al. 2022) to 74 participants (315 implants) (Ebinger et al. 2016).

The number of implants per patient for the edentulous maxilla varied from 2 to 6 implants: 2 implants (1 out of 21 studies) (Ebinger et al. 2016), 3 implants (Mo et al. 2022) (1/21), and 4 or 6 implants (19/21) with variations in terms of the location (implant position) categorized as being in the anterior or posterior regions. Two sequential studies compared 6 implants placed in either the anterior or the posterior region with bar connections (Slot et al. 2014b; Boven et al. 2017). In those studies, anterior implant placement was preferred whenever possible to avoid sinus floor elevation and to reduce patient morbidity. However, posterior implant placement with sinus floor elevation was opted for when severe ridge resorption precluded the placement of implants in the anterior region. Three consecutive RCTs at 1, 5, and 10 years compared 4 or 6 implants placed in the posterior region with bar connections (Slot et al. 2014a, 2019, 2022).

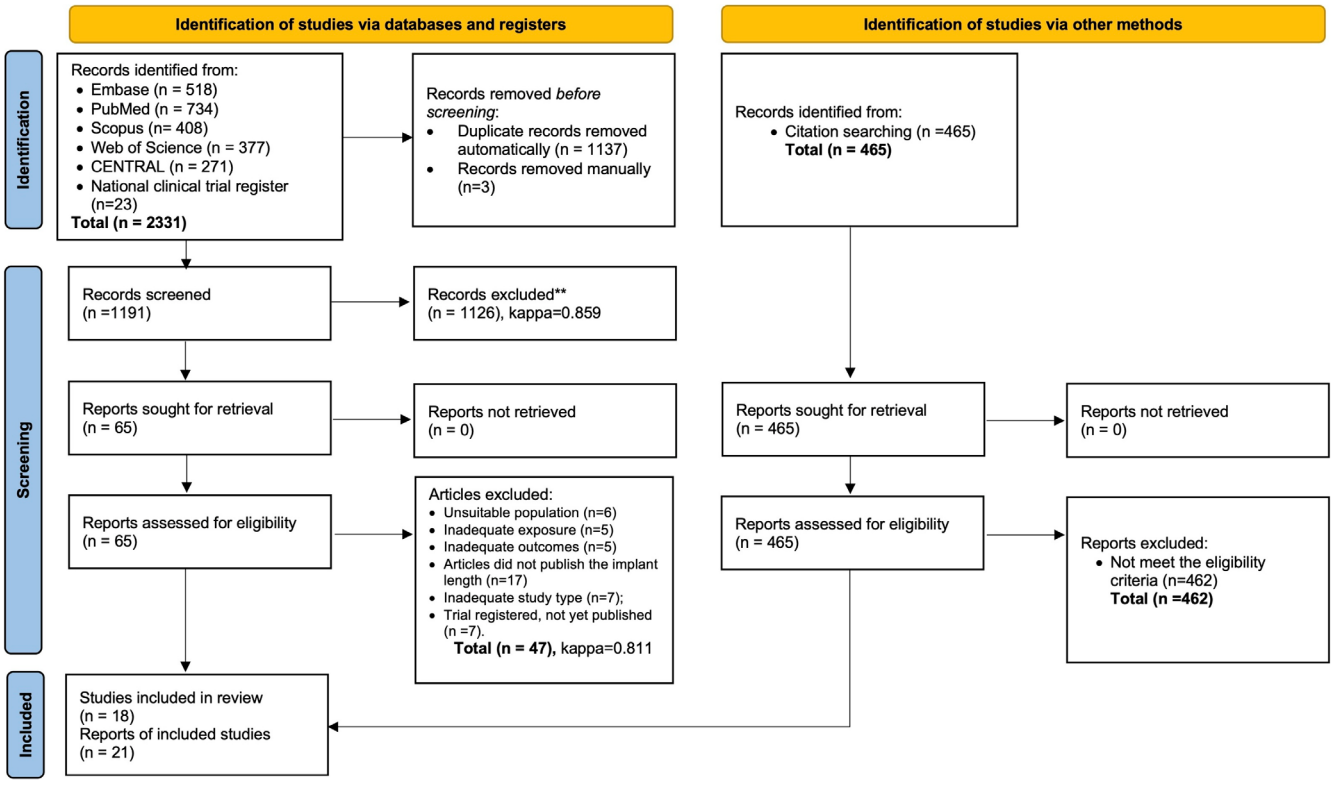

FIGURE 1 | PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers, and other sources.

TABLE 3 | Characteristics of the included studies—Participants and implants.

		Participants		Implants						
Authors/ Country	**Study design**	**Number of patients (M/F)**	**Mean age (y)**	**Number implants**	**Implant type, (number of implants in case of several types)**	**Number of implant pro patient, location (posterior–anterior–anterior–posterior)**	**Implant length (mm), [number of implants]**	**Diameter of implants [number of implants]**	**Implant system**	**Attachment system**
Agustín-Panadero et al. 2022	Case series	10 (NR)	NR	60	Standard	6; 2–1–1-2	Anterior 13.0 [20] Posterior 11.5 [40]	Anterior 3.3 [20] Posterior 4.1 [40]	3i Osseotite Sweden&Martina	Horizontal insertion pathway
Bernard et al. 2019	RCT	15 (12/3)	NR	90	Standard	6; 2–1–1-2	9.5 [2] 11.0 [42] 14.0 [46]	3.5 [73] 4.5 [17]	Ankylos	Syncone
Bouhy et al. 2020	Case series	30 (17/13)	66.4	116	Standard	4; 1–1–1-1	6.0 [9] 8.0 [34] 10.0 [59] 12.0 [14]	3.3 [45] 4.1 [62] 4.8 [9]	Straumann	Locator
Bouhy et al. 2023	Case series	30 (17/13)	66.4	116	Standard	4; 1–1–1-1	6.0 [9] 8.0 [34] 10.0 [59] 12.0 [14]	3.3 [45] 4.1 [62] 4.8 [9]	Straumann	Locator
Boven et al. 2017	Cohort	50 (24/26)	58.4 (anterior group) 59.1 (posterior group)	300	Standard	6; 1–2–2-1 (anterior group), 2–1–1-2 (posterior group)	Anterior at least 11.0 [150] Posterior 12.0 [150]	Anterior 4.0 [150] Posterior 4.1 [150]	Astra Straumann	Bar
Ebinger et al. 2016	Cohort	74 (NR)	NR	315	Standard	2–6 imps; NR	8.0–13.0 mm	3.5, 4.5 (Straumann) 3.5, 4.5 (Nobel Biocare)	Straumann Nobel Biocare	Bar (soldered gold or milled titanium), locator, ball
Eerdekens et al. 2015	Cohort	10 (NR)	56.6	60	Standard	6; NR	11.0 [35] 14.0 [25]	3.5 [56] 4.0 [4]	Dentsply implant	Syncone

(Continues)

TABLE 3 | (Continued)

		Participants		Implants						
Authors/ Country	**Study design**	**Number of patients (M/F)**	**Mean age (y)**	**Number implants**	**Implant type, (number of implants in case of several types)**	**Number of implant pro patient, location (posterior–anterior–anterior–posterior)**	**Implant length (mm), [number of implants]**	**Diameter of implants [number of implants]**	**Implant system**	**Attachment system**
Fonteyne et al. 2021	Cohort	21 (13/8)	63.4	84	Standard	4; NR	9.0–11.0 mm	4.0 [84]	Southern implant	Bar
Mo et al. 2022	Cohort	32 (13/19)	65	96	Standard	3; 1–1-1 (1 imp at each posterior side, and 1 imp at the middle of the arch)	8.0 or 9.0 [7] 10.0 [43] 11.0 [24] 12.0 or 13.0 [22]	3.3 [35] 3.5 [22] 4.0 or 4.1 [21] 4.5 [18]	Astra Straumann Osstem	Low-profile stud
Park et al. 2019	RCT	40 (30/10)	63.5 (bar group) 60.2 (ball group)	158	Standard	4; NR	7.0–13.0 mm	3.1 mm to 5.0 mm	Denitum	Bar, ball with O-ring
Pozzi et al. 2016	Cohort	18 (7/11)	65.4	36	Standard	4; NR	10.0–16.0 mm	3.5 [NR] 4.3 [NR]	Nobel Biocare	Bar
Romandini et al. 2019	Cross-sectional	15 (7/8)	68.8	60	Standard	4; 1–1–1-1	10.0 [37] 11.5 [4] 12.0 [3] 13.0 [4]	NR	3i Osseotite Nobel Biocare Straumann	Bar, locator
Slot et al. 2014a	Case series	50 (24/26)	58.4 (anterior group) 59.1 (posterior group)	300	Standard	6; 1–2–2-1 (anterior group), 2–1–1-2 (posterior group)	Anterior at least 11.0 mm [150] Posterior 12.0 [150]	Anterior 4.0 [150] Posterior 4.1 [150]	Astra Straumann	Bar
Slot et al. 2014b	RCT	66 (33/33)	59.3	330	Standard	4 or 6; 1–1–1-1 or 2–1–1-2	12.0 [330]	4.1 [330]	Straumann	Bar
Slot et al. 2016	RCT	50 (23/27)	59.8	250	Standard	4 or 6; 0–2–2-0 or 1–2–2-1	At least 11.0 mm	4.0 [250]	Astra	Bar
Slot et al. 2019	RCT	66 (33/33)	59.3	330	Standard	4 or 6; 1–1–1-1 or 2–1–1-2	12.0 [330]	4.1 [330]	Straumann	Bar

(Continues)

TABLE 3 | (Continued)

		Participants		Implants						
Authors/ Country	**Study design**	**Number of patients (M/F)**	**Mean age (y)**	**Number implants**	**Implant type, (number of implants in case of several types)**	**Number of implant pro patient, location (posterior–anterior–anterior–posterior)**	**Implant length (mm), [number of implants]**	**Diameter of implants [number of implants]**	**Implant system**	**Attachment system**
Slot et al. 2022	RCT	66 (33/33)	59.3	330	Standard	4 or 6; 1–1–1-1 or 2–1–1-2	12.0 [330]	4.1 [330]	Straumann	Bar
Slot et al. 2023	RCT	50 (23/27)	59.8	250	Standard	4 or 6; 0–2–2-0 or 1–2–2-1	At least 11.0 mm	4.0 [250]	Astra	Bar
Van Doorne et al. 2020	Cohort	31 (17/14)	62.3	185	Mini-implant	6; NR	10.0 [NR] 11.5 [NR]	2.4 [185]	Southern implant	Ball
Van Doorne et al. 2021	Cohort	31 (17/14)	62.3	185	Mini-implant	6; NR	10.0 [NR] 11.5 [NR]	2.4 [185]	Southern implant	Ball
Van Doorne et al. 2023	Cohort	31 (17/14)	62.3	185	Mini-implant	6; NR	10.0 [NR] 11.5 [NR]	2.4 [185]	Southern Implant	Ball

Abbreviations: Impl, implant; mm, milimeter; NR, not reported; RCT, randomized controlled trial.

Two consecutive RCTs at 5 and 10 years compared 4 or 6 implants placed in the anterior region with bar connections (Slot et al. 2016, 2023).

The diameter and length of the implants were described as exact values or as a range in all 21 included studies. Three consecutive prospective cohort studies reported 1-, 3-, and 5-year outcomes from a single cohort treated with mini dental implants (2.4 mm in diameter and 10 or 11.5 mm in length) (Van Doorne et al. 2020, 2021, 2023). Short implants of 6 mm were used in combination with standard-length implants in 2 studies (Bouhy et al. 2020, 2023), and standard-length implants ranging from 7 to 14 mm were used in the remaining 19 studies. None of the included studies utilized zygomatic implants.

Eighteen studies evaluated a single type of attachments. Among these, locators were used in 2 studies (Bouhy et al. 2020, 2023), ball attachments were used in 4 studies (Park et al. 2019; Van Doorne et al. 2020, 2021, 2023), bar attachments were used in 13 studies (Slot et al. 2014a, 2014b; Ebinger et al. 2016; Pozzi et al. 2016; Boven et al. 2017; Park et al. 2019; Romandini et al. 2019; Fonteyne et al. 2021; Agustín-Panadero et al. 2022), cone-anchored abutments (Syncone concept) were used in 2 studies (Eerdekens et al. 2015; Bernard et al. 2019), and low profile stud attachments were assessed in one study (Mo et al. 2022). One study used a specific type of bar attachment that facilitates the insertion of suprastructure into the slot of the bar attachment in the anteroposterior direction (horizontal insertion pathway concept) (Agustín-Panadero et al. 2022). One RCT compared bar attachments to ball attachments, one cross-sectional study reported the use of either bar or locator attachments, and one cohort study reported the use of bar, locator, and ball attachments.

Fifteen studies evaluated implants from a single brand. Among these, Straumann (5 studies), Southern Implant (4 studies), Ankylos (1 study), Astra (2 studies), Nobel Biocare (1 study), Dentium (1 study) and Dentsply (1 study) were included. Six studies evaluated implants from multiple brands, including different combinations of 3i, Osseotite, Sweden & Martina, Astra, Straumann, Nobel Biocare, and Osstem implants.

3.3 | Patient-Reported Outcomes (PROs) and Patient-Reported Outcome Measures (PROMs)

Table 4 provides detailed information regarding PROs and PROMs used in the selected studies. Out of the 21 studies, 15 studies utilized one scale each to evaluate PROs, whereas 6 studies utilized two scales (Pozzi et al. 2016; Bouhy et al. 2020, 2023; Fonteyne et al. 2021; Van Doorne et al. 2021; Mo et al. 2022). Among the 21 studies, 2 studies analyzed PROs as the primary outcome (Romandini et al. 2019; Van Doorne et al. 2021); one of those was OHRQoL changes using an OHIP-14 questionnaire (Van Doorne et al. 2021), whereas in the other study, patient satisfaction was assessed using a VAS-based questionnaire (Romandini et al. 2019).

Oral health impact profile (OHIP) questionnaires were utilized in 8 studies. Among them, 3 studies used OHIP-20 with 20 items rated 1–6, where lower scores indicate better oral health-related quality of life (OHRQoL) (Bouhy et al. 2020, 2023; Mo et al. 2022), 4 studies used OHIP-14 with 14 items rated 0–4, where lower scores indicate better OHRQoL (Ebinger et al. 2016; Fonteyne et al. 2021; Van Doorne et al. 2021, 2023), and 1 study used OHIP-21 with 21 items rated 0–5, where lower scores indicated better OHRQoL (Pozzi et al. 2016).

Visual analogue scale (VAS) was utilized in 8 studies, rated from 0 to 10 cm, where higher scores indicate better patient satisfaction or function in every domain. Out of the 8 studies, two studies on the same cohort utilized McGill Denture Satisfaction Instrument—a VAS that includes 6 domains assessing patient satisfaction (Bouhy et al. 2020, 2023).

Unstandardized questionnaires with separately analyzed questions were utilized in 11 studies. Among those studies, 7 studies from the same research group utilized the same questionnaire with numerical ratings where lower scores indicated better outcomes related to denture complaints (54 items rated 0–3) and chewing ability (3 items rated 0–2) and higher scores indicated better satisfaction (1 item rated 0–10) (Slot et al. 2014a, 2014b; Boven et al. 2017). Among the other unstandardized questionnaires, 1 study evaluated one domain on postoperative pain rated 0–10 where the lower score indicated less pain (Van Doorne et al. 2021); 1 study evaluated three domains in which items were rated 0–10 for pain (lower the less) and satisfaction (higher the better) or a "yes" or "no" for recommendation of treatment (Van Doorne et al. 2020); and 1 study evaluated 7 domains rated 1–5 where the lower score indicated superior outcomes (Mo et al. 2022).

As for the evaluated domains, function was evaluated in all but one study (Van Doorne et al. 2020). Mostly evaluated domains were the post-operative pain (10 out of 21 studies), discomfort (17/21), aesthetics (15/21), patients' satisfaction (13/21), phonetics (8/21), and OHRQoL (9/21). Stability or retention were evaluated in 6 studies (Eerdekens et al. 2015; Bernard et al. 2019; Romandini et al. 2019; Bouhy et al. 2020, 2023; Mo et al. 2022). 'Feeling as it is my own teeth' was evaluated in 2 studies (Eerdekens et al. 2015; Bernard et al. 2019). Cleanability was evaluated in 2 studies (Bouhy et al. 2020, 2023).

Among the 18 prospective studies, 17 recorded PROMs at the baseline situation before the delivery of the new IODs, whereas one study recorded PROMs after the delivery of the new IODs (Park et al. 2019). Most of those prospective studies were performed on participants who were dissatisfied with their previous conventional complete dentures; however, some studies did not report the specific reasons for rehabilitation other than having edentulous maxillae. Maximum follow-up periods at which PROMs were recorded varied from 1 to 10 years.

3.4 | Clinician-Reported Outcomes (ClinROs) and Their Measures

Table 5 displays data on ClinROs including the assessed time points and the respective complications. Regarding objective aspects of ClinROs, marginal bone loss (MBL) was reported in 15 studies, ranging from 0.03 mm (at 2 years follow-up) (Bernard et al. 2019) to 1.3 mm (at a mean follow-up of 6 years)

TABLE 4 | Characteristics of the included studies—Patient-reported outcome measures.

	PROMs			
Authors/Country	**Utilized scale**	**Evaluated question (key aspects/domain)**	**Number of evaluated items; Scale range (min/max)**	**Interpretation**
Agustín-Panadero et al. 2022	VAS	Satisfaction with treatment Esthetics Function	3 items rated 0–10 cm	Higher score = satisfaction or better function in every domain
Bernard et al. 2019	VAS	Prosthesis retention Comfort Speech Function Esthetics Self-esteem Feeling of "being my own teeth"	7 items rated 0–10 cm	Higher score = satisfaction or better QoL in every domain
Bouhy et al. 2020	OHIP-20 VAS (McGill Denture Satisfaction Instrument)	OHIP-20: Functional limitations Physical discomfort Psychological discomfort Physical disability Psychological disability Social disability Handicap VAS: General comfort Stability Ability to chew Speech Cleaning ability Pain	OHIP-20: 20 items rated 1–6; (20/120) VAS: 6 items rated 0–10 cm	OHIP-20: lower scores indicated better oral health-related QoL VAS: higher scores indicated better patient satisfaction

(Continues)

TABLE 4 | (Continued)

	PROMs			
Authors/Country	**Utilized scale**	**Evaluated question (key aspects/domain)**	**Number of evaluated items; Scale range (min/max)**	**Interpretation**
Bouhy et al. 2023	OHIP-20 VAS (McGill Denture Satisfaction Instrument)	OHIP-20: Functional limitations Physical discomfort Psychological discomfort Physical disability Psychological disability Social disability Handicap VAS: General comfort Stability Ability to chew Speech Cleaning ability Pain	OHIP-20: 20 items rated 1–6; (20/120) VAS: 6 items rated 0–10 cm	OHIP-20: lower scores indicated better oral health-related QoL VAS: higher scores indicated better patient satisfaction
Boven et al. 2017	Unstandardized questionnarie with separately analyzed questions	Denture complaints Chewing ability Overall denture satisfaction	Denture complaints: 54 items rated 0–3 Chewing ability: 3 items rated 0–2 Overall denture satisfaction: 1 item rated 1–10	Lower score: better outcome (denture complaints, chewing ability) Higher score: more satisfaction (Overall denture satisfaction)
Ebinger et al. 2016	OHIP-14	Oral health related quality of life (OHRQoL)	14 items rated 0–4; (0/56)	Lower score: better outcome
Eerdekens et al. 2015	VAS	Comfort Retention Function Esthetics Feeling as its own teeth Speech Self-esteem	7 items rated 0-100 mm	Higher score = better function in every domain

(Continues)

TABLE 4 | (Continued)

	PROMs			
Authors/Country	**Utilized scale**	**Evaluated question (key aspects/domain)**	**Number of evaluated items; Scale range (min/max)**	**Interpretation**
Fonteyne et al. 2021	OHIP-14 VAS	OHIP-14: Functional limitations Physical pain Psychological discomfort Physical disability Psychological disability Social disability Handicap VAS: Satisfaction with speech Overall satisfaction with oral health	OHIP-14: 14 items rated 0–4; (0/56) VAS: 2 items rated 0-100 mm	OHIP-14: lower scores indicated better oral health-related QoL VAS: higher scores indicated better patient satisfaction
Mo et al. 2022	Unstandardized questionnaire with 7 items OHIP-20 (20/120)	Denture Satisfaction Scale: General satisfaction Retention Comfort Stability Speech Appearance Occlusion OHIP-20: Functional limitations Handicap Physical disability Physical discomfort Psychological disability Psychological discomfort Social disability	Denture Satisfaction Scale: 7 items rated 1/5 OHIP-20: 20 items rated 1/6; (20/120)	Lower score = better function in every domain
Park et al. 2019	VAS	Mastication Pronunciation Aesthetics Pain Overall satisfaction	5 items rated 0-10 cm	Higher score = better function in every domain

(Continues)

TABLE 4 | (Continued)

	PROMs			
Authors/Country	**Utilized scale**	**Evaluated question (key aspects/domain)**	**Number of evaluated items; Scale range (min/max)**	**Interpretation**
Pozzi et al. 2016	Unstandardized questionnarie with separately analyzed questions OHIP-21	Function Esthetics OHIP-21: Functional limitations Physical pain Psychological discomfort Physical disability Psychological disability Social disability Handicap	Function, esthetics: each rated 1–10 OHIP-21: 21 items rated 0–5	Function, esthetics: Higher score = better function in every domain OHIP-21: lower scores indicated better oral health-related QoL
Romandini et al. 2019	VAS	General satisfection Ability to chew Ability to speak Stability Comfort Appearance Easy of cleaning Pain around implants Pain in gingiva Repeat the same rehabilitation	10 items rated 0-10 cm	Function, esthetics: Higher score = better function in every domain
Slot et al. 2014a	Unstandardized questionnarie with separately analyzed questions	Denture complaints Chewing ability Overall denture satisfaction	Denture complaints: 54 items rated 0–3 Chewing ability: 3 items rated 0–2 Overall denture satisfaction: 1 item rated 1–10	Lower score: better outcome (denture complaints, chewing ability) Higher score: more satisfaction (Overall denture satisfaction)
Slot et al. 2014b	Unstandardized questionnarie with separately analyzed questions	Denture complaints Chewing ability Overall denture satisfaction	Denture complaints: 54 items rated 0–3 Chewing ability: 3 items rated 0–2 Overall denture satisfaction: 1 item rated 1–10	Lower score: better outcome (denture complaints, chewing ability) Higher score: more satisfaction (Overall denture satisfaction)

(Continues)

TABLE 4 | (Continued)

	PROMs			
Authors/Country	**Utilized scale**	**Evaluated question (key aspects/domain)**	**Number of evaluated items; Scale range (min/max)**	**Interpretation**
Slot et al. 2016	Unstandardized questionnarie with separately analyzed questions	Denture complaints Chewing ability Overall denture satisfaction	Denture complaints: 54 items rated 0–3 Chewing ability: 3 items rated 0–2 Overall denture satisfaction: 1 item rated 1–10	Lower score: better outcome (denture complaints, chewing ability) Higher score: more satisfaction (Overall denture satisfaction)
Slot et al. 2019	Unstandardized questionnarie with separately analyzed questions	Denture complaints Chewing ability Overall denture satisfaction	Denture complaints: 54 items rated 0–3 Chewing ability: 3 items rated 0–2 Overall denture satisfaction: 1 item rated 1–10	Lower score: better outcome (denture complaints, chewing ability) Higher score: more satisfaction (Overall denture satisfaction)
Slot et al. 2022	Unstandardized questionnarie with separately analyzed questions	Denture complaints Chewing ability Overall denture satisfaction	Denture complaints: 54 items rated 0–3 Chewing ability: 3 items rated 0–2 Overall denture satisfaction: 1 item rated 1–10	Lower score: better outcome (denture complaints, chewing ability) Higher score: more satisfaction (Overall denture satisfaction)
Slot et al. 2023	Unstandardized questionnarie with separately analyzed questions	Denture complaints Chewing ability Overall denture satisfaction	Denture complaints: 54 items rated 0–3 Chewing ability: 3 items rated 0–2 Overall denture satisfaction: 1 item rated 1–10	Lower score: better outcome (denture complaints, chewing ability) Higher score: more satisfaction (Overall denture satisfaction)
Van Doorne et al. 2020	Unstandardized questionnarie with separately analyzed questions	Perception of pain Final satisfaction Whether the patient would recommend the treatment	Perception of pain, final satisfaction: 1 item each, rated 1–10 Whether the patient would recommend the treatment: 1 item (“Yes” or “No”)	Lower score: less pain (perception of pain) Higher score = better function in every domain (satisfaction)

(Continues)

TABLE 4 | (Continued)

	PROMs			
Authors/Country	**Utilized scale**	**Evaluated question (key aspects/domain)**	**Number of evaluated items; Scale range (min/max)**	**Interpretation**
Van Doorne et al. 2021	Unstandardized questionnaire with one question OHIP-14	Postoperative pain OHIP-14: Functional limitations Physical pain Psychological discomfort Physical disability Psychological disability Social disability Handicap	Postoperative pain: 1 item rated 0–10 OHIP-14: 14 items rated 0–4; (0/56)	Postoperative pain: Lower score indicated less pain OHIP-14: lower scores indicated better oral health-related QoL
Van Doorne et al. 2023	OHIP-14	Functional limitations Physical pain Psychological discomfort Physical disability Psychological disability Social disability Handicap	14 items rated 0–4; (0/56)	Lower scores indicated better oral health-related QoL

Abbreviations: NR, not reported; OHIP, oral health implant profile; OHRQoL, Oral Health-related Quality of Life; VAS, visual analogue scale.

TABLE 5 | Characteristics of the included studies –clinician-reported outcomes, including complications and evaluated timepoints.

		ClinROs				Complications				
			Subjective (clinician's perception-related) ClinROs							
Authors/ Country	Evaluated time points	Objective ClinROs	Utilized scale	Evaluated parameter	Number of evaluated items	Drop out	Intraoperative (yes +/ no –)	Postoperative (yes +/ no –)	Biological (yes +/ no –)	Technical (yes +/ no –)
Agustín-Panadero et al. 2022	•6 years	MBL Implant survival Prothesis survival	NR	NR	NR	NR	NR	NR	—	+ •Loss of anteroposterior retention •Fracture and replacement of resin teeth
Bernard et al. 2019	•After loading •1 year •2 years	MBL Implant survival BOP Probing depth Recession or CAL PI	NR	NR	NR	0	NR	NR	NR	NR
Bouhy et al. 2020	•Baseline •1 week •4 weeks •3 months •6 months •1 year	Peri-implant bone remodeling Implant survival Peri-implant health Prosthesis survival Prosthodontic success Probing depth BOP PI	NR	NR	NR	1	NR	+ •Postoperative pain	+ •Peri-implant mucosa hyperplasia	+ •Inserts renewed •Prosthesis modification due to implant failure •Base fracture •Acrylic tooth fracture •Metallic renfort
Bouhy et al. 2023	•Baseline •1 year •3 years •5 years	MBL Implant survival Peri-implant health Prosthesis survival Prosthodontic success Pocket depth (≥ 6 mm) Probing depth BOP PI	NR	NR	NR	3	NR	NR	NR	+ •Excessive wear •Repeated fracture leading to the need of a metal framework

(Continues)

TABLE 5 | (Continued)

		ClinROs				Complications				
			Subjective (clinician's perception-related) ClinROs							
Authors/ Country	**Evaluated time points**	**Objective ClinROs**	**Utilized scale**	**Evaluated parameter**	**Number of evaluated items**	**Drop out**	**Intraoperative (yes +/ no –)**	**Postoperative (yes +/ no –)**	**Biological (yes +/ no –)**	**Technical (yes +/ no –)**
Boven et al. 2017	•Baseline •After implant placement •1 year •5 years	MBL Implant survival PI Presence of calculus GI SBI Pocket probing depth	NR	NR	NR	5	NR	NR	+ •Peri-implantitis	—
Ebinger et al. 2016	•6.5 ± 2.7 years (average)	Implant survival PI Probing depth > 4 mm BOP	NR	NR	NR	0	NR	NR	+ •Mucosal fenestrations	NR
Eerdekens et al. 2015	•1 month •3 months •6 months •1 year •2 years •3 years •5 years	Implant survival Implant success Prosthesis success Bone quality and quantity mPI mBI	NR	NR	NR	0	NR	+ •Gingival swelling and redness	NR	NR
Fonteyne et al. 2021	•Baseline •4 weeks •3 years	Articulation disorder	NR	NR	NR	5	NR	NR	NR	NR
Mo et al. 2022	•Baseline •0.5–1 year •4–5 years	MBL Implant survival Implant success Prosthesis success Peri-implant suppuration mPI mBI	NR	NR	NR	0	NR	NR	NR	+ •Delaminated acrylic tooth •Partial fracture of denture •Matrix housing loosening •Attachment retention loss •Nylon ring replacement

(Continues)

TABLE 5 | (Continued)

		ClinROs				Complications				
			Subjective (clinician's perception-related) ClinROs							
Authors/ Country	**Evaluated time points**	**Objective ClinROs**	**Utilized scale**	**Evaluated parameter**	**Number of evaluated items**	**Drop out**	**Intraoperative (yes +/ no –)**	**Postoperative (yes +/ no –)**	**Biological (yes +/ no –)**	**Technical (yes +/ no –)**
Park et al. 2019	•Baseline •3 months •1 year	MBL Implant survival Implant-quality scale Prosthodontic maintenance PI BOP GI	NR	NR	NR	8	NR	NR	NR	+ •Bar-clip or o-ring change •Female reconnection •Screw loosening •Screw fracture •Denture tooth fracture •Base(flange) fracture
Pozzi et al. 2016	•Baseline •2 weeks •1 year	MBL Implant survival Implant success Prosthesis survival Prosthesis success BI PI	NR	NR	NR	0	NR	NR	—	—
Romandini et al. 2019	•7–12 years after loading	Recession Peri-implant health Implant survival Prosthesis survival	NR	NR	NR	0	NR	NR	+ •Peri-implantitis •Peri-implant mucositis	NR
Slot et al. 2014a	•Baseline •1 year	MBL Implant survival PI Presence of calculus GI SBI Pocket probing depth	NR	NR	NR	0	NR	—	NR	NR

(Continues)

TABLE 5 | (Continued)

		ClinROs				Complications				
			Subjective (clinician's perception-related) ClinROs							
Authors/ Country	**Evaluated time points**	**Objective ClinROs**	**Utilized scale**	**Evaluated parameter**	**Number of evaluated items**	**Drop out**	**Intraoperative (yes +/ no –)**	**Postoperative (yes +/ no –)**	**Biological (yes +/ no –)**	**Technical (yes +/ no –)**
Slot et al. 2014b	•Baseline •1 year	MBL Implant survival Prosthesis survival PI Presence of calculus GI SBI Pocket probing depth	NR	NR	NR	0	NR	—	NR	NR
Slot et al. 2016	•Baseline •1 year •5 years	MBL Implant survival Prosthesis survival PI Presence of calculus GI SBI Pocket probing depth	NR	NR	NR	4	NR	NR	+ •Peri-implantitis •Peri-implant mucositis •Removal of hyperplasia	+ •Repair of denture base/teeth •Relining
Slot et al. 2019	•Baseline •1 year •5 years	MBL Implant survival Prosthesis survival PI Presence of calculus GI SBI Pocket probing depth	NR	NR	NR	6	NR	NR	+ •Peri-implantitis •Peri-implant mucositis •Removal of hyperplasia	+ •Repair of denture base/teeth •Relining •Readjustment of occlusion •New bar

(Continues)

TABLE 5 | (Continued)

		ClinROs				Complications				
			Subjective (clinician's perception-related) ClinROs							
Authors/ Country	**Evaluated time points**	**Objective ClinROs**	**Utilized scale**	**Evaluated parameter**	**Number of evaluated items**	**Drop out**	**Intraoperative (yes +/ no –)**	**Postoperative (yes +/ no –)**	**Biological (yes +/ no –)**	**Technical (yes +/ no –)**
Slot et al. 2022	•Baseline •1 year •5 years	MBL Implant survival Prosthesis survival PI Presence of calculus GI SBI Pocket probing depth	NR	NR	NR	20	NR	NR	+ •Peri-implantitis •Peri-implant mucositis •Removal of hyperplasia	+ •Repair of denture base/teeth •Relining •Readjustment of occlusion •New bar
Slot et al. 2023	•Baseline •1 year •5 years	MBL Implant survival Prosthesis survival PI Presence of calculus GI SBI Pocket probing depth	NR	NR	NR	14	NR	NR	+ •Peri-implantitis •Peri-implant mucositis •Removal of hyperplasia	+ •Repair •Relining •Readjustment of occlusion •New bar
Van Doorne et al. 2020	•6 months •1 year •2 years	Implant survival Prosthesis survival Implant stability at surgery	NR	NR	NR	0	NR	NR	NR	NR
Van Doorne et al. 2021	•Baseline •After definitive prosthesis •1 months •1 year •2 years •3 years	Implant survival Prosthesis survival	NR	NR	NR	0	NR	NR	NR	NR

(Continues)

TABLE 5 | (Continued)

Authors/ Country	Evaluated time points	ClinROs				Complications			
		Objective ClinROs	Subjective (clinician's perception-related) ClinROs			Drop out	Intraoperative (yes +/ no −)	Postoperative (yes +/ no −)	Biological (yes +/ no −)	Technical (yes +/ no −)
			Utilized scale	Evaluated parameter	Number of evaluated items					
Van Doorne et al. 2023	•Baseline •After definitive prosthesis •1 month •1 year •2 years •3 years •5 years	MBL Implant survival Prosthesis survival Peri-implant health Probing depth BOP	NR	NR	NR	0	NR	NR	NR	NR

Abbreviations: BI, bleeding index; BOP, bleeding on probing; CAL, clinical attachment loss; GI, gingival index; Impl., implant; m, months; mBI, modified bleeding index; MBL, marginal bone loss; mPI, modified plaque index; NR, not reported; PI, plaque index; SBI, sulcus bleeding index; y, years.

(Agustín-Panadero et al. 2022). Survival rates of implants, prostheses, or both were reported in all but one study (Fonteyne et al. 2021), which solely reported on the incidence of articulation disorder. Implant survival rates ranged from 80.6% (at 5-year follow-up) (Bouhy et al. 2023) to 100% (at 1-year follow-up) (Pozzi et al. 2016) in studies involving short and/or standard-length implants, while a cohort with mini dental implants showed a 76.8% survival rate at 5-year follow-up (Van Doorne et al. 2023). In terms of the number of implants used, using just three implants with low-profile studs for IOD therapy resulted in a survival rate of 96.9% (Mo et al. 2022), which was not significantly different from the survival rates reported in studies using 4–6 implants.

As for prostheses, survival rates ranged from 80.0% (at a mean follow-up of 6 years) (Agustín-Panadero et al. 2022) to 100% (at 1 year follow-up) (Pozzi et al. 2016). The cohort from Slot et al. which had the longest follow-up period (10 years) among the included articles, presented relatively lower prosthesis survival rates of 57.9% (4 implants subgroup) and 29.4% (6 implants subgroup) (Slot et al. 2023).

Success rate of implant, prosthesis, or both was reported in 5 studies (Eerdekens et al. 2015; Pozzi et al. 2016; Bouhy et al. 2020, 2023; Mo et al. 2022). Regarding implant and prosthetic success, studies with more than 5 years of follow-up reported implant success rates ranging from 78.2% (Bouhy et al. 2023) to 95.0% (Mo et al. 2022), and prosthetic success rates ranging from 55.0% (Mo et al. 2022) to 90.0% (Eerdekens et al. 2015). One study with a 1-year follow-up showed 100% success for both implants and prostheses (Pozzi et al. 2016). The studies using locator attachments defined implants as successful when they exhibited a modified plaque index and modified bleeding index of 0 (Bouhy et al. 2020, 2023), while the other studies considered implants successful if they showed no signs of pain, infection, fixture mobility, or perifixtural radiolucency, and functioned effectively as anchors for functional prostheses (Eerdekens et al. 2015; Pozzi et al. 2016; Mo et al. 2022). Regarding prosthetic success, three studies defined the prostheses as successful when the repair or replacement of the patrix or matrix occurred fewer than twice within the first year or fewer than five times within the first 5 years (Bouhy et al. 2020, 2023; Mo et al. 2022). In contrast, one study proposed success criteria based on PROMs, stating that implants were successful if there were no implant failures and all VAS-based PROMs questions achieved a score of 70% or higher (Eerdekens et al. 2015). Another study referred to prosthetic success as cases where the prostheses were maintained satisfactorily in terms of both functionality and aesthetics (Pozzi et al. 2016).

Bleeding index, modified bleeding, or bleeding on probing was evaluated in 16 studies, while plaque index was evaluated in 15 studies. Probing depth was reported in 12 studies. None of the included articles presented outcomes related to subjective aspects of ClinROs.

Complications were analyzed in 13 studies. 11 studies reported technical complications (Slot et al. 2014a, 2014b; Park et al. 2019; Bouhy et al. 2020, 2023; Agustín-Panadero et al. 2022; Mo et al. 2022), 8 studies reported biological complications (Ebinger et al. 2016; Slot et al. 2016, 2019, 2022, 2023; Boven et al. 2017; Romandini et al. 2019; Bouhy et al. 2020), and 2 studies reported

postoperative complications (Eerdekens et al. 2015; Bouhy et al. 2020).

3.5 | Risk of Bias Assessment

The quality assessment of the included RCTs by the RoB 2 risk of bias assessment tool is illustrated in Figure 2. The complete risk of bias assessment for the remaining studies is displayed in Tables S2 and S3.

4 | Discussion

The present systematic review, which aimed to identify PROs and ClinROs and their methods of assessment in clinical studies utilizing short and/or standard-length and/or zygomatic implants for maxillary IOD treatments, predominantly revealed the following:

i. An ongoing attempt to report PROs solely or in conjunction with traditional objective ClinROs.
ii. A large heterogeneity in the reporting of PROs with a frequent reliance on unstandardized PROMs or questionnaires.
iii. A lack of reporting subjective ClinROs assessing clinicians' perceptions.

Whilst most studies still focus on traditional outcomes heavily related to the biologic and physiologic remodeling processes around dental implants, there also have been attempts to report PROs for implant-supported removable prostheses. PROs, apart from biological, aesthetic, and technical complications, encompass the patient's perception following implant therapy. This is usually based on questionnaires that address the patient's quality of life thereby assessing benefit/advantage/disadvantage when implants are placed to support removable prostheses. The quality of life and the patient's perception of implant therapy address speech, discomfort, physical disability, function, aesthetics among further parameters.

The assessment of PROMs has substantially enhanced the decision-making process in implant dentistry. The present systematic review demonstrated that although PROMs were used in many clinical studies, even serving as a primary outcome, they were often unstandardized. This resulted in a large heterogeneity among the included studies. Differences in measurement tools, scales, timing of measurement, and definition of outcomes hinder the ability to combine and compare data effectively, making it difficult to draw reliable conclusions from a meta-analysis. This can lead to misleading conclusions about the intervention, which was the reason for the exclusion of such comparisons from the current review.

Standardizing a PROM involves developing it through a rigorous scientific process, which includes a literature review, expert consultations, and pilot testing. Input from patients, clinicians, and other relevant stakeholders should be integrated during its development. To reduce variability and bias, it is essential to have clear and consistent guidelines for the administration, scoring, and interpretation of the PROM. The measure must be backed by peer-reviewed studies that demonstrate its reliability, validity, cross-cultural validity, and responsiveness. Additionally, the PROM should be widely accepted and utilized in both clinical practice and research, showcasing its credibility and utility (Beaton et al. 2000).

The most used PROMs were the Oral health impact profile (OHIP) questionnaires. OHIP is a well validated tool for measurement of OHRQoL. The use of different versions of OHIP was observed including OHIP-14, −20, and −21, which are shortened

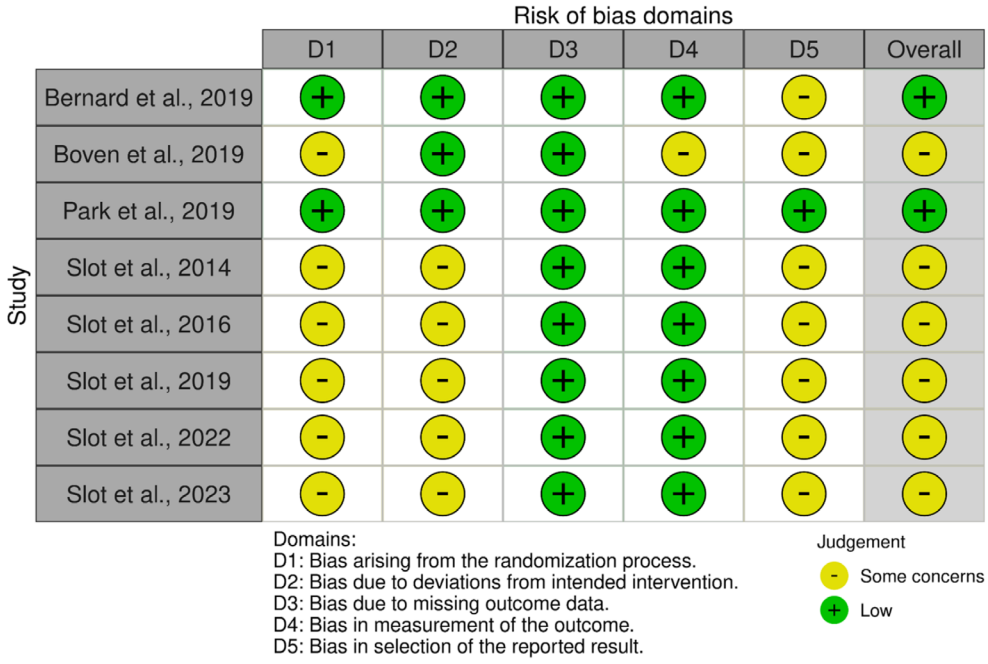

FIGURE 2 | Risk of bias assessment for randomized controlled trials.

versions of the original OHIP-49, assessing seven-domain scores and one summary score. OHIP-14 is the most widely used generic version, while OHIP-20–a variation of OHIP-19–has been specifically adapted for edentulous patients (John 2022). Recent systematic reviews (Mittal et al. 2019; Rener-Sitar et al. 2021) however provided evidence that currently available multi-item PROMs essentially measured only four dimensions (oral function, orofacial pain, orofacial appearance, and psychosocial impact), which have been captured by OHIP-5. The 5-item OHIP has been recommended as the core metric to assess patient-perceived oral health across various clinical settings (John et al. 2022). Application of the abbreviated core metrics may reduce the practical burden of answering questionnaires thereby allowing widespread standardized assessment of OHRQoL in all research and clinical settings.

VAS and unstandardized questionnaires were used alone or in combination with OHRQoL measurements. Such ad hoc instruments were used for the assessment of satisfaction specific to the treatment, which can be perceived as more easily understood by the patient and clinician compared to the multidimensionally assessed OHRQoL. Satisfaction can be relative to the initial needs of the patient, whereas OHRQoL can be a more comprehensive assessment (Allen et al. 2001). Nonetheless, such undefined applications of PROMs have been the cause of heterogeneity within the literature despite the validation and widespread use of certain instruments specific to overall denture satisfaction (Vervoorn et al. 1988; de Souza et al. 2020). The assessment of satisfaction has varied from single global items to ad hoc scales, with no apparent standardized assessment instrument. A major concern with ad hoc scales is that they often lack consideration of content validity and other psychometric properties, raising doubts about whether they are accurately measuring what they are intended to assess (McGrath et al. 2012).

In contrast, ClinROs—apart from traditional standardized outcomes such as changes in marginal bone level and survival rates of implants and prostheses—have not focused on assessing the clinician's perceptions and ease of treatment in the studies included. Over the past decade, there has been a shift in implant dentistry from specialists to private practitioners. This transition has also led to a tendency in the current academic field to shift from efficacy trials to effectiveness trials, with a focus on results derived from practitioner settings. This trend suggests a need for clinical approaches in implant dentistry, which would reduce the complexity and skills needed to perform treatment with dental implants. One possible option is to reduce both the number and size of implants. Such an approach would shorten the planning phase, reduce surgery time, and minimize the invasiveness of the treatment, making implant therapy more accessible for private practitioners, thereby increasing patient access.

Shorter dental implants, originally introduced as adjunctive or transitional solutions rather than long-term solutions, are currently under extensive investigation for various clinical indications, particularly in single-tooth fixed dental prostheses (Rossi et al. 2016). In the present systematic review, only two studies utilized short implants of a length of 6 mm, whilst in 19 studies, implants of at least 7 mm in length were placed to support removable prostheses. This lack of clinical studies using shorter implants is to some extent surprising, since the dimension of the maxillary sinus extends following tooth extraction, limiting the available ridge height in the posterior maxilla for the placement of a standard-length dental implant.

It is anticipated that following recommended clinical guidelines, which suggest the use of four implants to support a removable prosthesis in the maxilla, more studies will focus on strategies to minimize invasiveness and reduce the need for large bone augmentation procedures. Apart from shorter dental implants, other options serving a similar purpose include mini dental implants, angulated standard-length implants in the posterior region, or even zygomatic implants. The latter treatment option has been suggested for maxillary edentulous patients with a severely reduced ridge dimension to support fixed implant-borne prostheses. Common indications encompass: sites where a sinus augmentation is impractical (failed previous sinus augmentation), a rehabilitation after tumor resection or trauma, failure of conventional implants, failure of previous bone grafts, and utilization of remaining bone in the maxilla (predominantly the zygomatic bone).

Placement of zygomatic implants requires highly skilled clinicians with great expertise, which somewhat contradicts the current trend towards simpler clinical procedures (Brennand Roper et al. 2023). Notably, none of the included clinical studies addressed the use of zygomatic implants to support removable prostheses. Given the challenges and limitations associated with zygomatic implants, it is unlikely that a larger number of clinical studies will address this scenario.

A key finding of this systematic review was the variability in the reported PROMs across the included studies, which made statistical synthesis difficult. One approach to address this issue is the adoption of a Core Outcome Set, which specifies the essential outcomes that should be consistently collected and reported (Clarke 2007). In the field of implant dentistry, recent efforts have been made to standardize a minimum set of outcomes (Tonetti et al. 2023). Implementing a Core Outcome Set does not restrict a study to only those outcomes; rather, it ensures that these core outcomes are always collected and reported, while allowing researchers to include additional outcomes that are relevant to their specific research goals (Williamson et al. 2012). Moreover, these core outcomes are expected to evolve over time. This review represents a more focused effort to identify which outcomes can be refined or added for patients with an edentulous maxilla undergoing rehabilitation with implant-supported removable prostheses.

The present review has some limitations. Since this study aimed to investigate patient- and clinician-reported outcomes in relation to implant length, outcome comparison with standard treatment approaches without implants (i.e., complete denture) was not conducted and should be noted as one of the limitations. Moreover, the lack of studies discussing clinicians' perceptions makes it difficult to establish guidelines for selecting appropriate IOD therapy options, especially among practitioners with varying levels of expertise.

5 | Future Perspective

Incorporating ClinROs based on standardized questionnaires with a defined scale is crucial for the entire research community.

Additionally, the use of electronic records (ePROMs/iPROMs) based on big data, consistently reported in future studies, will provide valuable information to support decision-making during treatment planning, benefiting both clinicians and patients.

6 | Conclusions

Despite the frequent use of PROMs in clinical trials, the lack of standardization makes it difficult to conduct meaningful comparisons across studies. While objective ClinROs have been documented in most of the various studies, subjective ClinROs that reflect clinicians' perceptions were notably absent.

Author Contributions

Jin-Young Park: writing – original draft, investigation. **Seung-Hyun Park:** data curation, investigation, writing – review and editing, formal analysis, project administration. **Sofya Sadilina:** methodology, data curation, project administration, investigation, formal analysis. **Ronald Jung:** supervision. **Daniel Thoma:** supervision, writing – original draft, writing – review and editing, conceptualization, methodology. **Franz J. Strauss:** formal analysis, supervision, writing – review and editing. **Ui-Won Jung:** conceptualization, writing – review and editing, supervision, visualization.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.