Different Interventions for Rehabilitation of the Edentulous Maxilla with Implant-Supported Prostheses: An Overview of Systematic Reviews

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Purpose: To synthesize evidence derived from systematic reviews (SRs) on different interventions for rehabilitation of the edentulous maxilla with implant-supported restorations. ***Materials and Methods:*** A protocol-oriented search was established to address the PICO question: What is the current evidence regarding rehabilitation of the edentulous maxilla with different implant-supported prostheses in terms of implant and prosthesis survival? The primary outcomes were implant and prosthesis survival rates evaluated from SRs of clinical studies including adult patients with complete edentulism of the maxilla and comparing different implant-supported rehabilitation strategies. Methodologic quality of the SRs was assessed with the AMSTAR-2 tool. ***Results:*** The final selection process led to the inclusion of 36 SRs that were grouped as: *(1)* addressing maxillae with sufficient bone to place implants; *(2)* addressing maxillae with insufficient bone to place implants; and *(3)* comparing different types of prosthesis, number of implants, patient-reported outcomes, and economic evaluations. The literature describes four or more implants as suitable for full-arch fixed prostheses and implant-supported overdentures; in both cases, the overall survival rate is > 95%. Mini-implants present very high short-term failure rates (> 30%). Poor description of technical complications, adjustments, and maintenance and corresponding costs precluded a cost-effectiveness analysis. ***Conclusion:*** No implant-supported rehabilitation of the edentulous maxilla (fixed or removable) should be supported on fewer than four implants. A one-piece full-arch fixed dental prosthesis can be supported by a minimum of two anterior axial plus two posterior distally tilted implants or by six to eight axial implants symmetrically distributed through the posterior and anterior regions of the arch. Four to six implants is the advised number to support an overdenture. The use of mini-implants in the maxilla is inadvisable. *Int J Prosthodont 2020;34(suppl):s63–s84. doi: 10.11607/ijp.7162*

The most recent estimates regarding the burden of oral conditions derived from the Global Burden of Diseases study[1] indicate an age-standardized prevalence of complete tooth loss of 3.3% (2.9% to 3.7%), affecting more than 10% of people in cohorts over 50 years of age. Upper-middle and high-income countries present the greatest burden of total tooth loss,[2] with a prevalence of approximately 200 million people. However, the prevalence or incidence of the edentulous maxilla by itself is not clear.

In addition to being associated with several comorbidities,[3] an edentulous maxilla impairs the ability to chew and speak properly and even affects and changes an individual's appearance. The sequelae are not only physical, but could also be social, psychologic, and emotional, particularly in cases of early onset, with consequences in quality of life and self-esteem.[4]

An implant-supported prosthetic rehabilitation for edentulous patients is a well-established and highly predictable treatment modality.[5–7] Dental implants enhance the support, retention, and stability of a prosthesis[8–10] but require adequate bone volume (either pristine or regenerated) for placement in the desired locations. Though the long-term stability and success of implant procedures have been highly associated

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with the quality and quantity of the supporting bone,[11,12] the prosthesis itself also plays a decisive role, particularly in the maintenance and survival of the restoration and patient-reported outcomes.[8,13] In fact, the prosthetic options for a patient missing all their maxillary teeth should consider the individual's esthetic and functional needs—such as lip support and lip line height, interarch space, and dexterity to perform oral hygiene[14–16]—rather than merely considering the available bone to place implants.

The healing process that follows tooth extraction comprises resorption of the alveolar ridge in a time-dependent and highly variable manner that translates into significant vertical and horizontal dimensional changes.[17,18] Most of these 3D changes take place during the immediate postextraction period, seem to be more pronounced at the buccal aspect of the ridge,[19] and continue throughout life, contributing to the progressive atrophy in the maxilla. As a consequence, rehabilitation of the edentulous maxilla becomes highly challenging, particularly in situations of severe ridge resorption[20–22] resulting from disuse atrophy due to long-term edentulism,[18,23–25] an ill-fitting prosthesis, trauma, periodontal disease, or situations of limited bone volume in the posterior region due to pneumatization of the maxillary sinus.

Implant rehabilitation of the edentulous maxilla is possible using fixed or removable prostheses. The choice, as previously mentioned, should be based primarily on patient expectations and prosthetic considerations, always considering anatomical limitations and financial issues.[15,26,27]

If there is no need for bone grafting (meaning there is sufficient bone volume in width and height), rehabilitation with an implant-supported fixed prosthesis (one-piece or segmented) could be performed using an adequate number of axial, parallel conventional implants maximally distributed across the arch (anteriorly and posteriorly). A similar approach can be used for an implant-supported removable prosthesis (overdenture), generally using fewer implants, splinted by a bar or free-standing.[13,27,28]

If there are anatomical constraints related to bone volume, then grafting procedures can be considered. To avoid the invasiveness of large restorations, the use of shorter/narrow implants with enhanced surface topographies or of tilted or extraalveolar implants (including pterygoid and zygomatic implants) can also be considered, irrespective of the type of prosthesis.[29]

Bearing this in mind, it is important to clarify the many influencing factors in the treatment options for rehabilitation of the edentulous maxilla. Despite the importance of meeting patient-specific needs, the possibility of bone augmentation procedures and the appropriate number, diameter, size, and positioning of the implants should be discussed according to the availability of bone volume and the type of prosthesis in order to increase the predictability and longevity of the treatments.

Thus, the aim of the present work was to synthesize evidence derived from systematic reviews (SRs) with or without meta-analyses on different interventions for rehabilitation of the edentulous maxilla with implant-supported restorations in order to create a decision tree to help facilitate the decision-making process for the clinician.

MATERIALS AND METHODS

Criteria for Considering Reviews for Inclusion

The present overview used the following research question: What is the current evidence regarding rehabilitation of the edentulous maxilla with different implant-supported prostheses in terms of implant and prosthesis survival?

The present overview considered eligible for inclusion SRs of RCTs, quasi-RCTs (QRCTs), and cohort studies comparing different modalities of prosthetic rehabilitation of the edentulous maxilla that met the following criteria for participants and interventions:

- Participants: Adult patients (≥ 18 years) with complete edentulism of the maxillary arch, regardless of the cause of tooth loss.
- Interventions: All modalities of rehabilitation of the edentulous maxilla using any type of implant-supported prosthesis. This could include comparisons of fixed vs removable implant-supported prostheses, evaluation of the number of implants needed for implant-supported full-arch rehabilitations of the maxilla, comparisons of different implant distributions and prosthesis designs (one-piece vs segmented, free-standing vs splinted), and comparisons of bone regeneration procedures vs implant angulations.

Reviews of study designs other than RCTs, QRCTs, or cohort studies, or narrative reviews with insufficient explanation of the research strategy, were excluded.

If a review pooled together data from individual studies for situations of complete maxillary edentulism and partial edentulism, the authors included that data with no modifications. However, the authors extracted data pertaining only to completely edentulous patients in cases where it was possible to do so. A similar procedure was applied to reviews addressing both the maxilla and mandible.

In the case of identification of overlapping reviews (ie, reviews exploring the same participants, interventions, comparisons, and outcomes), the most up-to-date and comprehensive review was selected, and the remaining reviews were excluded.

Since this overview focused only on maxillary completely edentulous patients and not on patients with terminal dentition, reviews including studies on hopeless teeth extraction and immediate placement of implants were excluded, unless there was a comparison of immediate vs delayed or early implant placement procedures, for which the data were extracted.

Outcomes

The primary outcomes of interest to this overview were:

- Implant failure, defined as a biologic failure due to peri-implant radiolucency, mobility, pain, or infection or removal of stable implants dictated by progressive marginal bone loss; or as a mechanical failure due to implant fracture or any other mechanical failure impairing the use of the implant
- Prosthesis failure, defined as fracture of any part of the definitive prosthesis requiring replacement with a new one

Secondary outcomes included the assessment of:

- Biologic complications, encompassing peri-implant mucositis,[30] peri-implantitis,[31] and inflammation and/or hypertrophy/hyperplasia of the soft tissue under the prosthetic elements.
- Technical complications, defined as unanticipated events that affected the prostheses, requiring corrective intervention but not replacement. These were categorized as implant-related (screw loosening and/or fracture) or prosthesis-related (chipping of veneering material, wear of acrylic resin teeth, fracture of retentive elements in overdentures).
- Maintenance appointments to perform hygiene of the prosthesis or to replace retention inserts.
- Patient satisfaction and quality of life (QoL) using validated instruments.
- Cost-effectiveness.

Search Methods for Identification of Reviews

For identification of reviews to be included, a sensitive search strategy was developed for the Cochrane Database of Systematic Reviews (CDSR), MEDLINE via PubMed, and the Dentistry & Oral Sources Database via EBSCOhost, from inception to October 20, 2019, considering the population and intervention concepts of the PICO question. The specific search protocols are available in Appendices 1 to 3 (see appendices in the online version of this article at www.quintpub.com/journals). The electronic search was complemented by a hand search of the following journals: *Journal of Clinical Periodontology*, *Journal of Periodontology*, *Periodontology 2000*, *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *European Journal of Oral Implantology*, *Journal of Dentistry*, *The International Journal of Prosthodontics*, *The International Journal of Oral & Maxillofacial Implants,* and *Journal of Oral and Maxillofacial Surgery*.

Only reviews in the English language were considered.

Data Collection and Analysis

Selection of reviews

After removal of duplicates, two authors (A.M. and P.N.) independently screened the titles and abstracts for relevance based on the objectives of each review, the population included, and the interventions and outcomes assessed, excluding obviously irrelevant reviews. The two authors then assessed the full texts of the remaining reviews in order to select the final sample to be included. If at any point disagreement arose between the two authors, a third author (F.G.) was consulted to reach consensus.

Data extraction and management

The same two authors independently extracted the data from each review to specific form-containing fields related to the principal features of the review: authors, aims and rationale, number and types of studies included, date interval of studies included, participants, interventions, comparisons, tool used for quality assessment, outcomes, main results with or without meta-analysis, and conclusions. Disagreements were debated with the same third author to achieve consensus.

Assessment of methodologic quality of included reviews

The methodologic quality of the included reviews was assessed using the AMSTAR-2 measurement tool for appraisal of SRs of randomized and nonrandomized studies of health care interventions.[32]

Data synthesis and statistical analysis

The statistical unit of analysis was the SR included. Relevant data from each review were synthesized in summary of results tables including the primary and secondary outcomes of the interventions, the number of studies and participants, mean estimates (continuous outcomes), and relative risks (binary outcomes) with 95% CI. If extracting these data was not possible, a narrative synthesis was inserted in the tables instead.

RESULTS

The original electronic search in MEDLINE (PubMed), EBSCOhost, and the CDSR retrieved 191, 62, and 4 records, respectively. The hand search identified 16 potentially relevant records. After removing duplicates, the titles and abstracts of 248 records were screened. This analysis allowed for the exclusion of 166 records, and 82 full texts were retrieved. After critical analysis

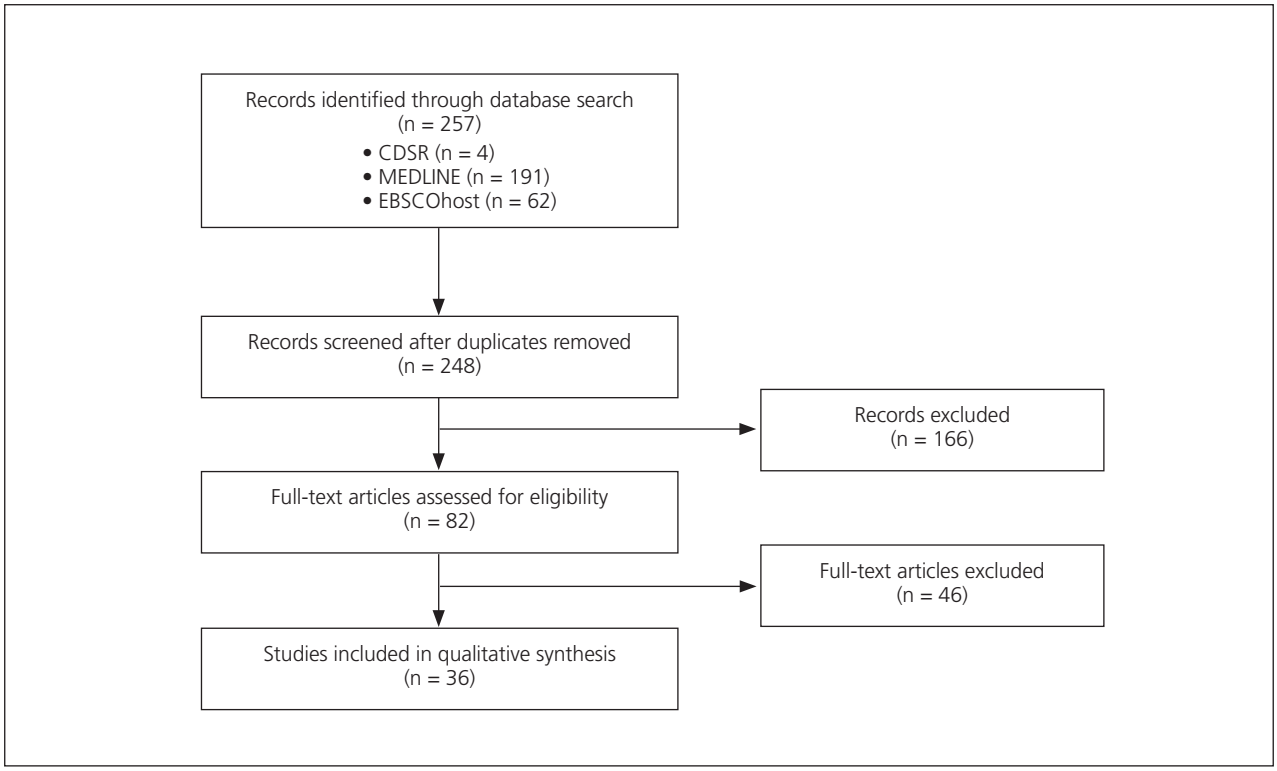

Fig 1 Flowchart for study selection.

of the texts, 48 studies were excluded (Appendix 4). Figure 1 describes the process of identification of the remaining studies.

Study Characteristics

The selection process led to the inclusion of 34 SRs. Only 1 SR was exclusively based on RCTs.[33] All other cases extended the inclusion criteria to nonrandomized trials and cohort designs. The included studies are summarized in Table 1.[5,7,8,11,26,28,29,33–59]

Twenty-one of the 34 reports included only participants with completely edentulous maxillae. Fifteen reviews included a mixed population of participants: 12 reviews also included completely edentulous mandibles,[8,26,34–43] 1 review also included partially edentulous patients,[33] and 2 reviews included completely edentulous mandibles, as well as partially edentulous patients.[44,45]

Even though there was broad heterogeneity and clinical variation among the selected SRs, within the context of the focus question, the authors could identify three main categories based on the interventions assessed:

1. Addressing rehabilitation of the edentulous maxilla with minimal atrophy/sufficient bone to place implants (n = 8)
2. Addressing rehabilitation of the edentulous maxilla with moderate to severe atrophy/insufficient bone to place implants, without bone grafting procedures (n = 10) and with bone grafting procedures (n = 4)
3. Addressing the types of rehabilitation, number of implants required, patient-reported outcomes, and economic evaluations (n = 12)

It was not possible to identify evidence on the outcome defined a priori of peri-implantitis risk.

The application of the AMSTAR-2 tool identified 7 high-quality SRs,[34,37,39,43,46–48] 15 moderate-quality SRs,[5,8,11,29,33,38,40,41,44,49–54] and 12 low-quality SRs.[7,26,28,35,36,42,45,55–59] The main reasons for a score of moderate quality were the absence of a list of excluded studies and corresponding reasons for exclusion and no description of the source of funding of the studies included in the review. SRs classified as low quality had major methodologic flaws, such as study selection and data extraction not performed in duplicate, inadequate description of the studies included, or no evaluation of the risk of bias.

Interventions for Rehabilitation of the Edentulous Maxilla

With minimal atrophy/bone loss

Eight SRs (Table 2) reported the clinical outcomes of full-arch fixed dental prostheses and implant-supported

Table 1 Description of the Systematic Reviews Included

Study, y	Date range of studies included	Objectives (as stated within review)	No. of studies included and study types	Outcome measures
Aghaloo et al,[11] 2016	1990–2014	The aim of this systematic review was to evaluate literature from the last 30 years to determine predictability for bone augmentation in the edentulous maxilla for implant placement as well as implant survival.	40 RCT/CCT: 7 Prospective: 6 Case series: 3 Retrospective: 24	Implant survival
Al-Moraissi et al,[33] 2018	2009–2018	The authors hypothesized there would be no differences in implant and prosthesis failures, marginal bone changes, and intra- and postoperative complications between short implant placement without augmentation or with crestal sinus lift with or without bone grafting and long implant placement using lateral sinus lift with or without bone grafting for rehabilitation of the posterior maxilla with an intermediate residual bone height. Hence, the specific aims of this network meta-analysis were to challenge this hypothesis and to identify the best rehabilitation method for patients with a posterior atrophic maxilla with 4 to 8 mm of alveolar ridge in relation to implant and prosthesis failure rates, marginal bone changes, and intra- and postoperative complications.	3[a] RCT/CCT: 3	Implant survival; technical complications
Alfadda,[49] 2014	2003–2012	The objectives of this literature review were to present sound clinical evidence about the use of an immediately loaded implant-supported overdenture in the edentulous maxilla, to scientifically appraise the reported clinical and psychosocial outcomes.	6 Prospective: 6	Implant survival; prosthesis survival
Apaza Alccayhuaman et al,[34] 2018	2001–2017	The objective of the present systematic review was to answer the following focused question: "what is the rate of biological complications, technical complications, and patient-reported outcome measures (PROMs) among partially/fully edentulous adult patients treated with tilted and straight implants after at least 3 years of function?"	14[a] Prospective: 7 Retrospective: 7	Implant survival; technical complications
Araújo et al,[50] 2019	1994–2015	Thus, the aim of this systematic review was to analyze pterygoid implant survival rates in patients with atrophic posterior maxilla.	6 Case series: 6	Implant survival; technical complications
Att et al,[7] 2009	1981–2008	The aim of the present report was to describe the different treatment approaches available for the fixed rehabilitation of the edentulous maxilla in the presence of various hard and soft tissue conditions and to review the clinical outcome of each treatment approach.	41	Implant survival; prosthesis survival
Chiapasco,[35] 2004	1966–2003	The main objective of this review was to evaluate the reliability of studies of early and immediate loading of implants placed in the edentulous mandible and maxilla and rehabilitated with either implant-supported overdentures or implant-supported fixed prostheses.	8[a] Prospective: 6 Retrospective: 2	Implant survival
Chiapasco et al,[36] 2009	1975–2008	The objective of this review was to analyze publications related to augmentation procedures and to evaluate *(1)* the success of different surgical techniques for the reconstruction of the deficient alveolar bone and *(2)* the survival/success rates of implants placed in the reconstructed areas.	105[a,b] RCT/CCT: 6 Prospective: 22 Retrospective: 77	Success of augmentation procedures; morbidity; implant survival
Chrcanovic et al,[44] 2015	1999–2014	The purpose of the present review was to test the null hypothesis of no difference in the implant failure rate, marginal bone loss, and postoperative infection for patients being rehabilitated by tilted or by axially placed dental implants, against the alternative hypothesis of a difference.	37[a] Prospective: 22 Retrospective: 15	Implant survival
Chrcanovic et al,[55] 2016	1998–2015	The purpose of the present systematic review was to assess the survival rate of zygomatic implants and the prevalence of complications based on previously published clinical studies.	68 RCT/CCT: 1 Prospective: 16 Retrospective: 51	Implant survival
Daudt Polido et al,[37] 2018	1995–2017	A focused question using the PICO (population, intervention, comparison, outcomes) format was developed, questioning whether "in patients with an implant-supported fixed complete dental prosthesis, do implant/prosthetic outcomes differ between five or more compared to fewer than five supporting implants?"	47[a] RCT/CCT: 6 Prospective: 18 Retrospective: 23	Implant survival; prosthesis survival
de Luna Gomes et al,[38] 2019	2000–2018	The purpose of this systematic review was to evaluate the outcomes of complete-arch prostheses in studies with different numbers of implants and a follow-up of at least 5 years.	11[a] CCT/RCT: 5 Prospective: 6	Implant survival; prosthesis survival
Di Francesco et al,[51] 2019	2000–2017	Thus, the aim of this systematic review was to analyze the results of research investigating the number of implants required to support a maxillary overdenture in order to obtain optimal treatment outcomes in terms of implant survival, overdenture longevity, and patient satisfaction.	28 RCT/CCT: 4 Prospective: 13 Retrospective: 11	Implant survival; prosthesis survival; patient satisfaction

[a]Number of studies reporting on the completely edentulous maxilla (exclusively or combined with mandible).
[b]Onlay bone grafts (n = 24)*: prospective = 5, retrospective = 19; sinus floor elevation with lateral approach (n = 59): RCT = 2, CCT = 4, prospective = 12, retrospective = 41; sagittal osteotomy (n = 4): prospective = 1; retrospective = 3; vertical distraction osteogenesis (n = 5): prospective = 3; retrospective = 2; Le Fort I osteotomy with inlay grafts (n = 13): prospective = 1; retrospective = 12.

Table 1 Description of the Systematic Reviews Included *(continued)*

Study, y	Date range of studies included	Objectives (as stated within review)	No. of studies included and study types	Outcome measures
Goodacre and Goodacre,[26] 2017		Therefore, the purpose of this literature review was to compare implant-fixed complete dentures (IFCD) with implant overdentures (IOD), based on the comparisons that have been studied in the dental literature.	Not specified	Implant survival: prosthesis survival; technical complications; maintenance; patient satisfaction
Heydecke et al,[45] 2012	1995–2011	The aim of the present systematic review was therefore to assess the 5-year survival and complication rates of implant-supported fixed reconstructions in partially and totally edentulous patients with regard to the optimal number and distribution of dental implants—and to derive a recommendation for the lowest number of implants required for a certain type of reconstruction.	5[a] Prospective: 4 Retrospective: 1	Implant survival
Jokstad et al,[29] 2016	1994–2014	The main objective of this systematic review was to identify and critically appraise scientific publications to evaluate the possible effect of implant design on treatment outcomes in the rehabilitation of the fully edentulous maxilla.	105	–
Kern et al,[39] 2016	1996–2013	Thus, the aim of this systematic review was to address the following focused question: Is there an impact of implant location (maxilla vs mandible), implant number, type of prosthesis (fixed vs removable), and/or different anchorage systems on the implant loss rate concerning the implant-prosthodontic rehabilitation of edentulous patients?	18[a] Prospective: 18	Implant survival
Kwon et al,[40] 2014	1995–2013	Therefore, the aim of this systematic review was to investigate both short (5–10 years) and long-term (10 years or more) survival and success of fixed dental hybrid prosthesis and supporting dental implants used for rehabilitating a completely edentulous ridge.	10[a] Prospective: 5 Retrospective: 5	Implant survival: prosthesis survival; technical complications; patient satisfaction
Lambert et al,[56] 2009	1990–2005	This study assessed implant survival rates in relation to surface characteristics, ancillary procedures, and prosthodontic considerations, evaluating the survival rate of fixed implant–supported rehabilitations with regard to prosthetic design, dental materials, and implant number and distribution along the edentulous arch.	33 Prospective: 33	Implant survival; prosthesis survival
Lemos et al,[41] 2017	2010–2013	Therefore, the aim of this systematic review was to verify the viability of using mini-implants to retain overdentures.	3[a] Prospective: 33	Implant survival; prosthesis survival
Lin and Eckert,[52] 2018	2007–2017	The primary aim of this systematic review of the literature was to determine the clinical performance of dental implants that are intentionally tilted toward distal aspect of edentulous jaws when compared with implants that are placed following the long axis of the residual alveolar ridge, in the edentulous patients.	42 RCT/CCT: 2 Prospective: 20 Case series: 15 + Gray literature: 1 SRs: 4	Implant survival: prosthesis survival; technical complications; patient satisfaction
Mericske-Stern and Worni,[28] 2014	1981–2011	The aim of the present review was to identify reliable data on the fixed dental prostheses on oral implants in the edentulous jaw. The focus was placed on the number of implants that were used to support the prostheses.	29 RCT/CCT: 2 Prospective: 18 Retrospective: 8	Implant survival: prosthesis survival; technical complications
Ohkubo and Baek,[42] 2010	1996–2009	This review addresses the question of whether the existence of remaining teeth is a risk factor for the longevity of implant overdentures.	10[a]	Implant survival and success
Osman et al,[57] 2012	1991–2010	The aim of this review is to critically evaluate the literature on prosthodontic maintenance requirements for maxillary implant overdentures using different prosthodontic designs.	18 Prospective: 8 Retrospective: 10	Prosthesis survival; technical complications
Papaspyridakos et al,[5] 2014	2001–2013	The purpose of this systematic review was to investigate the effect of immediate implant loading with fixed prostheses on implant and prosthesis survival, failure, and complications in edentulous patients compared to early and conventional loading.	62 RCT/CCT: 6 Prospective: 34 Retrospective: 22	Implant survival; prosthesis survival
Poli et al,[46] 2019	1997–2017	"In edentulous patients with severely resorbed jaws that underwent Le Fort I osteotomy to receive implant- supported rehabilitations, what are the survival and success rates of dental implants?"	20	Implant survival
Raghoebar et al,[47] 2019	2008–2018	Therefore, the objectives of the current review were to assess the ≥ 5-year effectiveness of MSFA procedures that use the lateral window technique as well as to assess differences in outcome between simultaneous and delayed implant placement, partially or fully edentulous patients, and various grafting procedures.	11 Prospective: 11	Implant survival; technical complications;
Ravidà et al,[48] 2019	1998 –2017	Thus, the aim of this systematic review was to identify studies reporting on bone- and tissue-level extra-short implants with regard to failure, prosthetic/biologic complications, MBL, and patient-reported outcomes.	19 RCT/CCT: 11) Prospective: 7	Implant survival: prosthesis survival; technical complications

Table 1 Description of the Systematic Reviews Included *(continued)*

Study, y	Date range of studies included	Objectives (as stated within review)	No. of studies included and study types	Outcome measures
Sadowsky and Zitzmann,[58] 2016	1997–2014	The purpose of this study was to complete a systematic review of articles evaluating patient-based outcomes after max IOD treatment.	20 RCT/CCT: 2 Prospective: 13 Retrospective: 5	Implant survival; prosthesis survival; technical complications; patient satisfaction
Schiegnitz and Al-Nawas,[53] 2018	1995–2017	The aim of this comprehensive literature review was to conduct a meta-analysis comparing the implant survival of NDI (narrow diameter implants) and SDI (standard diameter implants).	72 in qualitative analysis, 16 in quantitative analysis	Implant survival
Schimmel et al,[43] 2014	2002–2012	The purpose of this systematic review and meta-analysis is to test the hypothesis that immediate loading protocols for implant-supported overdentures show 1-year survival rates similar to early or conventional loading protocols.	13[a] RCT/CCT: 1 Prospective: 12	Implant survival and success
Schley and Wolfart,[54] 2011	1990–2010	The aim of the present systematic review was to identify all relevant clinical studies, or rather randomized controlled trials (RCTs), on the prosthetic rehabilitation of the edentulous maxilla by means of implant insertion.	27 RCT/CCT: 3 Prospective: 24	Implant survival; prosthesis survival; technical complications
Tuminelli et al,[59] 2017	2006–2015	The purpose of this systematic review was to report on the outcome of immediately loaded zygomatic implant scenarios, the surgical and prosthetic success, and complications from 1990 until June 2016.	38	Implant survival: prosthesis survival; technical complications
Yao et al,[8] 2018	2000–2016	The purpose of this systematic review was to assess the existing evidence from edentulous patients' PROMs of their fixed or removable implant-supported prostheses.	8[a] Prospective: 4 Retrospective: 3 Cross-sectional: 1	Patient satisfaction

PROMs = patient-reported outcome measures.
[a]Number of studies reporting on the completely edentulous maxilla (exclusively or combined with mandible).
[b]Onlay bone grafts (n = 24)*: prospective = 5, retrospective = 19; sinus floor elevation with lateral approach (n = 59): RCT = 2, CCT = 4, prospective = 12, retrospective = 41; sagittal osteotomy (n = 4): prospective = 1; retrospective = 3; vertical distraction osteogenesis (n = 5): prospective = 3; retrospective = 2; Le Fort I osteotomy with inlay grafts (n = 13): prospective = 1; retrospective = 12.

overdentures after variable times of follow-up (from 1 to 15 years). Four of these addressed fixed full-arch dental prostheses,[5,7,40,56] and one addressed both fixed and removable implant-supported prostheses.[35] Despite the classification of low and moderate quality in the AMSTAR-2 classification, these SRs indicate 5-year implant survival rates ranging from 82%[7] to 91.4%[40] and prosthesis survival rates over 93%.[7,40,56] For implant-supported overdentures, one high-quality SR[43] presented implant survival rates over 97.4% for overdentures supported by four or more implants, regardless of the use of splinted or unsplinted implants, for follow-ups ranging from 1 to 10 years. Lower survival rates were reported for overdentures with a lower number of implants.[49]

With moderate to severe atrophy/bone loss

Without bone grafting procedures. Strategies for rehabilitation of the edentulous maxilla with moderate to severe atrophy without the use of bone grafting procedures included the use of short implants (SI),[33,41] the use of narrow-diameter implants (NDI)[53] and mini-implants,[41] the use of tilted implants,[34,44,52] and the use of extra-alveolar implants (zygomatic implants[55,59] or pterygoid implants[50]), as detailed in Table 3.

SIs were evaluated for up to 5 years, presenting a failure risk similar to that of of long implants with lateral sinus floor elevation, with an odds ratio (OR) of 1.20 (0.49 to 3.34)[33] and lower intraoperative complications. Very limited data are available detailing the performance of these implants in completely edentulous maxillae. The high-quality SR by Ravidà et al[48] indicates that the survival of SI in the maxilla reduced from 96.9% at 1 year to 91.7% at 5 years, but splinting reduced the relative risk of implant failure by 1.96 (95% CI: 0.8 to 4.8) times—although this was not significant—and the risk of prosthetic complications by 3.32 times (95% CI: 1.9 to 5.7), which was significant.

The use of NDIs for mixed indications in the maxilla and mandible was evaluated according to their classification as NDI Category 1 (one-piece implants < 3-mm diameter), NDI Category 2 (one- or two-piece implants 3.0–3.5-mm diameter), and NDI Category 3 (two-piece implants with 3.3–3.5-mm diameter).[53] On one hand, the use of NDI Category 1 implants, or mini-implants, to retain maxillary overdentures is associated with very high short-term failure rates (31.7% at 1 to 2 years of follow-up), conversely to what happens in similar mandibular

Table 2 Summary of Results of Systematic Reviews Addressing the Edentulous Maxilla with Sufficient Bone and Methodology Quality Assessment

Study, y	Title	Study population/ no. of participants (no. of implants)	Intervention(s)	Duration of follow-up	Meta-analysis performed
Alfadda,[49] 2014	Early and Immediate Loading Protocols for Overdentures in Completely Edentulous Maxillas: A Comprehensive Review of Clinical Trials	Completely edentulous patients (maxilla)/145 (708)	Immediate or early loading of implant-supported overdentures with 3–8 implants	1–2 y	No
Att et al,[7] 2009	Fixed Rehabilitation of the Edentulous Maxilla: Possibilities and Clinical Outcome	Completely edentulous patients (maxilla)/793 (5,278)	Full-arch fixed dental prostheses	1–15 y	No
Chiapasco,[35] 2004	Early and Immediate Restoration and Loading of Implants in Completely Edentulous Patients	Completely edentulous patients/53 (463)	Immediate or early loading of implant-supported overdentures and full-arch fixed dental prostheses	1–5 y	No
Kwon et al,[40] 2014	Systematic Review of Short- (5–10 Years) and Long-Term (10 Years or More) Survival and Success of Full-Arch Fixed Dental Hybrid Prostheses and Supporting Implants	Completely edentulous patients/not possible to determine	Full-arch fixed dental prostheses	5–10 y, > 10 y	No
Lambert et al,[56] 2009	Descriptive Analysis of Implant and Prosthodontic Survival Rates with Fixed Implant–Supported Rehabilitations in the Edentulous Maxilla	Completely edentulous patients (maxilla)/1,320 (8,376)	Full-arch fixed dental prostheses	1–15 y	No
Ohkubo and Baek,[42] 2010	Does the Presence of Antagonist Remaining Teeth Affect Implant Overdenture Success? A Systematic Review	Completely edentulous patients/259 (NR)	Implant-supported overdentures	3.2–10 y	No
Papaspyridakos et al,[5] 2014	Implant Loading Protocols for Edentulous Patients with Fixed Prostheses: A Systematic Review and Meta-Analysis	Completely edentulous patients/1,244 (6,956)	Conventional, early, or immediate loading of full-arch fixed dental prostheses	1–10 y	No
Schimmel et al,[43] 2014	Loading Protocols for Implant-Supported Overdentures in the Edentulous Jaw: A Systematic Review and Meta-Analysis	Completely edentulous patients/167 (727)	Immediate, early, or conventional loading of implant-supported overdentures with splinted and unsplinted implants	1–10 y	Yes

NR = not reported.

rehabilitations (4.9%).[41] On the other hand, the use of NDI Class III implants in completely edentulous maxillae presents survival rates ranging from 97% to 100%,[53] supporting both overdentures and full-arch fixed dental prostheses.

Three nonoverlapping SRs described the performance of intentionally tilted implants[34,44,52] both in the mandible and maxilla. In Chrcanovic et al,[44] data pooled only from the maxilla indicated higher failure risk for tilted implants, with an OR of 1.70 (1.05 to 2.74). However, when considering exclusively completely edentulous maxillae, Lin and Eckert[52] presented survival rates of tilted implants ranging from 93.6% to 100%, which were comparable to axial implants (95.3% to 100%) for follow-ups of 1 to 5 years. Likewise, Apaza Alccayhuamann et al[34] presented similar survival rates for tilted implants with an OR of 0.95 (0.70 to 1.28), but cautions when interpreting these results because of the low precision in the estimates and quality of evidence.

Results	Conclusions (as stated within review)	AMSTAR-2 quality grade
Implant survival: 84.7% to 99.3% Prosthesis survival: 100%	The immediate/early loading of dental implants with a maxillary overdenture is a predictable treatment approach and provides favorable implant/prosthesis survival, soft tissue health, and psychological outcomes.	Moderate
5 y: Implant survival: 82% to 98% Prosthesis survival: 93.3% to 100% 10 y: Implant survival: 81% to 96.6% Prosthesis survival: 81% to 100%	To date, implant-supported fixed dental prosthesis can be recommended only if regular implants are placed and a delayed loading protocol is used.	Low
No articles on immediate or early loading of implant-supported overdentures. Full-arch fixed prostheses implant survival: 87.5% to 100%	No meaningful data are available about immediate or early loading of edentulous maxillae with implant-supported overdentures. The use of immediate or early loading of fixed implant-supported prostheses in the maxilla is not supported by sufficient data to consider this treatment modality as routine, although preliminary results seem to be encouraging.	Low
5–10 y: Implant survival: 91.4% to 100% Prosthesis survival: 93.3% to 100% > 10 y: Implant survival: 78.3% to 93% Prosthesis survival: 82% to 92.8%	Within the limitation of the current study, implants and full-arch fixed dental hybrid prostheses showed rather high short-term survival rates. However, due to limited available literature, their long-term survival rates could not be obtained.	Moderate
1 y: Implant survival: 94% Prosthesis survival: 98.2% 5 y: Implant survival: 90.7% Prosthesis survival: 94.6% 10 y: Implant survival: 90.3% Prosthesis survival: 92.1%	The descriptive implant survival rate when restoring an edentulous maxilla with implant-supported fixed prostheses decreased from 94% at 1 year, to 92.3% at 3 years, 90.7% at 5 years, 90.3% at 10 years, and 87.7% at 15 years. When restoring an edentulous maxilla with implant-supported fixed prostheses, the prosthodontic survival rate decreased from 98.2% at 1 year, to 95.8% at 3 years, 94.6% at 5 years, and 92.1% at 10 years. The prosthetic design, veneering material, and number of prostheses per arch had no influence on the prosthodontic survival rate. The implant number and distribution along the edentulous maxilla seem to influence the long-term prosthodontic survival rate.	Low
Implant survival: 72.9% to 99.2%	In maxillary implant overdentures, the presence of antagonist teeth might be a risk factor for success, but is certainly not a contraindication.	Low
1 y: Implant survival: 99.2% to 99.6% Prosthesis survival: 99.1% to 99.9%	With careful patient selection and using implants with rough surfaces, immediate loading with fixed prostheses in edentulous patients has the same effect on implant survival, failure, and complications as with early and conventional loading in maxillary and mandibular arches.	Moderate
Implant survival: 97.4% to 100%	There are only a few prospective case-series available to document the feasibility of immediate loading of implants in the maxilla, but employing four or more implants seems to provide high survival rates.	High

One other alternative to grafting procedures in maxillae with moderate to severe atrophy is the use of extra-alveolar implants such as zygomatic[55,59] and pterygoid implants.[50] The survival rate of zygomatic implants is estimated to be 97.6% after 5 years, decreasing to 95.2% at 10 years. While Tuminelli et al[59] related few complications associated with these implants (mainly prosthetic), Chrcanovic et al[55] indicated that complications can develop at any time with several degrees of severity and can include biologic complications such as sinusitis, soft tissue infection, paresthesia, and oroantral fistulas. Technical complications, namely intraoperative hemorrhage, are also a major concern associated with pterygoid implants, which present a 5-year survival rate of 94.9%.[50]

With bone grafting procedures. Four SRs[11,36,46,47] addressed the use of grafting procedures in atrophic edentulous areas (Table 4). The described interventions included horizontal augmentation with onlay bone grafts, bone splitting/expansion, guided bone

Table 3 Summary of Results of Systematic Reviews Addressing the Edentulous Maxilla with Insufficient Bone and No Grafting Approaches and Methodology Quality Assessment

Study, y	Title	Study population/no. of participants (no. of implants)	Interventions	Duration of follow-up	Meta-analysis performed
Al-Moraissi et al,[33] 2019	What is the Most Effective Rehabilitation Method for Posterior Maxillas with 4 to 8 mm of Residual Alveolar Bone Height Below the Maxillary Sinus with Implant-Supported Prostheses? A Frequent Network Meta-Analysis	Patients with atrophic posterior maxilla (residual bone height of 4–8 mm)/239 + 340 (452 SI + 680 LI + LSFE), of which 66 (172) corresponded exclusively to completely edentulous patients	SI vs LSFE + LI	1–5 y	Yes
Apaza Alccayhuaman et al,[34] 2018	Biological and Technical Complications of Tilted Implants in Comparison with Straight Implants Supporting Fixed Dental Prostheses. A Systematic Review and Meta-Analysis	Partially or completely edentulous patients/1,750 (3,688 tilted + 3,880 axial), of which 1,094 (2,173 tilted + 2,153 axial) corresponded exclusively to the maxilla	Tilted implants vs axial implants supporting fixed dental prosthesis	3–8 y	Yes
Araújo et al,[50] 2019	Clinical Outcomes of Pterygoid Implants: Systematic Review and Meta-Analysis	Patients with atrophic posterior maxilla (residual bone height < 8 mm)/at least 1,448 (1,893)	Pterygoid implants vs implants placed in posterior maxilla	1–12 y	Yes
Chrcanovic et al,[44] 2015	Tilted Versus Axially Placed Dental Implants: A Meta-Analysis	Partially or completely edentulous patients/NR (5,029 tilted + 5,732 axial), of which NR (1,511 tilted + 1,791 axial) were used in the meta-analysis on the maxilla	Tilted implants vs axial implants supporting fixed dental prosthesis	NR	Yes
Chrcanovic et al,[55] 2016	Survival and Complications of Zygomatic Implants: An Updated Systematic Review	Partially or completely edentulous patients (maxilla)/2,161 (4,556)	Full-arch, fixed partial and implant-supported overdentures with ZIs	1–10 y	No
Lemos et al,[41] 2017	Complete Overdentures Retained by Mini Implants: A Systematic Review	Completely edentulous patients/896 (2,494), of which NR (164) corresponded exclusively to the maxilla	Implant-supported overdentures with mini implants	1–2 y (maxilla)	No
Lin and Eckert,[52] 2018	Clinical Performance of Intentionally Tilted Implants Versus Axially Positioned Implants: A Systematic Review	Completely edentulous patients/NR (NR)	Full-arch fixed dental prosthesis with tilted implants	1–5 y	No
Ravidà et al,[48] 2019	Long-Term Effectiveness of Extra-Short (≥ 6 mm) Dental Implants: A Systematic Review	Partially or completely edentulous patients receiving 1 or more extra-short implants (≤ 6 mm)/705 (751), of which NR (369) corresponded exclusively to the maxilla	Full-arch and fixed partial dental prostheses with short implants	1–5 y	No
Schiegnitz and Al-Nawas,[53] 2018	Narrow-Diameter Implants: A Systematic Review and Meta-Analysis	Partially or completely edentulous patients receiving 1 or more narrow-diameter implants/NDI Class I 1,280 (5,441) + NDI Class II 823 (1,133) + NDI Class III 3,842 (5,612)	NDIs with mixed indications in maxilla and mandible; 4 studies specifically address the edentulous maxilla	NDI Class I: 1–6 y NDI Class II: 1–5 y NDI Class III: 1–9 y	Yes
Tuminelli et al,[59] 2017	Immediate Loading of Zygomatic Implants: A Systematic Review of Implant Survival, Prosthesis Survival and Potential Complications	Partially or completely edentulous patients with zygomatic implants (maxilla)/2,161 (4,556)	Zygomatic implants	NR	No

SI = short implant; LI = long implant; NR = not reported; OR = odds ratio; NDI = narrow-diameter implant; LSFE = lateral sinus floor elevation; RBH = residual bone height; Zis = zygomatic implants.

Results	Conclusions (as stated within review)	AMSTAR-2 quality grade
Implant survival: OR = 1.20 (0.49–3.34) Prosthesis survival: OR = 0.85 (0.32–2.24) Technical complications: OR = 0.34 (0.16–0.76)	No relevant differences between SI placement alone and standard implant placement combined with LSFE for implant and prosthesis survival at 1- to 5-year follow-up. Concerning surgical complications... evidence indicated that SI placement alone was a superior method in decreasing intraoperative complications compared to LI-LSFE. There is moderate-quality evidence... showing that...SI placement alone seems superior to LI placement with LSFE and bone grafting for patients with intermediate maxillary RBH (4–8 mm). The result of this study shows that LSFE for patients with intermediate RBH is not a suitable treatment because of the unjustified increase in complications and financial cost.	Moderate
Implant survival: Tilted: 95% to 100% Axial: 87.5% to 100% RR overall: 0.95 (0.70–1.28) RR maxillary implants: 5.00 (0.25–100)	In conclusion, besides heterogeneity and the serious risk of bias of most of the studies selected, the present systematic review demonstrated by means of meta-analysis that implant inclination had no effect on peri-implant bone loss or implant survival. Likewise, the assessment of biological and technical complications could not be extracted from the data due to lack of accurate reporting and study design.	High
1-y implant survival: 95.4% 5-y implant survival: 94.9% Technical complications: intraoperative hemorrhage	Due to the retrospective nature of all studies included...their level of evidence was considered poor and inconsistent, with restricted clinical impact. Within the limits of this meta-analysis, this study demonstrates comparable implant survival rates between pterygoid and conventional implants in other regions of the maxilla.	Moderate
Implant survival: OR: 1.70 (1.05–2.74)	Within the limitations of the existing investigations, the present study suggests that the differences in angulation of dental implants in relation to the mesial–distal occlusal plane might not affect the survival of these dental implants or marginal bone loss. A statistically significant difference was found for implant failures when studies evaluating implants inserted in maxillae only were pooled, in favour of axially placed implants.	Moderate
1-y implant survival: 98.4% 5-y implant survival: 97.6% 10-y implant survival: 95.2% Technical complications: sinusitis; soft tissue infection; paresthesia; oroantral fistula; accidental cavity penetrations	The ISRs and the 12-year CSR are encouraging , but there are not many studies including a reasonable number of Zis in which the patients were followed for at least 5 years. The main complication that seems to occur with Zis is sinusitis, which can develop several years after their placement.	Low
Mini-implant survival: 68.3% Prosthesis survival: 90.6% (combined)	The maxilla showed higher failures rates (31.7%) when compared with mandible (4.9%) and this should be considered during treatment plan.	Moderate
Implant survival Tilted: 93.6% to 100% Axial: 95.3% to 100% Prosthesis survival: 92.2% to 100%	Level I studies that are designed to directly compare the performance of tilted implants to that of axially loaded implants were not identified. An analysis of the descriptive data from Level I and Level II studies suggests no differences in clinical performance of implants whether placed in an axial or in a tilted configuration. Lower-level studies and a large population unpublished study appear to confirm the observations regarding the clinical performance of tilted implants in comparison to axially loaded implants. Insufficient information is available regarding the most appropriate number of implants needed to provide immediate support and retention of a definitive prosthesis; however, there are numerous low-level studies that demonstrate acceptable performance when four implants are used to support and retain full-arch fixed prostheses.	Moderate
1-y implant survival: 96.9% 5-y implant survival: 91.7% Technical complications: screw loosening	Within the limitations of this review, extra-short implants presented an overall satisfactory survival rate, which was higher in the mandible than in the maxilla. Although complications were rare, the most common prosthetic concern of extra-short implants was screw loosening. Nonsplinted implants showed a higher overall prosthetic complication rate and a higher incidence of implant failure compared with splinted implants.	High
NDI Class I: Implant survival: 94.7% ± 5%, OR = 4.54 (1.51–13.65) NDI Class II: Implant survival: 97.3% ± 5%; OR = 1.06 (0.31–3.61) NDI Class III: Implant survival: 97.7% ± 2.3%; OR = 1.19 (0.83–1.70) Implant survival in completely edentulous maxilla: 97% to 100%	Within the limits of this meta-analytic approach to the literature with the identified high risk of bias and heterogeneity in the included studies therein, the included studies describe NDI as a possible treatment alternative with promising survival rates. Their clinical advantage might be in the extension of treatment options. NDI of Category 1 performed statistically significantly worse than SDI and were mainly described for the rehabilitation of the highly atrophic maxilla or mandible. Category 2 and Category 3 NDI indicated no difference in implant survival compared to SDI…NDI of Category 3 were described in all regions, including posterior single-tooth restorations.	High
Implant survival: 96% to 100% Technical complications: fracture of prosthetic screw, fracture of prosthesis	Based on the present systematic review, the authors recommend immediately loading and splinting zygomatic implants for the restoration of the severely atrophic maxilla with or without anterior conventional implants. The complication rates are relatively few, rarely catastrophic, and easily managed.	Low

Table 4 Summary of Results of Systematic Reviews Addressing Bone Grafting Procedures in the Edentulous Maxilla with Insufficient Bone and Methodologic Quality Assessment

Study, y	Title	Study population/no. of participants (no. of implants)	Intervention(s)	Duration of follow-up	Meta-analysis performed
Aghaloo et al,[11] 2016	Bone Augmentation of the Edentulous Maxilla for Implant Placement: A Systematic Review	Completely edentulous patients (maxilla)/onlay bone grafting: 515 (2,446); guided bone regeneration: 27 (179); Le Fort I: 250 (1,588); lateral sinus floor elevation: 561 (4,860); combination technique: 166 (925)	Onlay bone grafting, guided bone regeneration, Le Fort I interpositional grafting, lateral sinus floor elevation	Onlay bone grafting: 1–12 y Guided bone regeneration: 1–5 y Le Fort I: 1–12 y Sinus floor elevation: 1–11.5 y Combination technique: 1.5–6 y	No
Chiapasco et al,[36] 2009	Bone Augmentation Procedures in Implant Dentistry	Partially or completely edentulous patients with deficient ridges/onlay bone grafting: 593 (2,463); lateral sinus floor elevation: 4,630 (13,889); bone splitting/expansion: 542 (1,182); vertical distraction osteogenesis: 181 (462); Le Fort I interpositional graft: 261 (881)	Onlay bone grafting, lateral sinus floor elevation, bone expansion, vertical distraction osteogenesis, Le Fort I interpositional grafting	Onlay bone grafting: 0.5–20 y Bone splitting/expansion: 0.5–7 y Vertical distraction osteogenesis: 0.5–6 y Le Fort I: 0.5–12 y Sinus floor elevation: 0.5–12 y	No
Poli et al,[46] 2019	Clinical Outcome Of Dental Implant Therapy In Association With Le Fort I Osteotomy Preprosthetic Surgery: A Systematic Review	Completely edentulous patients with severe maxillary atrophy/483 (3,596)	Le Fort I interpositional grafting	1–10 y	No
Raghoebar et al,[47] 2019	Long-term Effectiveness of Maxillary Sinus Floor Augmentation: A Systematic Review and Meta-Analysis	Partially or completely edentulous patients requiring lateral sinus floor elevation (residual bone height ≤ 6 mm)/383 (1,517)	Full-arch, fixed partial and implant-supported overdentures	5 y	No

regeneration and vertical augmentation with vertical distraction osteogenesis, Le Fort I interpositional grafts, and, in the posterior maxilla, sinus floor elevation. In completely edentulous patients, onlay bone grafting showed an implant survival rate of 85.2%,[11] which can increase with staged approaches.[36] Major concerns of this procedure relate to postoperative complications such as wound dehiscence and infection/morbidity of the donor site. Le Fort I interpositional grafting presents survival rates superior to 89.6%,[11,36,46] with better prognoses with staged approaches. Frequency of intraoperative and postoperative complications might rise to 2.3% and 12.2%, respectively, but these percentages do not compromise the future rehabilitation.[46]

Sinus floor elevation is one of the most studied augmentation procedures, with one of the SRs including 4,630 patients and 13,889 implants. Reported implant survival rates for lateral sinus floor elevation ranged from 91.5%[11] to 97.8%,[47] but some factors were identified as modifiers of the prognosis—namely residual bone height, sinus anatomy, and materials used.[47] Intraoperative membrane perforation and postoperative sinusitis are frequent complications of this procedure.

Results	Conclusions (as stated within review)	AMSTAR-2 quality grade
Implant survival: Onlay bone grafting: 85.2% (80.8% to 88.8%) GBR: 96.1% to 100% Le Fort I interpositional grafting: 89.6% (85.5% to 92.7%) Sinus floor elevation: 91.5% (86.4% to 94.8%) Combination technique: 93.6% (84.6% to 97.5%)	Within the limitations of this systematic review and analysis, all five treatment modalities discussed here, such as onlay bone grafting, GBR, Le Fort I interpositional grafting, maxillary sinus augmentation, and/or nasal floor inlay grafting or the combination approach can be successfully used to augment edentulous maxillary ridge with high implant survival rates.	Moderate
Onlay bone grafting: Implant survival: 79.5% (60% to 100%), but higher with staged approach (89.9%) Technical complications: morbidity of donor site, wound dehiscence/ infection (3.3%), total loss of graft (1.4%) Lateral sinus floor elevation: Implant survival: 95% (60% to 100%), but higher with rough-surface implants (97.1%) Technical complications: sinusitis (3%), total or partial loss of graft (< 1%) Bone splitting/expansion: Implant survival: 94% (91% to 97%) Technical complications: fracture of buccal plate Vertical distraction osteogenesis: Implant survival: 95.9% (88% to 100%) Technical complications: relapse of initial bone gain (7.7%), otherwise minor (related to the device) Le Fort I: Implant survival: 87.9% (66.7% to 95%), but higher with staged approach (90.9%) Technical complications: surgical complications (3.1%)	This literature review has demonstrated that a wide range of surgical procedures can be used to correct deficient edentulous ridges. On the basis of available data, it is difficult or impossible to determine that one surgical procedure offers a better outcome than another, as far as predictability of the augmentation and survival/success rates of implants placed in the augmented sites are concerned. Every surgical procedure presents advantages and disadvantages, which must be carefully evaluated before surgery. Moreover, it is not yet known if some surgical procedures that are widely used in clinical practice, such as sinus grafting procedures in the case of limited/moderate sinus pneumatization or reconstruction of atrophic edentulous mandibles with onlay autogenous bone grafts, are really useful for improving the long-term survival of implants…priority should be given to procedures that are simpler and less invasive, involve less risk of complications, and reach their goals within the shortest time frame.	Low
Implant survival: 91.0% ± 6.3%, but statistically better performance of rough-surface implants and staged approaches Technical complications: intrasurgical (2.3%) or postsurgical (12.2%) donor site morbidity	Le Fort I osteotomy as a reconstructive technique in preprosthetic surgery can be considered a predictable procedure associated with a low rate of complications and high survival and success rates of dental implants. Within the limitations of this systematic review, a statistically significantly higher implant failure has been observed when implants were inserted contextually with Le Fort I osteotomy procedures. Caution has to be taken when using machined implants, particularly in case of a simultaneous approach.	High
5-y implant survival: 97.8% (88.6% to 100%), but lower with mixture of autogenous bone and bone substitutes compared to autogenous bone or bone substitutes alone; Implant loss per year was independent of simultaneous or delayed implant placement in relation to maxillary sinus floor augmentation (0.38 vs 0.39, $P > .05$) or dental status at time of implant placement (0.13 vs 0.23, $P > .05$)	This review shows that MSFA (lateral window technique) is a safe and predictable procedure as part of oral rehabilitation of severely atrophic maxillae with dental implants. The survival of implants is high, with no difference in simultaneous or delayed implant placement, dental status being partially or fully edentulous, or using autogenous bone or bone substitutes as augmentation material.	High

Types of rehabilitation, number of implants required, patient-reported outcomes, and economic evaluations

Table 5 details the 12 studies that evaluated the different types and designs of prosthetic restorations, the adequate number of implants, and the outcomes reported by the patients. Very limited data were found regarding the maintenance costs of each type of rehabilitation; thus, a cost-effectiveness analysis could not be performed.

The number of implants required for a full-arch fixed dental prosthesis was addressed in six reviews.[28,39,37,38,45,54] Generally, the literature reports the use of fewer than five implants and five or more implants. However, no evidence could be found regarding fixed prostheses supported by fewer than four implants. The vast majority of prostheses supported by less than five implants described in the literature report on the All-on-Four technique, for which data are mainly derived from retrospective studies but encompass a very large number of patients and implants. The literature indicates that, for this case, implants are placed as two anterior parallel/axial implants and two posterior distally tilted implants to widen distribution, and implant survival

Table 5 Summary of Studies Addressing Different Types of Prostheses, Number of Implants, and Patient-Reported Outcome Measures (PROMs) and Methodology Quality Assessment

Study, y	Title	Study population/no. of participants (no. of implants)	Intervention(s)	Duration of follow-up	Meta-analysis performed
Daudt Polido et al,[37] 2018	Number of Implants Placed for Complete-Arch Fixed Prostheses: A Systematic Review and Meta-Analysis	Completely edentulous patients/2,285 (10,678)	Full-arch fixed dental prostheses with ≥ 5 vs < 5 implants	1–15 y	Yes
De Luna Gomes et al,[38] 2019	Optimal Number of Implants for Complete-Arch Implant-Supported Prostheses with a Follow-up of At Least 5 Years: A Systematic Review and Meta-Analysis	Completely edentulous patients/1,006 (NR)	Full-arch fixed dental prostheses with < 5 vs > 4 implants	5–15 y	Yes
Di Francesco et al,[51] 2019	The Number of Implants Required to Support a Maxillary Overdenture: A Systematic Review and Meta-Analysis	Completely edentulous patients (maxilla)/783 (NR)	Implant-supported overdentures	2–10 y	Yes
Goodacre and Goodacre,[26] 2017	Fixed vs Removable Complete Arch Implant Prostheses: A Literature Review of Prosthodontic Outcomes	Completely edentulous patients/NR	Full-arch fixed dental prostheses vs implant-supported overdentures	NR	No
Heydecke et al,[45] 2012	What is the Optimal Number of Implants for Fixed Reconstructions: A Systematic Review	Partially and completely edentulous patients/1,369 (5,642)	Fixed dental prosthesis and full-arch fixed dental prosthesis	5–15 y	Yes
Jokstad et al,[29] 2016[a]	A Systematic Review of the Role of Implant Design in the Rehabilitation of the Edentulous Maxilla	Completely edentulous patients/3,205 (12,599)	Full-arch fixed dental prosthesis and implant-supported overdentures with different implant characteristics (design, tilting, extraalveolar placement)	1–15 y	No

OHRQoL = oral health–related quality of life; NR = not reported.
[a]Extensive review of the literature that covers many different situations—including tilted implants—placed in the zygomatic and pterygoid bone, among others. For the purpose of the present overview, only results from analyses of the effects of specific implant design/features on outcomes are considered.

Results	Conclusions (as stated within review)	AMSTAR-2 quality grade criteria
Overall: Implant survival: 96% Prosthesis survival: 99% < 5 implants: Implant survival 97% Prosthesis survival: 98% ≥ 5 implants: Implant survival: 95% Prosthesis survival: 98.5%	Evidence from this systematic review and meta-analysis shows that the most reported number of implants for the 'fewer than five' group is four for the maxilla...whereas for the "five or more" implants group, the most reported number of implants was six for the maxilla...data analyzed from the included papers suggest that the use of fewer than five implants for the rehabilitation of the edentulous maxilla or mandible with a one-piece fixed prosthesis has survival rates (implant and prostheses) similar to those observed using five or more implants per arch ...with a median follow-up time of 8 years, ranging from 1 to 15 years. For both maxillary and mandibular rehabilitations, the use of distal implants with posterior inclination did not seem to affect the overall survival rate for implants and restorations. This was the most reported configuration when using fewer than five implants. When five or more implants were used, the more classic use of parallel implants was reported. However, additional key variables should ultimately be considered by clinicians when planning treatment for edentulous arches... the number of implants is only one of these variables.	High
< 5 implants: Implant survival: 99% Prosthesis survival: 100% > 4 implants: Implant survival: 95.6% Prosthesis survival: 89.6%	The number of implants used in complete-arch prostheses did not influence implant survival rate, prosthesis survival rate, prosthesis complications, or marginal bone loss, in studies with a follow-up period of between 5 and 15 years.	Moderate
Overall: Implant survival: 73.5% to 100% Prosthesis survival: 87.5% to 100% ≥ 6 splinted implants: Implant survival: 86.1% to 100% Prosthesis survival: 94.7% to 100% 4 splinted implants: Implant survival: 77% to 100% Prosthesis survival: 87.5% to 100% 4 unsplinted implants: Implant survival: 95% to 100% Prosthesis survival: 95% to 100% < 4 implants: Implant survival: 73.5% to 100% Prosthesis survival: 95% to 100%	The findings of our analysis indicate that overall the most frequent tendency is to place at least four implants, splinted or unsplinted, in order to ensure a higher survival rate of implants. Conversely, the relationship between overdenture survival, the patient's quality of life, and the number of implants required to support a maxillary overdenture has yet to be clarified. Future research is required to address these issues, especially by long-term analysis comparing maxillary overdentures supported by differing numbers of implants and with different types of attachments. Only when these issues have been clarified will it be possible to set guidelines regarding the optimal number of implants in MIODs which guarantee effective treatment outcomes in terms of implant survival, overdenture longevity and patient satisfaction.	Moderate
Full-arch fixed dental prostheses (10–15 y): Technical complications: resin tooth wear or fracture (33% to 70%), abutment screw loosening (13.4% to 20.8%), abutment screw fracture (6.3%), framework fracture (8.8%) Implant-supported overdentures (1–6 y): matrix-patrix maintenance (8∞ to 55%), loss of retention (55% to 75%), relining (10% to 27%)	*(1)* Studies reported high implant and prosthesis survival rates for traditional fixed complete dentures and overdentures. With 'all-on-4' fixed complete dentures, implant and prosthesis survival rates were also high, with comparable implant survival rates reported for both upright and tilted implants. *(2)* A substantial number of prosthetic maintenance/complication issues have been reported with both implant fixed complete dentures and implant overdentures. More maintenance/complications were encountered with implant overdentures than with implant-fixed complete dentures. *(3)* With fixed complete dentures, resin tooth wear was a common sequela from usage, with one systematic review indicating 70% of prostheses presented with some form of wear and another review reporting this was the most common mechanical maintenance requirement with a 33% frequency at 5 years and 66% at 10 years. Other less frequently reported issues included screw-related and aesthetic complications. *(4)* With 'all-on-4' fixed complete dentures, the major prosthetic complication was fracture of the all-resin conversion prosthesis. *(5)* With implant overdentures, the most common prosthetic maintenance requirement involved the retentive mechanism that frequently needed either an adjustment or replacement.	Low
Full-arch fixed dental prostheses: Implant survival: 80.3% to 98.7% Prosthesis survival: 78.3% to 99.2% Full-arch fixed dental prostheses (maxilla): 5-y prosthesis survival: 97.5% (94.1% to 98.9%) 10-y prosthesis survival: 95.0% (88.5% to 97.9%) Technical complications: veneering fractures (up to 40%), abutment screw loosening (up to 10%), framework fractures (up to 16%)	For edentulous patients, most of the included studies reported on survival and complication rates for FAFDPs supported by 4–6 implants without addressing the implant distribution or how many of the reconstructions there were supported with 4, 5, or 6 implants. Whether there is an indication for more than 6 implants is unclear from current evidence.	Low
–	This systematic review failed to identify compelling evidence to conclude that any particular implant or feature affects the outcome of the treatment of patients with fully edentulous maxillae.	Moderate

Table 5 Summary of Studies Addressing Different Types of Prostheses, Number of Implants, and Patient-Reported Outcome Measures (PROMs) and Methodology Quality Assessment *(continued)*

Study, y	Title	Study population/no. of participants (no. of implants)	Intervention(s)	Duration of follow-up	Meta-analysis performed
Kern et al,[39] 2016	A Systematic Review and Meta-Analysis of Removable and Fixed Implant-Supported Prostheses in Edentulous Jaws: Post-Loading Implant Loss	Completely edentulous patients/2,368 (9,267)	Full-arch fixed dental prosthesis and implant-supported overdentures, regardless of loading protocol	1–10 y	Yes
Mericske-Stern and Worni,[28] 2014	Optimal Number of Oral Implants for Fixed Reconstructions: A Review of the Literature	Completely edentulous patients/4,833 (31,353)	Full-arch fixed dental prosthesis	1–15 y	No
Osman et al,[57] 2012	Prosthodontic Maintenance of Maxillary Implant Overdentures: A Systematic Literature Review	Completely edentulous patients (maxilla)/518 (2,549)	Implant-supported overdentures with different designs	1–10 y	No
Sadowsky and Zitzmann,[58] 2016	Protocols for the Maxillary Implant Overdenture: A Systematic Review	Completely edentulous patients (maxilla)/530 (NR)	Implant-supported overdentures with different designs	1–22 y	No
Schley and Wolfart,[54] 2011	Which Prosthetic Treatment Concepts Present a Reliable Evidence-Based Option for the Edentulous Maxilla Related to Number and Position of Dental Implants? Systematic Review, Consensus Statements, and Recommendations of the 1st DGI Consensus Conference	Completely edentulous patients (maxilla)/1,130 (7,028)	Full-arch fixed dental prosthesis and implant-supported overdentures, regardless of loading protocol	3–15 y	No
Yao et al,[8] 2018	Patient-Reported Outcome Measures of Edentulous Patients Restored with Implant-Supported Removable and Fixed Prostheses: A Systematic Review	Completely edentulous patients/NR (NR)	Full-arch fixed dental prostheses and implant-supported overdentures	0.5–10 y	No

OHRQoL = oral health–related quality of life; NR = not reported.
[a]Extensive review of the literature that covers many different situations—including tilted implants—placed in the zygomatic and pterygoid bone, among others. For the purpose of the present overview, only results from analyses of the effects of specific implant design/features on outcomes are considered.

rates are determined to be over 97% after variable periods of follow-up.[37,38] The prostheses are always built as a one-piece cross-arch metal framework with acrylic veneering—the so-called "wrap-around"—and the survival rates are over 98%. This technique was also associated with zygomatic implants replacing the posterior distally tilted implants,[29] with expected complication rates similar to the other options but more severe when either an implant was lost or a prosthesis was compromised due to implant failure.

The use of five or more implants has been described with a higher evidence level, with prospective studies and RCTs. Generally, studies describe the use of six fixtures evenly distributed within the first molar and

Results	Conclusions	AMSTAR-2 quality grade criteria
Overall implant survival: > 95% < 4 nonsplinted implants + overdenture: Implant survival < 90% (67.2% to 89.4%) < 4+ overdenture: risk of implant loss per 100 implants/y: 7.22 (5.41–9.64) 4 implants + overdenture - risk of implant loss per 100 implants/y: 2.31 (1.56–3.42) ≥ 6 implants + fixed dental prosthesis: risk of implant loss per 100 implants/y: 0.28 (0.20–0.39)	Maxilla: (a) The insertion of six or more implants for a fixed reconstruction in the maxilla reveals favorable results. Considering the "all-on-4" concept for the maxilla, one study (Crespi et al, 2012) with an acceptable level of evidence was found, revealing a satisfactory outcome…this one study could not be used for a meaningful statistical comparison. (b) The insertion of four implants for a removable overdenture in the maxilla reveals satisfying results. Data on minimal concepts with < 4 implants in the maxilla is scarce and demonstrated significantly worse results, calling for a cautious and controlled application of these therapeutic options.	High
Implant survival: 87% to 92.1%; some clustering effect (majority of implant failures occurred within a few patients)	Long-term results and RCTs comparing different numbers of implants and designs for fixed prostheses in the edentulous jaws are not available. The selected articles of the present review exhibit a great heterogeneity and differences in methodology to report on survival of implants, prostheses, crestal bone loss, and complications. In spite of a dispersion of results, similar outcomes are reported with regard to survival, bone stability and with a different number of implants per jaw. The fact that such data do not show up indicates that the number of implants is not a major issue.	Low
Maintenance of matrices, maintenance of patrices (less frequent), relines (40% at 3 y), fracture of overdenture bases, mucosal complications (hyperplasia); higher incidence of prosthodontic complications for ball attachments compared to bars (77.5% vs 42.9%)	This review finds that prosthodontic maintenance requirements of maxillary implant overdentures are a direct consequence of the attachment system and the number and distribution of implants.	Low
Implant and prosthesis survival: 84% to 100% Absence of prosthetic complications: 56% to 98.4%	A maxillary IOD offers a stabilized removable solution for the edentulous maxilla that provides increased patient satisfaction and oral health QoL. A higher failure rate is experienced with machined implants. Four to six implants are widely applied in successful cohort studies. When four or less implants are used for max IODs, unsplinted designs have a higher implant/prosthetic failure rate than splinted implants. In general, both splinted and solitary anchorage systems are advocated. Maintenance may be higher for solitary attachments. Increased soft tissue inflammation has been reported under bars. Palateless design offers better patient satisfaction.	Low
Implant-supported overdentures: Implant survival: 60% to 100%; no significant difference regarding implant survival for ball- or bar-retained overdentures Prosthesis survival: 87.5% (Dolder bar), 94.7% (milled bars) Full-arch fixed dental prostheses: Prosthesis survival: 82.4% to 100%	…4–5 implants should be supplied with a removable denture. An evidence-based recommendation concerning different anchorage systems cannot be made at the moment, although bar-retention seems to be investigated best…6 implants offer the opportunity of an either fixed or removable restoration. Individual, patient-related circumstances (anatomy, patient's wishes, etc) are the decisive factors when determining if the prosthesis is of a removable or fixed design…with more than 6 implants both fixed and removable suprastructures can be used. Individual, patient-related circumstances (anatomy, patient's wishes etc) are again the decisive factors when determining if the prosthesis is of a removable or fixed design. Based on the results of this review, there is no evidence concerning the use of a one-piece, full-arch bridge or, in contrast, the use of a segmented restoration.	Moderate
OHRQoL and satisfaction; trend for fixed dental prosthesis to be higher than overdentures, but not statistically significant; better capacity to conduct oral hygiene with overdentures	On the basis of the current evidence, it is not possible to support a solid conclusion on which type of prosthesis would result in better PROMs. One clear conclusion appears to emerge, however... agreement on the IOD being easier to maintain oral hygiene. This might be of significance when selecting a treatment for patients with difficulties in conducting oral hygiene such as the elderly, patients with disabilities, or Parkinson's disease. Meanwhile, it is also apparent that IFCD needs to have a design that allows access for efficient oral hygiene and that patients...must be adequately trained for their particular prosthesis.	Moderate

second premolar maxillary zones to support one-piece cross-arch prostheses, with implant survival rates ranging from 88.5% to 97.9% at 10 years, showing a small risk of implant failure.[39] Interestingly, it has been reported[28] that implant failure presents a clustering effect in these rehabilitations, with most implant failures occurring in a limited number of patients. These one-piece cross-arch prostheses also present very good survival rates in studies with a follow-up between 5 and 15 years (89.6% to 98.5%),[37,38] even though limited data are available when six or more implants are used with one-piece prostheses. The use of more than six implants—up to eight—allows segmentation of the prostheses, which is estimated to result in a 96.4% survival rate at 10 years, a value that

does not differ from that of one-piece prostheses.[56] Though there is limited clinical research on the concept of using eight implants, some authors suggest that implants should be distributed in each hemi-arch in the positions of the first molar, first premolar, canine, and central incisor to allow the insertion of four prosthetic units: 6 x 4, 3 x 1, 1 x 3, and 4 x 6.[28] In all cases, the most frequently encountered technical complications appear to be resin tooth wear or fracture with increasing incidence over time (33% to 70%), abutment screw loosening (up to 20%) or fracture (8.8%), and framework fracture (up to 16%).[26,45]

Information regarding the number and distribution of implants and the retention systems of implant-supported overdentures was found in six of the SRs detailed in Table 5.[26,29,39,51,57,58] Implant-supported overdentures reported in the literature usually present with fewer than four implants, four implants, or more than four implants (up to six). The use of fewer than four implants to support an implant overdenture is a high-risk situation, with implant survival at a medium-term follow-up ranging from 67.2% to 89.4%,[39,51] splinted or free-standing.

The use of four implants seems to be the benchmark for maxillary overdentures, reducing the risk by more than 3 times in relation to those with fewer than four implants.[39] In overdentures supported by four implants, implant survival varies from 94.9% to 98.3%,[51] depending on whether the implants are splinted or free-standing, respectively, whereas the overdentures present survival rates of over 96% regardless of the retention system. The use of more than four implants (up to six) with a bar does not reflect a higher implant survival rate, but raises the overdenture survival rate up to 99.4%. This might be a viable treatment option for patients with associated risk factors, such as reduced bone quality or parafunction.

When implants are inserted into native alveolar bone, splinting the implants using a bar can contribute to compensation of nonaligned implants while reducing follow-up maintenance and prosthodontic complications in the long term[57,58] (such as matrix replacement, loss of retention, and relines[26]), even though a minor biologic complication (tissue hyperplasia) was frequently reported under the bar structure. However, preference should be given to rigid structures with nonresilient bars to avoid rotation and frictional wear of attachments.[57]

Only one review[8] specifically focused on literature evaluating patient-reported outcomes with full-arch fixed dental prostheses and implant-supported overdentures. The results reported a trend for higher overall satisfaction with fixed prostheses, but higher satisfaction with the capacity to perform oral hygiene with overdentures, an important factor to be considered when planning the rehabilitation.

DISCUSSION

The present overview aimed to answer the focus question: What is the current evidence regarding rehabilitation of the edentulous maxilla with different implant-supported prostheses in terms of implant and prosthesis survival? This review analyzed previously published SRs dealing with the comparison of different implant-supported rehabilitations of edentulous maxillae with different degrees of atrophy.

The abundance of SRs and clinical studies in the literature reflect the fact that the use of implants to support fixed or removable prostheses in the edentulous maxilla is a well-documented principle. In fact, the included SRs covered both fixed and removable options for the edentulous maxilla, as well as possible solutions to overcome situations of insufficient bone volume either using ancillary grafting procedures or using short, narrow, or tilted implants (alveolar or extra-alveolar).

Different approaches to restoring the edentulous maxilla with moderate to severe atrophy while avoiding bone augmentation procedures present the highest number of resources. The use of distally tilted implants to overcome atrophy of the posterior maxilla is supported by one high-quality review[34] and one moderate-quality[52] review that report no differences in the clinical performance of axial vs distally tilted implants. However, the first SR,[34] as well as a third,[44] suggest that there might be a higher risk for failure of tilted implants when data are pooled exclusively from the maxilla—although, as they present very high survival rates, they remain a viable option. When the tilted implant is extra-alveolar, the literature is not so clear. For instance, two low-quality SRs present similar survival rates for zygomatic implants but different conclusions on their use: On one hand, Tuminelli et al[59] report few complications that are rarely catastrophic and easily managed; on the other hand, Chrcanovic[55] warns about the risk of several technical complications, among which is penetration of the orbital cavity during implant placement and the development of sinusitis any time after placement, suggesting that zygomatic implants are an advanced procedure that should be reserved for experienced surgeons. Likewise, data on pterygoid implants are considered inconsistent despite the 94.9% survival rate at 5 years, and this procedure is recommended for experienced surgeons only due to the risk of intraoperative hemorrhage and other complications.[50]

On the contrary, the evidence on short implants (< 8 mm) is given only by one high-quality review[48] and one moderate-quality review,[33] indicating a similar clinical performance of short and standard implants, particularly when short implants are splinted—as in the case of one-piece full-arch fixed prostheses or bar overdentures, suggesting that lateral sinus floor elevation plus the use

of long implants in maxillae with intermediate residual bone height is an unjustified treatment that exposes the patient to the possibility of complications and increases the financial cost.[33]

Regarding the use of NDI, the evidence is clear excluding the possibility of using Class I NDI (ie, mini-implants) in completely edentulous maxillae, as stated by one high-quality review[53] and one moderate-quality review.[41] However, no restrictions were determined for Class III NDI (3.3-mm diameter), indicating Class III might be a suitable option for areas with limited horizontal bone volume in conjunction with standard-diameter implants.

Implant distribution seems to contribute to the longevity of rehabilitations more than a specific implant diameter, design feature,[29] or even number.[28,39,54] Arrangements for the maximum anterior-posterior distribution of the implants to be as symmetrical as possible have been preferred to reduce the cantilever extension and ensure maximization of cross-arch implant support. That is the principle underlying the distal angulation of the posterior implants in the All-on-Four concept, which has been documented by thousands of cases, even though most data were collected retrospectively. Besides being surgically challenging to ensure correct angulation of the posterior implants, the major drawback of the technique is that the loss of one implant inevitably leads to loss of the prosthesis, since the use of fewer than four implants in the maxilla is not advised for fixed or removable restorations.

Equally well-documented and with the longest follow-up periods are fixed rehabilitations with six implants, usually inserted in the positions of the first molar, first premolar, and lateral incisor on each hemiarch, or, alternatively, in the positions of the second premolar, canine, and central incisor, allowing for more sophisticated veneering materials for the prosthesis (ie, ceramics) and therefore better "aging."[26] This does not mean that full-arch fixed prostheses with six implants are exempt from maintenance or complications; for instance, from screw loosening or fracture, which must be accounted for when delivering the restoration.

A similar situation is expected for implant-supported overdentures, which—with the recommended number of implants of four to six distributed anteriorly to the premolar region—provide very satisfying implant and prosthesis survival rates but present high maintenance requirements, particularly during the adaptation period.[8,26,57] Free-standing attachments and resilient bars seem to be particularly prone to technical complications such as matrix adjustment, loss of retention, and correction of soft tissue compression areas, among others, and the choice of retention system should consider those risks.

Strengths and Limitations

A major strength of the present overview is the robust methodology for identification of the relevant literature (SRs) focusing on the options available for restoring the completely edentulous maxilla, with a comprehensive search of three databases. Additionally, the selection and data extraction/synthetization processes involved two reviewers, requiring agreement at every stage.

Unfortunately, the broad methodologic heterogeneity and clinical variation among the primary research included within each systematic review is, by extension, also a limitation of this overview. The frequent inclusion of retrospective and prospective cohort studies due to apparent lack of RCTs or QRCTs, the highly variable follow-up periods, the impossibility of pooling data pertaining to the edentulous maxilla in some studies,[36,47,50,55,59] and the absence of standardization in reporting results limit the level of evidence associated with options to rehabilitate the edentulous maxilla. This, along with some methodologic flaws of the reviews, translated into a small fraction (7/34) of the reviews being classified as high quality and a large fraction (12/34) classified as low quality by the AMSTAR-2 tool. Results derived from the latter should therefore be interpreted with caution.

One additional limitation of the present review is related to the outcomes implant survival and prosthesis survival, rather than the term "success." Implant survival reports an implant that is in situ, not reflecting the biologic status or success of the implant. Implant success is not often reported, and when it is, the applied criteria vary greatly among studies, hampering comparisons across the literature. This can be extended to the prosthesis, for which survival means that the same prosthesis, or at least the same type of prosthesis, is still in function at the end of the follow-up. It does not mean that technical complications did not occur or that repairs and adaptation were not necessary. More often than not, maintenance and repair interventions of the prosthesis are unreported and frequently exceed the range of normal maintenance service, increasing the associated costs and frequently frustrating patients and clinicians.

Implications for Clinical Practice

The literature is clear in refuting the idea held into the early 90s that "the more (implants) the merrier" regarding implant and prosthesis survival, maintenance, and technical complications. However, a "one-fits-all" approach is definitely not an option for the maxillary completely edentulous patient, who presents individual needs to be met, namely esthetics (lip support, smile line), cleansibility, comfort, and economics, as well as technical and biologic factors to be considered by the clinician, such as anatomy of the edentulous ridge, residual bone volume, and available prosthetic space. As demonstrated in the present overview, there is a wide

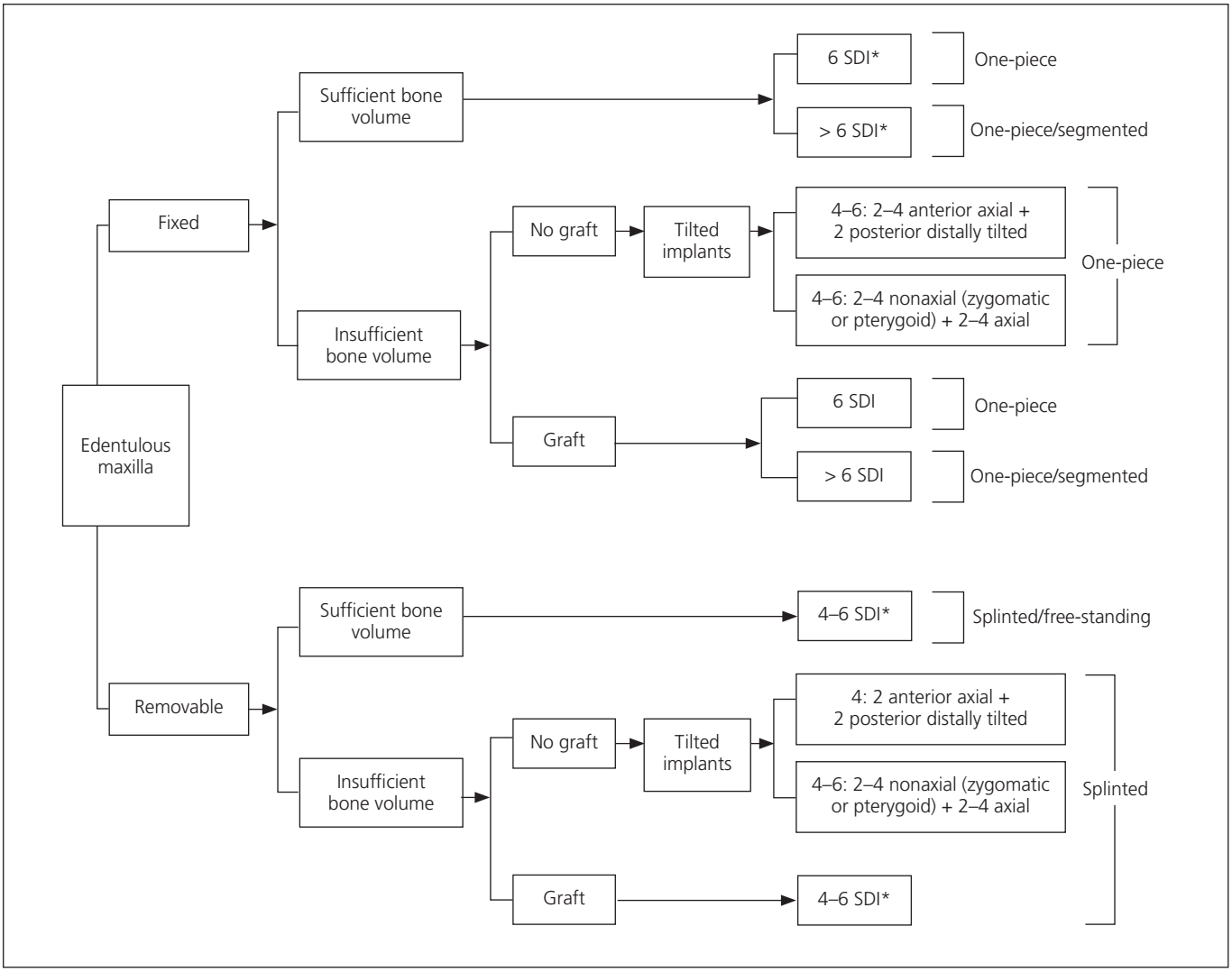

Fig 2 Decision tree for treatment approach in the completely edentulous maxilla. *Includes the possibility of combining standard-diameter implants (SDI) with axially placed short implants and/or Category 3 narrow-diameter implants (NDI) in one-piece (fixed) or splinted (removable) options.

array of options with high survival rates for both the implants and prostheses. In order to structure all information, the authors suggest a decision tree (Fig 2) based on an initial decision node of opting for a fixed or removable implant-supported prosthesis as a function of the aforementioned factors to deliver the patient not only the desired treatment, but also the best option for their individual case. The following decision nodes evaluate the need (sufficient or insufficient bone volume) and/or the willingness of the patient to undergo additional procedures of bone augmentation. Though the different options for and clinical performance of augmentation procedures have been explored within the context of the present overview, further decisions on which procedure is to be used are not included due to the specificity of each case. However, the tree does present the options advocated for the postaugmentation stage, as well as the options for insufficient bone with no augmentation and sufficient bone branches. Complementary images exemplifying the suggested implant distributions (alveolar and extra-alveolar, anterior and posterior, axial and tilted) can be found in the work of Jokstad et al.[29]

The options included are substantiated in the literature, presenting high survival rates for both the implants and prosthesis. However, both the patient and clinician must be aware that no option is exempt from the possibility of developing technical and biologic complications, or even from the possibility of failure. For this reason, the establishment of an adequate maintenance program can contribute to the reduction of complications and ensure the longevity of the restoration at reasonable costs.

Implications for Future Research

There is less literature published on the maxillary completely edentulous patient than on the mandibular completely edentulous patient, and at higher risks of bias. A good part of the data is derived from retrospective studies or prospective cohort studies with no control arm, decreasing the level and quality of evidence. Future research should counter this trend, investing in well-designed RCTs to assess specific situations, such as the comparison of tilted and axial implants placed in regenerated bone or the advantages of segmentation of fixed restorations. RCTs should include more comprehensive clinical evidence, including PROMs, in order to develop cost-effectiveness evaluations to compare treatment options.

It would also be fundamental to introduce clear criteria for categorizing interventions performed during prosthesis follow-up care to enable the distinctions among maintenance, minor repairs, major repairs, and technical complications, which are time consuming and increase the total cost of the rehabilitation in the long term.

CONCLUSIONS

Within the limitations of the present overview, it is possible to conclude that:

- Bone augmentation procedures such as onlay bone grafts, lateral sinus floor elevation, vertical distraction osteogenesis, and Le Fort I interpositional grafting are valid procedures to overcome severe atrophy of the edentulous maxilla for rehabilitation with dental implants.
- The use of extra-alveolar implants (zygomatic and pterygoid) to overcome severe maxillary atrophy is subject to caution.
- No implant-supported rehabilitation of the edentulous maxilla (fixed or removable) should be supported on fewer than four implants.
- A one-piece full-arch fixed dental prosthesis can be supported on a minimum of two anterior axial plus two posterior distally tilted implants or on six to eight axial implants symmetrically distributed through the posterior and anterior regions of the arch.
- Four to six implants is the advised number to support an overdenture. Both splinted and free-standing anchorage systems are advocated.
- Short implants can be used in conjunction with standard implants in splinted configurations to overcome situations of moderate atrophy of the maxillary sinus.
- The use of mini-implants in the completely edentulous maxilla is not advisable for permanent implant-supported restorations.
- The currently available data do not allow for a cost-effectiveness analysis regarding rehabilitation of the edentulous maxilla.

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APPENDIX 1 Search Strategy for the Cochrane Database of Systematic Reviews up to October 20, 2019

1. MeSH descriptor: [Mouth, Edentulous] explode all trees
2. MeSH descriptor: [Jaw, Edentulous] explode all trees
3. (edent*):ti,ab,kw
4. (toothless):ti,ab,kw
5. MeSH descriptor: [Maxilla] explode all trees
6. ("maxillary arch"):ti,ab,kw
7. ("maxillary bone"):ti,ab,kw
8. ("upper jaw"):ti,ab,kw
9. MeSH descriptor: [Dental Prosthesis, Implant-Supported] explode all trees
10. MeSH descriptor: [Denture, Overlay] explode all trees
11. MeSH descriptor: [Dental Prosthesis] explode all trees
12. MeSH descriptor: [Dental Prosthesis Design] explode all trees
13. (implant-supported dental prosthesis):ti,ab,kw
14. (complete fixed prosthesis):ti,ab,kw
15. (full arch):ti,ab,kw
16. (fixed complete denture):ti,ab,kw
17. ("overdentures"):ti,ab,kw
18. (implant supported prosthesis):ti,ab,kw
19. (implant supported removable denture):ti,ab,kw
20. (implant-retained):ti,ab,kw
21. #1 OR #2 OR #3 OR #4
22. #5 OR #6 OR #7 OR #8
23. #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20
24. #21 AND #22
25. #24 AND #23 in Cochrane Reviews, Cochrane Protocols

APPENDIX 2 Search Strategy for the MEDLINE via PubMed Database up to October 20, 2019

1. Edentulous mouth [MeSH Terms]
2. Edentulous jaw [MeSH Terms]
3. Edent* [All fields]
4. Toothless [All fields]
5. Maxilla [MESH terms]
6. Maxillary arch [All fields]
7. Maxillary bone [All fields]
8. Upper jaw [All fields]
9. Dental prosthesis, implant supported [MESH Terms]
10. Overdenture [MESH Terms]
11. Dental prosthesis [MESH Terms]
12. Dental prosthesis design [MESH Terms]
13. Implant-supported dental prosthesis [All fields]
14. Implant supported dental prosthesis [All fields]
15. Implant supported prosthesis [All fields]
16. Complete fixed prosthesis [All fields]
17. Full arch [All fields]
18. Fixed complete denture [All fields]
19. Overdentures [All fields]
20. Implant supported removable denture [All fields]
21. Implant retained [All fields]
22. OR/1-4
23. OR/5-8
24. OR/9-21
25. 22 AND 23 AND 24
26. 22 AND 23 AND 24 (Filters activated: English language; Systematic reviews; Review)

APPENDIX 3 Search strategy in the Dentistry & Oral Sciences Database via EBSCOhost up to October 20, 2019

Using the boolean/phrase search mode expanded to related words and equivalent subjects

1. Edentulism [SU]
2. Edentulous [SU]
3. Edentulous patient [SU]
4. Edent* [All fields]
5. Toothless [All fields]
6. Maxilla [SU]
7. Jaw or mandible [SU]
8. Maxillary [SU]
9. Maxillary arch [All fields]
10. Maxillary bone [All fields]
11. Upper jaw [All fields]
12. Prosthesis [SU]
13. Prosthesis OR Prosthetics OR Prosthetics [SU]
14. Prosthesis and implants [SU]
15. Implants dental [SU]
16. Implantology [SU]
17. Overdenture [SU]
18. Overdenture [All fields]
19. Implant overdenture [All fields]
20. Implant-supported prostheses [All fields]
21. Complete fixed prosthesis [All fields]
22. Full-arch implant rehabilitation [All fields]
23. Fixed complete denture [All fields]
24. Implant retained [All fields]
25. Implant supported bridge [All fields]
26. OR/S1-S5
27. OR/S6-S11
28. OR/S12-S21
29. 22 AND 23 AND 24
30. 25 AND Review of literature OR literature review OR meta-analysis OR systematic review [SU]

APPENDIX 4 Excluded Studies and Reason(s) for Exclusion

Study, y	Reason for exclusion
Abdunabi et al,[1] 2019	Does not address primary outcome
Al-Johany,[2] 2019	Overlapping review/outdated; not possible to individually extract data on complete rehabilitations
Aparicio et al,[3] 2014	Insufficient explanation of search strategy/narrative review
Attard and Zarb,[4] 2005	Insufficient explanation of search strategy/narrative review; overlapping review/outdated
Bedrossian and Bedrossian,[5] 2018	Insufficient explanation of search strategy/narrative review
Block et al,[6] 2009	Insufficient explanation of search strategy/narrative review
Bryant et al,[7] 2007	Overlapping review/outdated
Carlsson,[8] 2014	Insufficient explanation of search strategy/narrative review
Carlsson,[9] 2016	Insufficient explanation of search strategy/narrative review
Chiapasco et al,[10] 2006	Overlapping review/outdated
De Bruyn et al,[11] 2014	Insufficient explanation of search strategy/narrative review
De Bruyn et al,[12] 2015	Does not address primary outcome
Del Fabbro et al,[13] 2012	Overlapping review/outdated
Del Fabbro and Ceresoli,[14] 2014	Overlapping review/outdated
Del Fabbro et al,[15] 2006	Overlapping review/outdated
Duan et al,[16] 2017	Overlapping review/outdated
Duello,[17] 2012	Insufficient explanation of search strategy/narrative review
Durkan et al,[18] 2019	Insufficient explanation of search strategy/narrative review
Emami et al,[19] 2014	Insufficient explanation of search strategy/narrative review
Esposito et al,[20] 2014	Overlapping review/outdated
Esposito et al,[21] 2010	Overlapping review/outdated
Esposito et al,[22] 2010	Overlapping review/outdated
Esposito and Worthington,[23] 2013	Empty review
Esposito et al,[24] 2005	Empty review
Esposito et al,[25] 2003	Empty review
Gallucci et al,[26] 2016	Insufficient explanation of search strategy/narrative review
Goiato et al,[27] 2014	Overlapping review/outdated
Goiato et al,[28] 2014	Overlapping review/outdated
Henry,[29] 2002	Insufficient explanation of search strategy/narrative review
Klein et al,[30] 2014	Overlapping review/outdated
Kutkut et al,[31] 2018	Does not address primary outcome
Lemos et al,[32] 2016	Not possible to individually extract data on complete rehabilitations
Menini et al,[33] 2012	Overlapping review/outdated
Mokcheh et al,[34] 2019	Overlapping review/outdated
Nielsen et al,[35] 2019	Overlapping review/outdated; not possible to individually extract data on complete rehabilitations
Payne et al,[36] 2018	No studies addressing maxilla
Peñarrocha-Diago et al,[37] 2017	Insufficient explanation of search strategy/narrative review
Zhang et al,[38] 2017	Not possible to individually extract data on maxillary rehabilitations
Raghoebar et al,[39] 2014	Overlapping review/outdated
Roccuzzo et al,[40] 2012	No studies addressing maxilla

Rohlin et al,[41] 2012	Overlapping review/outdated
Sadowsky,[42] 2007	Overlapping review/outdated
Sadowsky,[43] 2015	Not possible to individually extract data on complete rehabilitations
Sorni et al,[44] 2005	Insufficient explanation of search strategy/narrative review
Stanford,[45] 2016	Does not address primary outcome
Thoma et al,[46] 2015	Overlapping review/outdated
Ting et al,[47] 2017	Overview
Trakas et al,[48] 2006	Insufficient explanation of search strategy/narrative review; overlapping review/outdated

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