A Systematic Review of the Role of Implant Design in the Rehabilitation of the Edentulous Maxilla

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Purpose: *To identify and critically appraise scientific publications evaluating the possible effect of implant design on treatment outcomes in the rehabilitation of patients with a fully edentulous maxilla.* ***Materials and Methods****: Scientific reports were sought in three electronic bibliographic databases, combined with searches for meeting abstracts, and in the grey literature. English, German, or Scandinavian scientific publications on prospective or retrospective longitudinal studies with effects of an implant design or feature on the treatment outcomes were eligible. Minimum requirement for inclusion was at least 10 study participants who were followed up for at least 2 years after implant loading. The PRISMA guidelines were followed for selecting data to extract from the individual studies. These were characteristics of the individual studies, risk of bias within individual studies, and the results of individual studies. Three editorial teams independently identified and extracted the data.* ***Results:*** *The search resulted in 998 primary studies, of which 525 met the inclusion criteria and were read in full text. Of these, 105 studies were included in qualitative syntheses. Seventeen studies were designed with an objective to assess effects of implant design or feature on outcomes, 23 studies described tilted implants to enable placement of longer implants, 30 studies reported effects of implants placed in zygomatic bone with or without additional alveolar implants, and 9 studies reported effects of implants placed in pterygoid bone or other bony buttresses with or without additional alveolar implants. Sixteen articles reported bone augmentation with simultaneous or delayed implant placement in patients with a predominantly Cawood-Howell bone class V and VI maxilla. Ten papers reported effects of implant design on outcomes, despite the lack of an a priori stated objective to assess a particular implant design or feature. There is a lack of compelling data to state that one particular implant system or design feature stands out amidst others, when applied to restoring the fully edentulous maxilla with implant-retained prostheses.* ***Conclusion:*** *This systematic review failed to identify compelling evidence to conclude that any particular implant or feature affects the treatment outcome in patients with a fully edentulous maxilla.* Int J Oral Maxillofac Implants 2016;31(suppl):s43–s57. doi:10.11607/jomi.16suppl.g2

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Individuals with a fully edentulous maxilla frequently report low social self-confidence and related low quality of life because of compromised oral functions and poor esthetics. Most may benefit from the relatively low-cost technical solution of a correctly designed removable dental prosthesis individually fitted to the remaining oral tissues, which can restore both oral functions as well as the facial and oral appearance to a certain level.[1] Many, however, are unable to adapt to a more or less removable dental prosthesis. This could be attributed to specific conditions of general or oral health, compromised local anatomy that impedes optimal prosthesis design, or psychological barriers.[2] The introduction of endosseous titanium dental implants has provided a more predictable alternative than a conventional removable prosthesis to restore the patient's facial appearance and oral functions with a dental device retained or supported by these root-analogues.[3]

With implant-supported prostheses having a high predictability of re-establishing oral functions and esthetics, new dental implant designs and material compositions have increased rapidly. There were 45 dental implant systems available in the market in 1988,[4] 98 systems in 2000,[5] 225 systems from 78 manufacturers in 2002,[6] and 600 systems from 146 manufacturers in 2008.[7] Currently, there are at least 364 dental implant manufacturers producing an estimate of 1,600 different implant systems. Distinct minorities of these implant manufacturers have undertaken basic, animal, and human research when designing new or altering the components of existing implant systems. Consequently, many currently commercially available dental implants have insufficient, questionable, or simply totally lacking scientific justification of the product designs and material compositions. This is even more profound when looking for high-quality long-term evidence. Potential alterations of the implant design include both its macro-geometry as well as its surface microtopography, which transforms surface chemical and biochemical properties, corrosion characteristics and wear debris release, surface energy, and wettability as well as topography on micrometer and nanometer scales.[8–10]

It is uncertain whether one particular implant design is optimal for the fully edentulous maxilla. It is also doubtful whether one may extrapolate data from other clinical scenarios, such as in single implants or implant-supported small fixed dental prostheses in partial edentate jaws. 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. A secondary objective was to provide the basis for the development of evidence-based clinical guidelines for best management of patients with a fully edentulous maxilla. (See separate sections in the IJOMI supplement.)

MATERIALS AND METHODS

Protocol and Registration

The Academy of Osseointegration 2014 summit organizing committee determined the topic for this systematic review in July 2013 and established a task group to develop the PICO question (population, intervention, comparison, and outcome) and the criteria for study eligibility, and to conduct the reviewing process. An intranet website hosted by the University of Iowa served for sharing all relevant evidence and as the communication tool for the task group.

Focused Question

The task group developed the following PICO question: "For patients with a fully edentulous maxilla who desire an implant-supported prosthesis, does the implant design affect the following outcomes: crestal bone loss or implant failure; patient satisfaction; and biological and technical adverse events of implant and prosthesis, including surgical complications, maintenance needs, and cost aspects?"

Eligibility Criteria

The authors considered all scientific publications reporting longitudinal studies that included the use of more than one implant system as eligible. Also eligible were reports with abstracts suggesting any effect of an implant design feature on the treatment outcomes. The minimum requirement for inclusion was that the report had to describe at least 10 study participants with a fully edentulous maxilla restored with an implant-retained or -supported prosthesis and followed for at least 2 years after their rehabilitation. The selected minimum follow-up time and cohort size was determined as a trade-off between the required time and resource allocation for conducting this systematic review compared with the clinical relevance of the length of the follow-up time. The authors considered both prospective and retrospective study designs published in full publications and/or meeting abstracts in the scientific and grey literature. These reports were restricted for logistical reasons to English, German, and Scandinavian languages (Danish, Norwegian, and Swedish).

The authors read the identified reports in full if the abstracts did not clearly state whether the general term "edentulous" encompassed study participants with a fully edentulous maxilla. Reports were not included for consideration if the research focus was on postrestoration interventions of adverse treatment outcomes, eg, of peri-implantitis, dehiscence, fenestration, repairs, etc, or preimplant augmentation interventions with no further reporting of outcomes of implants or supraconstruction. Moreover, this review did not include patients undergoing reconstructions related to extensive loss of oromaxillofacial tissues, eg, caused by trauma, cancer, or congenital defects.

Information Sources

Scientific reports were sought in three electronic bibliographic databases: MEDLINE through Pubmed (www.pubmed.com, National Library of Medicine), The Cochrane Central Registry of Controlled Trials (www.thecochranelibrary.com, Wiley Blackwell), and EMBASE via OVID (www.embase.com, Elsevier). The authors searched for clinical research not yet published in full text, or remaining unpublished in the abstract database of the International Association for Dental

Research (iadr.confex.com/iadr/search.epl). They also searched for potential clinical studies published in the grey literature or elsewhere through Google Scholar. The most recent search date was June 30, 2014, and went back to 1965, or the earliest records of the electronic bibliographic databases.

Search Strategy

The authors adopted the key words and MESH terms from a recent systematic review on the prosthetic rehabilitation of patients with edentulous jaws conducted by the Swedish Council on Health Technology Assessment (Table 1).[11] The search strategy was modified to fit the appropriate formats applicable to the different electronic bibliographic databases.

Reviews of the reference lists found in the relevant systematic reviews supplemented the search through the electronic databases (Tables 2a and 2b). The authors further hand searched recent issues of relevant scientific journals not yet recorded in the electronic databases. In addition, they used a personal indexed database of clinical studies related to oral implants and prosthetics built by the lead author containing over 4,500 references. Finally, the individual experts of the task group were asked to provide missing studies after having received tentative lists of identified publications for inclusion in the systematic review.

Study Selection

Three independent teams, each consisting of two or three coinvestigators, focused on one specific aspect of the implant design. The first focused on studies reporting on the role of overall implant body shape and thread design for the rehabilitation of the edentulous maxilla in healthy and medically compromised patients. The second focused on the role of implant length and diameter and the implant-abutment connection, while the third appraised the role of implant surface. Each team screened for study eligibility independently by using a common form and after completion, the teams swapped the topics and verified the previous search until they reached a consensus. The authors planned to resolve potential disagreements by forced decision by the task group chairs, but no such situations arose.

Data Collection Process

The three teams also collected data independently and resolved discrepancies by consensus. The authors of the primary publications were not contacted to obtain further data or to confirm extracted data.

Reports were excluded if the outcomes of the individual implants were presented as a function of their lengths or diameters, when these implants supported a prosthetic restoration jointly with other implants having different geometries. The authors also excluded studies in which the outcomes specific to a fully edentulous maxilla were not identified as a function of the implant design characteristic, if subsequent follow-up data could replace the earlier data, or if the full text of the report was inaccessible.

In situations with multiple publications from a single clinical study, the report with the longest follow-up was selected for data extraction. If particular details about materials and methods were lacking in the primary report, then the earlier reports were appraised.

Extracted Data Items

The authors followed the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines for selecting relevant data to extract from the individual studies. These were characteristics of the individual studies, risk of bias within the individual studies, and the results of individual studies, that is, items 18 to 20 in the PRISMA checklist.[12] Characteristics of the individual studies included identification of the lead author and description of the study participants' condition, including the anatomy of the maxilla with regard to remaining bone (Fig 1).[13] Moreover, the years when the implants were placed and whether the study was conducted in a single or multiple university, public health, or private practice settings were recorded. The number of study participants and implants placed with the follow-up time was supplemented with a description of implant-type(s) with diameters and lengths. Details of the actual intervention included: *(1)* status of the pre–implant surgery situation, *(2)* implant surgery details, *(3)* the protocols for immediate, early, or delayed implant loading, and *(4)* type of supraconstruction. Details of the treatment outcome included clinical as well as patient-relevant outcomes such as satisfaction with esthetics and function and quality of life (Table 3).

Risk of Potential Bias in Individual Studies

Elements that possibly could limit the study internal and external validity included the study's main objective and design methodology selected, the number of participants and accrued number of implants, follow-up time in years, drop-out numbers, statistical tests, and reported funding source.

Potential bias was assessed by comparing contents against a list of criteria (Table 4) compiled from two quality-assessment tools used in recent systematic reviews.[14,15] These in turn were derived from the Dutch Cochrane Centre and the Newcastle-Ottawa Scale.[16] The authors separated publications that reported an a priori intention to appraise effects of any aspect of implant design on treatment outcomes from those containing no reference to this study objective, but still reported such findings. It was considered likely that the observations made this latter category of studies spurious, and

Table 1 Search Strategy for MEDLINE through PubMed*

(“Dental Implants”[MeSH:noexp] OR “Dental Implantation, Endosseous”[MeSH:noexp] OR “Blade Implantation”[MeSH] OR ((“Dentistry”[MeSH] OR “dental”[Title/Abstract])
AND
(“Osseointegration”[MeSH] OR “osseointegration”[Title/Abstract])) OR (“dental”[Title/Abstract]
AND
(“implant”[Title/Abstract] OR “implants”[Title/Abstract] OR “implantation”[Title/Abstract]))
AND
(“Denture, Overlay”[MeSH] OR “Denture, Complete”[MeSH] OR “Denture, Partial, Removable”[MeSH] OR “Dental Prosthesis, Implant-Supported”[MeSH] OR “Denture, Fixed”[MeSH:noexp] OR “denture”[Title/Abstract] OR “prosthesis”[Title/Abstract])
AND
(“Edentulous”[Title/Abstract] OR “Jaw, Edentulous”[MeSH:noexp] OR “Mouth, Edentulous”[MeSH:noexp] OR “edentulism”[Title/Abstract]) NOT “partially edentulous”[Title/Abstract]
AND
“Maxilla” [MeSH]

*Adapted from Swedish Council on Health Technology Assessment.[11]

Table 2a Systematic Reviews Published Since 2009 With a Focus on Rehabilitation of the Fully Edentulous Maxilla Using Different Surgical Strategies or With a Focus on Assessing the Patient-Relevant Outcomes

Study (y)	Title	Source	Aim
Bassi et al (2013)	Economic outcomes in prosthodontics	Int J Prosthodont 2013;26:465–469	To identify the types of economic measures currently used in implant prosthodontics and determine the degree to which cost of care is considered in the context of any positive outcome of the care provided
Bassi et al (2013)	Functional outcomes for clinical evaluation of implant restorations	Int J Prosthodont 2013;26:411–418	To identify functional assessments of speech, swallowing, mastication, nutrition, sensation, and motor function as they relate to dental implant therapies
Bassi et al (2013)	Psychologic outcomes in implant prosthodontics	Int J Prosthodont 2013;26:429–434	To identify psychologic outcomes with properties deemed critical to meet clinical trial and clinical practice needs for the future
Bidra and Huynh-Ba (2011)	Implants in the pterygoid region: A systematic review of the literature	Int J Oral Maxillofac Surg 2011; 40:773–781	To identify clinical studies on the short- and long-term survival of implants placed in the pterygoid region
Bozini et al (2011)	A meta-analysis of prosthodontic complication rates of implant-supported fixed dental prostheses in edentulous patients after an observation period of at least 5 years	Int J Oral Maxillofac Implants 2011; 26:304–318	To systematically review clinical studies on prosthodontic complication rates of implant-fixed dental prostheses in edentulous patients after an observation period of at least 5 years
Cehreli et al (2010)	A systematic review of marginal bone loss around implants retaining or supporting overdentures	Int J Oral Maxillofac Implants 2010; 25:266–277	To evaluate, through a systematic review of the literature, the effects of implant design and attachment type on marginal bone loss in implant-retained/supported overdentures
Cehreli et al (2010)	Systematic review of prosthetic maintenance requirements for implant-supported overdentures	Int J Oral Maxillofac Implants 2010;25:163–180	To evaluate prosthetic maintenance requirements for implant-retained/supported overdentures via a review of the literature
Chrcanovic and Abreu (2012)	Survival and complications of zygomatic implants: A systematic review	Oral Maxillofac Surg 2013; 17:81–93	To answer the focused questions: “What is the survival rate of zygomatic implants (zis)?” and “What are the most common complications related to surgery of zygomatic implants?”

Table 2a ***Continued*** **Systematic Reviews Published Since 2009 With a Focus on Rehabilitation of the Fully Edentulous Maxilla Using Different Surgical Strategies or With a Focus on Assessing the Patient-Relevant Outcomes**

Study (y)	Title	Source	Aim
Chung et al (2011)	Immediate loading in the maxillary arch: Evidence-based guidelines to improve success rates—A review	J Oral Implantol 2011;37:610–621	To investigate the status of immediate loading of dental implants in the maxilla to determine its predictability as a treatment option for partial and complete maxillary edentulism
Corbella et al (2013)	Long-term outcomes for the treatment of atrophic posterior maxilla: A systematic review of literature	Clin Implant Dent Relat Res 2014;17:120–132	To estimate the implant survival rate in different types of techniques for the rehabilitation of posterior atrophic maxilla, after at least 3 years of follow-up
Del Fabbro and Ceresoli (2014)	The fate of marginal bone around axial vs tilted implants: A systematic review	Eur J Oral Implantol 2014;7:171–189	To compare the crestal bone level change around axially placed vs tilted implants supporting fixed prosthetic reconstructions for the rehabilitation of partially and fully edentulous jaws, after at least 1 year of function
Del Fabbro et al (2012-2010e)	Tilted implants for the rehabilitation of edentulous jaws: a systematic review	Clin Implant Dent Relat Res 2012;14:612–621	To evaluate the survival rate of upright and tilted implants supporting fixed prosthetic reconstructions for the immediate rehabilitation of partially and fully edentulous jaws, after at least 1 year of function
Dellavia et al (2014)	Functional jaw muscle assessment in patients with a full fixed prosthesis on a limited number of implants: A review of the literature	Eur J Oral Implantol 2014;7:155–169	To assess the function of jaw muscles in edentulous patients restored with full fixed prostheses on a limited number (≤ 6) of implants, compared with dentate subjects and edentulous subjects wearing dentures, implant-supported overdentures, or full fixed prostheses supported by more than six implants
Esposito and Worthington (2013)	Interventions for replacing missing teeth: Dental implants in zygomatic bone for the rehabilitation of the severely deficient edentulous maxilla	Cochrane Database Syst Rev CD004151 2013(p3) Update of: 2005(p2), 2003(p1)	To test the hypothesis of no difference in outcomes between zygomatic implants without bone augmenting procedures in comparison with conventional dental implants in augmented bone for severely resorbed maxillae
Esposito et al (2014)	Interventions for replacing missing teeth: Augmentation procedures for the maxillary sinus	Cochrane Database Syst Rev 2014;5:CD008397	To determine whether and when augmentation of the maxillary sinus is necessary and which are the most effective augmentation techniques for rehabilitating patients with implant-supported prostheses
Gallucci et al (2009)	Loading protocols for dental implants in edentulous patients	Int J Oral Maxillofac Implants 2009;24 (suppl 1):132–146	To present the current scientific and clinical evidence related to implant-supported rehabilitations for the edentulous mandible and maxilla
Goiato et al (2014)	Implants in the zygomatic bone for maxillary prosthetic rehabilitation: A systematic review	Int J Oral Maxillofac Surg 2014;43:748–757	To evaluate clinical studies on the follow-up survival of implants inserted in the zygomatic bone for maxillary rehabilitation
Heydecke et al (2012)	What is the optimal number of implants for fixed reconstructions: A systematic review	Clin Oral Implants Res 2012; 23(suppl 6): 217–228	To assess the 5- and 10-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
Kotsakis et al (2014)	A systematic review of observational studies evaluating implant placement in the maxillary jaws of medically compromised patients	Clin Implant Dent Relat Res 2015;17:598–609	To evaluate the survival of implants placed in the maxillary jaws of medically compromised patients

Table 2a ***Continued*** **Systematic Reviews Published Since 2009 With a Focus on Rehabilitation of the Fully Edentulous Maxilla Using Different Surgical Strategies or With a Focus on Assessing the Patient-Relevant Outcomes**

Study (y)	Title	Source	Aim
Lambert et al (2009)	Descriptive analysis of implant and prosthodontic survival rates with fixed implant-supported rehabilitations in the edentulous maxilla	J Periodontol 2009; 80:1220–1230	To review the 1- to 15-year survival rates of fixed implant rehabilitations in the edentulous maxilla
McGrath et al (2012)	An evidence-based review of patient-reported outcome measures in dental implant research among dentate subjects	J Clin Periodontol 2012;39:193–201	To conduct an evidence-based review of patient-reported outcome measures in dental implant research among dentate patients so as to gain an understanding of the use of such measures, and the potential evidence that can be gleaned from such studies
Menini et al (2012)	Tilted implants in the immediate loading rehabilitation of the maxilla: A systematic review	J Dent Res 2012;91:821–827	To evaluate the outcomes of upright and tilted implants supporting full-arch fixed dentures for the immediate rehabilitation of edentulous maxillae, after at least 1 year of function
Mericske-Stern and Worni (2014)	Optimal number of oral implants for fixed reconstructions: A review of the literature	Eur J Oral Implantol 2014;7:133–153	To review best evidence for the preferred or best number of implants to be used for the support of a fixed prosthesis in the edentulous maxilla or mandible
Monje et al (2012)	Marginal bone loss around tilted implants in comparison to straight implants: A meta-analysis	Int J Oral Maxillofac Implants 2012;27:1576–1583	To compare the amount of marginal bone loss around tilted and straight implants, and to compare the incidence of biomechanic complications as the secondary aim
Ohkubo and Baek (2010)	Does the presence of antagonist remaining teeth affect implant overdenture success? A systematic review	J Oral Rehabil 2010;37:306–312	To clarify the correlation between existing teeth and the survival/success rate of maxillary and mandibular implant overdentures
Papaspyridakos et al (2012)	A systematic review of biologic and technical complications with fixed implant rehabilitations for edentulous patients	Int J Oral Maxillofac Implants 2012;27:102–110	To assess the incidence and types of biologic and technical complications associated with implant-supported fixed complete dental prostheses for edentulous patients
Patzelt et al (2014-2013e)	The all-on-four treatment concept: A systematic review	Clin Implant Dent Relat Res 2014;16:836–855	To evaluate the all-on-four treatment concept with regard to survival rates of oral implants, applied fixed dental prostheses and temporal changes in proximal bone levels
Pommer et al (2014)	Patients' preferences towards minimally invasive treatment alternatives for implant rehabilitation of edentulous jaws	Eur J Oral Implantol 2014; 7:91–109	To evaluate patient satisfaction, oral health–related quality of life, and patients' preferences toward minimally invasive treatment options for graftless rehabilitation of complete edentulism by means of dental implants
Raghoebar et al (2014)	A systematic review of implant-supported overdentures in the edentulous maxilla, compared to the mandible: How many implants?	Eur J Oral Implantol 2014;7:191–201	To review the treatment outcome of concepts used for implant-supported maxillary overdentures, focusing on the survival of implants, survival of maxillary overdentures, and condition of the implant surrounding hard and soft tissues after a mean observation period of at least 1 year
Roccuzzo et al (2012)	What is the optimal number of implants for removable reconstructions? A systematic review on implant-supported overdentures	Clin Oral Implants Res 2012;23 (suppl 6):229–237	To assess the optimal number of implants for removable reconstructions

Table 2a ***Continued*** **Systematic Reviews Published Since 2009 With a Focus on Rehabilitation of the Fully Edentulous Maxilla Using Different Surgical Strategies or With a Focus on Assessing the Patient-Relevant Outcomes**

Study (y)	Title	Source	Aim
Sánchez-Ayala et al (2010)	Nutritional effects of implant therapy in edentulous patients: A systematic review	Implant Dent 2010;19:196–207	To present all the relevant studies that have evaluated the possible physical and nutrient intake improvements of edentulous subjects rehabilitated with removable and supported or retained implant dentures
Schley and Wolfart (2011)	Which prosthetic treatment concepts present a reliable evidence-based option for the edentulous maxilla related to number and position of dental implants?	Eur J Oral Implantol 2011;4:31–47	To answer the following questions: Which prosthetic treatment concept related to implant number and position presents a reliable evidence-based option for the edentulous maxilla?
Slot et al (2010)	A systematic review of implant-supported maxillary overdentures after a mean observation period of at least 1 year	J Clin Periodontol 2010;37:98–110	To assess the survival of implants, survival of maxillary overdentures, and the condition of surrounding hard and soft tissues after a mean observation period of at least 1 year
Vogel et al (2013)	Evaluating the health economic implications and cost-effectiveness of dental implants: A literature review	Int J Oral Maxillofac Implants 2013;28:343–356	To review the available literature on the costs and cost-effectiveness of dental implant-supported or -retained prostheses vs tooth-supported fixed partial denture restorations or mucosa-borne conventional complete or partial dentures

Table 2b **Systematic Reviews Published Since 2009 With a Focus on Effects of Characteristics of Implant***

Study (y)	Title	Source	Aim
Abrahamsson and Berglundh (2009)	Effects of different implant surfaces and designs on marginal bone-level alterations: A review	Clin Oral Implants Res 2009;20(suppl 4): 207–215	To evaluate the effect of different implant surfaces and designs on marginal bone-level alterations
Al-Nsour et al (2012)	Effect of the platform-switching technique on preservation of peri-implant marginal bone: A systematic review	Int J Oral Maxillofac Implants 2012; 27:138–145	To systemically review the effect of platform switching on preserving implant marginal bone
Aloy-Prósper et al (2011)	Marginal bone loss in relation to the implant neck surface: An update	Med Oral Patol Oral Cir Bucal 2011; 16:e36 5–e368	To appraise publications on the marginal bone loss of implants with a polished neck, rough neck with microthreading, and rough neck without microthreading
Alsabeeha et al (2012)	Hydroxyapatite-coated oral implants: A systematic review and meta-analysis	Int J Oral Maxillofac Implants 2012;27:1123–1130	To evaluate treatment outcomes of hydroxyapatite-coated implants in comparison to nonhydroxyapatite-coated implants
Andreiotelli et al (2009)	Are ceramic implants a viable alternative to titanium implants? A systematic literature review	Clin Oral Implants Res 2009;20(suppl 4): 32–47	To locate animal and clinical data on bone-implant contact and clinical survival/success that would help to answer the question "Are ceramic implants a viable alternative to titanium implants?"
Annibali et al (2011)	Short dental implants: A systematic review	J Dent Res 2012;91:25–32	To systematically evaluate clinical studies of implants < 10 mm in length, to determine short implant-supported prosthesis success in the atrophic jaw

*Characteristics such as material, surface, dimension including diameter or length, one- or two-piece, implant-abutment connection on outcomes.

Table 2b ***Continued*** **Systematic Reviews Published Since 2009 With a Focus on Effects of Characteristics of Implant***

Study (y)	Title	Source	Aim
Annibali et al (2012)	Peri-implant marginal bone level: A systematic review and meta-analysis of studies comparing platform switching versus conventionally restored implants	J Clin Periodontol 2012;39:1097–1113	To systematically review the literature to compare implant survival and marginal bone loss around platform-switched vs conventionally restored platform-matching dental implants
Atieh et al (2010)	Platform switching for marginal bone preservation around dental implants: A systematic review and meta-analysis	J Periodontol 2010;81:1350–1366	To systematically review radiographic marginal bone level changes and the survival of platform-switched implants compared with conventional platform-matched implants
Atieh et al (2012)	Survival of short dental implants for treatment of posterior partial edentulism: A systematic review	Int J Oral Maxillofac Implants 2012;27:1323-1331	To systematically review studies concerning dental implants of ≤ 8.5 mm placed in the posterior maxilla and/or mandible to support fixed restorations
Barrachina-Díez et al (2013)	Long-term outcome of one-piece implants. Part I: Implant characteristics and loading protocols–A systematic literature review with meta-analysis	Int J Oral Maxillofac Implants 2013;28:503–518	To evaluate the long-term clinical performance of one-piece implants
Barrachina-Díez et al (2013)	Long-term outcome of one-piece implants. Part II: Prosthetic outcomes–A systematic literature review with meta-analysis	Int J Oral Maxillofac Implants 2013; 28:1470–1482	To evaluate the long-term clinical performance of prosthetic reconstructions on one-piece implants, with a focus on technical and biological complications
Bateli et al (2011)	Implant neck configurations for preservation of marginal bone level: A systematic review	Int J Oral Maxillofac Implants 2011;26:290–303	To evaluate the effectiveness of various implant neck configurations in the preservation of marginal bone level as well as to identify the available scientific evidence
Bishti et al (2014-2013e)	Effect of the implant-abutment interface on peri-implant tissues: A systematic review	Acta Odontol Scand 2014;72:13–25	To determine the peri-implant tissue response to different implant abutment materials and designs available and to assess the impact of tissue biotype
Depprich et al (2014-2012e)	Current findings regarding zirconia implants	Clin Implant Dent Relat Res 2014;16:124–137	To analyze the available clinical data on the survival and success rate of dental zirconia implants
Elangovan et al (2013)	Quality assessment of systematic reviews on short dental implants	J Periodontol 2013;84:758–767	To analyze the quality of published systematic reviews focused on short dental implants using established checklists such as the assessment of multiple systematic reviews
Esposito et al (2014)	Interventions for replacing missing teeth: Different types of dental implants	Cochrane Database Syst Rev CD003815 2014(p4) Update of: 2007(p4), 2005(p3), 2003(p2), 2002(p1)	To test the null hypothesis of no difference in clinical performance between various root-formed osseointegrated dental implant types
Gracis et al (2012)	Internal vs. external connections for abutments/ reconstructions: A systematic review	Clin Oral Implants Res 2012;23(suppl 6):202–216	(1) To evaluate the accuracy of implant-level impressions in cases with internal and external connection abutments/reconstructions, and (2) to evaluate the incidence of technical complications
Junker et al (2009)	Effects of implant surface coatings and composition on bone integration: A systematic review	Clin Oral Implants Res 2009;20(suppl 4):185–206	To evaluate the bone integration efficacy of recently developed and marketed oral implants as well as experimental surface alterations

*Characteristics such as material, surface, dimension including diameter or length, one- or two-piece, implant-abutment connection on outcomes.

Table 2b ***Continued*** **Systematic Reviews Published Since 2009 With a Focus on Effects of Characteristics of Implant***

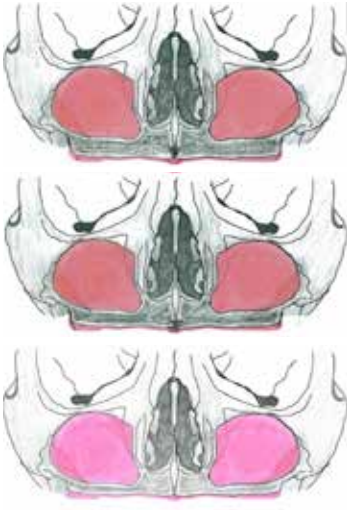
Study (y)	Title	Source	Aim
Kotsovilis et al (2009)	A systematic review and meta-analysis on the effect of implant length on the survival of rough-surface dental implants	J Periodontol 2009; 80:1700–1718	To address the focused question "Is there a significant difference in survival between short (or = 10 mm) rough-surface dental implants placed in (1) totally or (2) partially edentulous patients?"
Laurell and Lundgren (2011-2009e)	Marginal bone level changes at dental implants after 5 years in function: A meta-analysis	Clin Implant Dent Relat Res 2011;13:19–28	To compile and compare data on peri-implant marginal bone level changes from prospective studies that have registered the peri-implant marginal bone level radiographically after 5 years of follow-up for implant systems currently available on the market
Menchero-Cantalejo et al (2011)	Meta-analysis on the survival of short implants	Med Oral Patol Oral Cir Bucal 2011;16:e546–e551	To evaluate the success and failure rates of short implants (10 mm or less) for oral rehabilitations in cases of limited bone height
Monje et al (2013a)	Are short dental implants (< 10 mm) effective? A meta-analysis on prospective clinical trials	J Periodontol 2013; 84:895–904	To compare the survival rate of short (< 10 mm) and standard (≥ 10 mm) rough-surface dental implants under functional loading.
Monje et al (2013b)	Do implant length and width matter for short dental implants (< 10 mm)? A meta-analysis of prospective studies	J Periodontol 2013;84:1783–1791	To determine the effects of dental implant length and width on implant survival rate of short (6-9 mm) implants
Neldam and Pinholt (2012)	State of the art of short dental implants: A systematic review of the literature	Clin Implant Dent Relat Res 2012;14:622–632	To evaluate publications on short dental implants, defined as an implant with a length of ≤ 8 mm, installed in the maxilla or in the mandible with special reference to implant type, survival rate, location of implant site, and observation time
Pommer et al (2011)	Impact of dental implant length on early failure rates: A meta-analysis of observational studies	J Clin Periodontol 2011;38:856–863	To test the null hypothesis of no difference in failure rates of short (minimum length: 7 mm) and longer dental implants (≥ 10 mm) in a meta-analysis of prospective observational trials
Renvert et al (2011)	How do implant surface characteristics influence peri-implant disease?	J Clin Periodontol 2011;38(suppl 11):214–222	To review the literature on how implant surface characteristics influence peri-implant disease
Romeo et al (2010)	The use of short dental implants in clinical practice: Literature review	Minerva Stomatol 2010; 59:23–31	To evaluate the differences in survival rate and the rational use of short implants
Rungruanganunt et al (2013)	The effect of static load on dental implant survival: A systematic review	Int J Oral Maxillofac Implants 2013;28:1218–1225	To systematically review the current evidence related to the effects of static loading on the long-term stability of the osseointegrated interface
Schmitt et al (2013)	Performance of conical abutment (Morse Taper) connection implants: A systematic review	J Biomed Mater Res A 2014;102:552–574	To compare conical vs nonconical implant-abutment connection systems in terms of their in vitro and in vivo performances
Sohrabi et al (2012)	How successful are small-diameter implants? A literature review	Clin Oral Implants Res 2012;23:515–524	To determine (1) the survival of narrow diameter implants, (2) whether survival is dependent on whether these implants are placed using a flap or flapless approach, and (3) whether there is a relationship between length and implant survival in short dental implants
Srinivasan et al (2012)	Efficacy and predictability of short dental implants (< 8 mm): A critical appraisal of the recent literature	Int J Oral Maxillofac Implants 2012;27:1429–1437	To evaluate the predictability of treatment outcomes with short dental implants, implants shorter than 8 mm

*Characteristics such as material, surface, dimension including diameter or length, one- or two-piece, implant-abutment connection on outcomes.

Table 2b ***Continued*** **Systematic Reviews Published Since 2009 With a Focus on Effects of Characteristics of Implant***

Study (y)	Title	Source	Aim
Srinivasan et al (2013)	Survival rates of short (6 mm) micro-rough surface implants: A review of literature and meta-analysis	Clin Oral Implants Res 2014;25:539–545	To test the hypothesis that 6 mm micro-rough short Straumann implants provide predictable survival rates and verify that most failures occurring are early failures
Sun et al (2011)	Failure rates of short (≤ 10 mm) dental implants and factors influencing their failure: A systematic review	Int J Oral Maxillofac Implants 2011;26:816–825	To evaluate the long-term failure rates of short dental implants (≤ 10 mm) and to analyze the influence of various factors on implant failure
Telleman et al (2011)	A systematic review of the prognosis of short (< 10 mm) dental implants placed in the partially edentulous patient	J Clin Periodontol 2011;38:667–676	To evaluate, through a systematic review of the literature, the estimated implant survival rate of short (< 10 mm) dental implants placed in partially edentulous patients.
van Oirschot et al (2013-2012e)	Long-term survival of calcium phosphate-coated dental implants: A meta-analytical approach to the clinical literature	Clin Oral Implants Res 2013;24:355–362 [Epub 2012]	To systematically appraise and to conduct a meta-analysis of long-term survival data of calcium phosphate–coated dental implants in clinical trials
Vouros et al (2012)	Systematic assessment of clinical outcomes in bone-level and tissue-level endosseous dental implants	Int J Oral Maxillofac Implants 2012;27:1359–1374	To address the clinical and radiographic outcomes of bone-level implants vs tissue-level implants after restoration with dental prostheses
Wennerberg and Albrektsson (2009)	Effects of titanium surface topography on bone integration: A systematic review	Clin Oral Implants Res 2009;20(suppl 4):172–184	To analyze possible effects of titanium surface topography on bone integration

*Characteristics such as material, surface, dimension including diameter or length, one- or two-piece, implant-abutment connection on outcomes.



Cawood Howell–Anatomy

Class	Ridge form	Height	Width	Comment
II				Post extraction
III	Round	Adequate (> 10 mm)*	Adequate (> 4 mm)*	*
IV	Knife edge	Adequate (> 10 mm)	Inadequate (< 4 mm)	
V	Flat	Inadequate (< 10 mm)	Inadequate (< 4 mm)	
VI	Depression			Some loss of basal bone evident

*mm not described in original paper.

Fig 1 Illustration of approximate remaining maxillary bone according to the Cawood-Howell bone classification system.[13] Note that the authors did not state the dimensions in millimeters in their original study.

Table 3 Treatment Outcomes in Edentulous Maxilla
Immediate
Surgical complications
Prosthodontic complications
Late
Dissatisfaction with function
Speech/chewing ability/other (eg, saliva spray)
Dissatisfaction with appearance
Prominent chin ("bulge")
Sunken profile (posterior medial modiolus, large nasolabial angle, marked nasolabial fold)
Teeth not showing
Upper lip not showing (orbicularis oris collapse)
Transition line prosthesis: tissue visible upon smiling
Occlusally related
Even functional occlusion (articulation)
Overclosure
Pain in temporomandibular joint, possibly because of incorrect vertical dimension of occlusion
Biological adverse outcome
Ulcers/soreness/bleeding, possibly because of lack of oral health access
Inflammatory peri-implant diseases
Technical adverse outcome
Supraconstruction
Ill-fit supraconstruction to implants
Implant system components wear and break down
Cost/fiduciary aspects
Maintenance needs

Table 4 Appraisal of Risk of Potential Bias in Individual Studies			
1. Is there a clearly stated study objective that matches the reported outcome?	1	?	0
2. Is the study design appropriate with respect to the stated study objective?	1	?	0
3. Has an ethics board approved the study?	1	?	0
4. Are the characteristics of the study participants clearly described?	1	?	0
5. Is there a risk of selection bias – are the inclusion and exclusion criteria clearly described?	1	?	0
6. Are all steps of the intervention clearly described – if comparative, are all participants treated according to the same intervention (apart from factor of interest)?	1	?	0
7. Are the outcomes clearly described – are adequate methods used to assess these outcomes?	1	?	0
8. Has blinding been used when outcomes have been assessed?	1	?	0
9. Is the follow-up rate satisfactory?	1	?	0
10. Are all participants accounted for?	1	?	0
11. Can selective loss to follow-up likely be excluded?	1	?	0
12. Are the most important confounders or prognostic factors identified and are these taken into consideration with respect to the study design and analysis?	1	?	0
13. Are the statistical analyses appropriate in light of the study objective, test assumptions, and choice of statistical unit?	1	?	0
14. Is the funding source for the study declared?	1	?	0

1 = yes, 0 = no, ? = unclear

the article therefore probably more prone to bias than the studies designed for the purposes of appraising implant design effects.

The statistical method was appraised for appropriateness, in light of the stated study objective, with particular emphasis on statistical test assumptions and choice of statistical unit. In addition, the authors recorded whether a formal ethics board or committee had approved the study protocol, and whether the authors declared a funding source of the study. Both criteria were associated with a lower risk of potential bias. Formal statistical assessment to assess publication bias was not applied.

Summary Measures

The authors planned this systematic review to present primarily descriptive data as a basis for the development of clinical practice guidelines following the process described by Rosenfeld and Shiffman.[17] They considered using RevMan 5 (Nordic Cochrane Centre) for conducting meta-analyses, if possible. Unfortunately, the yield of the literature search was limited, and the reports too heterogeneous with regard to study methods as well as clinical procedures and variables. Hence, no forest or funnel plots were generated in this review. The authors recommend that the reader appraise the systematic reviews listed in Tables 2a and 2b for meta-analytic data.

RESULTS

Study Selection

Approximately 1,000 studies were identified initially. After screening the abstracts, about half of these (n = 473) were not eligible according to the a priori inclusion criteria. The predominant reason was a follow-up period of less than 2 years (n = 340) or fewer than 10 study participants (n = 91) or lacking both criteria (n = 34) (Fig 2). The heterogeneous formats of the abstract and reporting of clinical outcomes precluded conclusive decisions about inclusion and exclusion so the full text of the remaining 525 articles were scrutinized. About one fifth of these reports were selected for data extraction (n = 105). The major reason for exclusion was that the outcomes as a function of implant design aspects specific to a rehabilitated edentulous maxilla could not be identified in the report (n = 382) (Fig 2). Further details on the nonincluded and excluded reports, including reasons for decision are located on the website of the Academy of Osseointegration (www.osseo.org).

Within the overall PICO, the authors identified six subcategories by an amalgamation of the preimplant surgery characteristics of the study participants, combined with the complexity level and sequence of interventions (Table 5 and Figs 3–7).

Study Characteristics

Studies Designed to Assess Effects of Implant Design or Particular Feature on Outcomes (Fig 3). The literature search identified 196 reports, of which 77 were not included and 102 were excluded (Table 6)[18–31]. As many as 34 reports were from one study cohort, that is, the extensive Dental Implant Clinical Research Group (DICRG) study undertaken by 30 Veterans Affairs Medical Centers across the United States.[32] The predominant reason for noninclusion was reported observation period less than 2 years (n = 77), while the dominant reason for study exclusion was that outcomes as a function of aspects of implant design specific to a rehabilitated edentulous maxilla could not be identified in the article (n = 79). A common experience was that reports with focus on "maxillary posterior atrophy," with or without sinus grafting often failed to describe whether the study participants were partially or fully edentulous. The authors selected 17 reports published between 1995 and 2013 for data extraction.[18–34]

The studies selected for data extraction included study participant cohorts that encompassed all categories of patient conditions[23,26,32] or only participants with edentulous jaws or an edentulous maxilla. Four studies included study participants with terminal teeth, who received immediate postextraction implants.[19,25,30,31]

The 17 reports presented results based on 3,205 study participants with 12,599 implants placed between 1987[34,35] and 2008.[19] The study settings were single private (n = 6), university (n = 6), public (n = 2), or multicenter (n = 3). The study cohorts ranged between 12 and 829[32] participants with 72 to 2,955[32] implants, which were followed up from 2 to 15[21] years. The prevailing implant systems used were manufactured by Nobel Biocare (n = 10), Astra Tech and Biomet 3i (n = 3), Straumann (n = 2), and Lifecore (n = 1), Camlog (n = 1), Dentsply (n = 1), and CoreVent (n = 1). Two studies did not report the name of the implant manufacturer.

Studies Reporting the Effects of Tilted Implants to Enable Placement of Longer Implants (Fig 4). The literature search identified 46 reports, of which 21 were not included and 2 were excluded because cylindrical implants were placed in healed sites, whereas tapered implants were placed in all postextraction sites. The most predominant reason for noninclusion was lack of an observation period longer than 2 years (n = 18). Twenty-three reports remained for data extraction, primarily with the intent of comparing the outcome of the axial vs (invariably longer) tilted implants (Table 7).[35–57]

The studies selected for data extraction were published between 1999[57] and 2014,[35–37] and included study participant cohorts that encompassed partially edentate or fully edentulous maxilla. Some of the studies focused on patients with a general or posterior maxillary atrophy. Twelve reports included study participants with terminal teeth, who received immediate postextraction implants, either axially placed or tilted or both. It was often difficult to judge whether some of the reports described outcomes of the same or separate study participant cohorts.

The 23 reports presented results based on 1,516 study participants with 6,681implants placed between 1991[55] and 2012.[38] The study settings were single private (n = 8), university (n = 8), not reported (n = 4), public (n = 1), or multicenter (n = 2). The study cohorts ranged between 15 and 242 participants with 68 to 995 implants, followed up from 2 to 12 years. The prevailing implant systems used were manufactured by Nobel Biocare (n = 15), Biomet 31 (n = 2), and one each by Zimmer, Sweden & Martina, and Friatec/Friadent.Three studies did not report the name of the implant manufacturer. Separate outcomes as a function of different types or features of implants could be extracted from five reports.[42,46–48,52]

Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 5). The literature search identified 56 reports, of which 26 were not included because either the observation period was less than 2 years or the study population was less than 10. Thirty reports

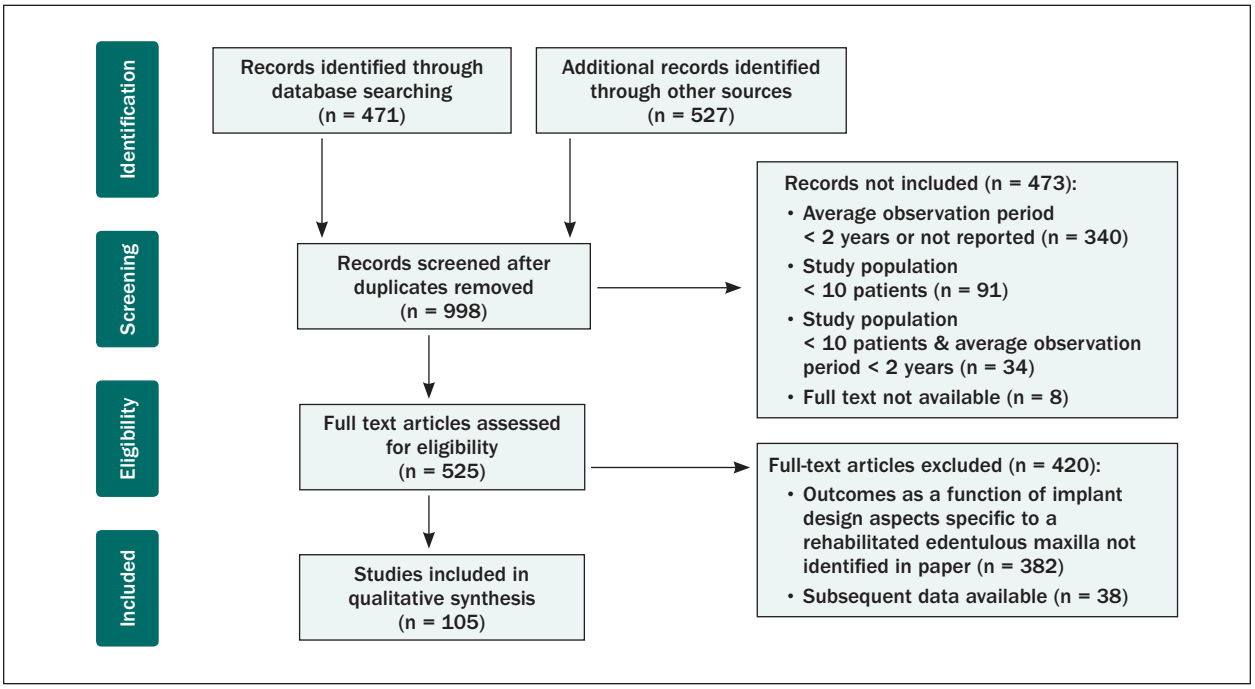


Fig 2 PRISMA flow-chart.[12] Reports of studies describing implant-supported prosthesis in fully edentulous maxilla.

Table 5 Subcategories of Reports Based on Characteristics of Study Design as well as Strategy for Surgical Intervention

Study Objective	Identified	Not Included	Excluded	Included
To assess effects of implant design or feature on outcomes (all categories of the Cawood-Howell bone classification system)[18–34]	196	77	102	17
To report effects of tilted implants to enable placement of longer implants (all categories of the Cawood-Howell bone classification system)[35–57]	46	21	2	23
To report effects of implants placed in zygomatic bone with or without additional alveolar implants (predominantly Cawood-Howell bone class V and VI)[58–87]	56	26	0	30
To report effects of implants placed in pterygoid bone or other bony buttresses with or without additional alveolar implants (predominantly Cawood-Howell bone class V and VI)[88–96]	13	4	0	9
To report bone augmentation with simultaneous or delayed implant placement (predominantly Cawood-Howell bone class V and VI)[97–112]	165	92	57	16
No a priori stated objective to assess a particular implant design or feature (all categories of the Cawood-Howell bone classification system)[113–122]	522	253	259	10
Total	998	473	420	105

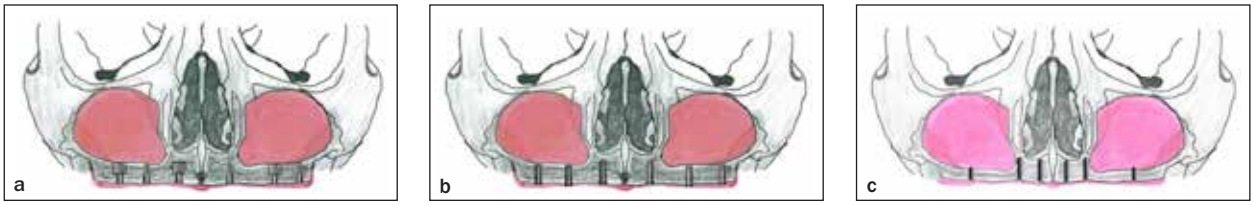


Fig 3 Examples of variations in study designs applied to appraise effects of implant design features, beyond parallel study cohort comparisons.[21] *(a)* Placement of implants in random locations, in this case, Brånemark implants with two different tap relief profiles.[34] *(b)* Split-mouth study, eg, comparing effects of different CoreVent implants.[32] *(c)* Comparing short Straumann implants placed in limited bone distally, with longer implants placed anteriorly in study participants with Cawood-Howell class IV maxilla.[22]

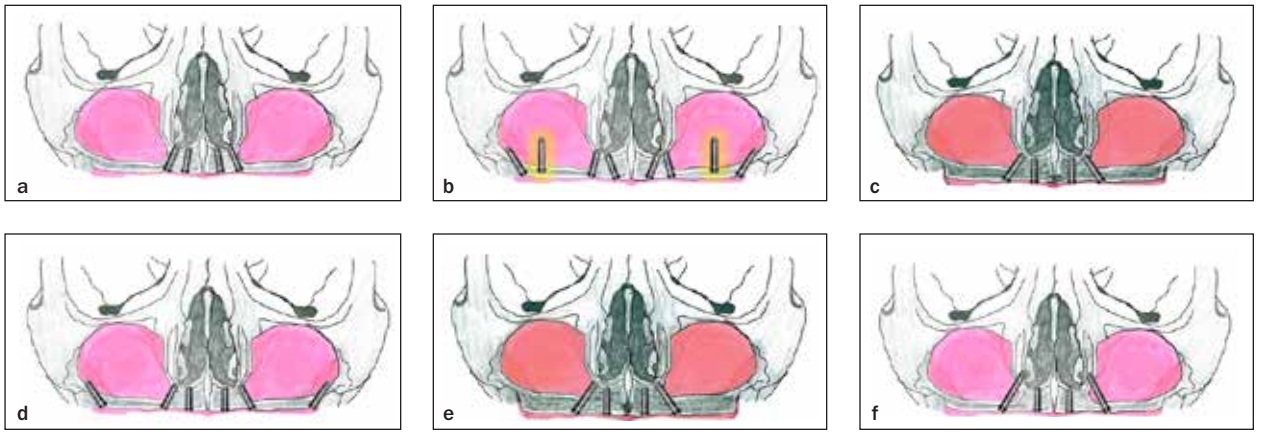


Fig 4 Examples of diversity of surgical approaches using tilted implants. Two left examples were alternatives to bone augmentation techniques in study participants with Cawood-Howell (C-H) bone class V/VI.[56, 57] *(a)* Four distally tilted Brånemark implants in a C-H V/VI maxilla[57]; *(b)* two axial and two 30- to 45-degree distally tilted Brånemark implants in C-H III/IV maxilla[55]; *(c)* two axial and two 30-degree distally tilted "externally hexed" implants in immediate extraction sockets (C-H II).[44] Note relative gain in tilted implant lengths vs axial as a function of increasing bone height. Bottom figures show alternatives to bone augmentation techniques in study participants with C-H V/VI bone; *(d)* two distally and four mesially 25- to 30-degree tilted and two Brånemark implants in palatal vault[56]; *(e)* two axial and four 25- to 30-degree mesially and distally tilted Brånemark implants[52]; *(f)* two axial and two distally tilted implants, but through the sinus to obtain fixation in four layers of cortical bone.[39]

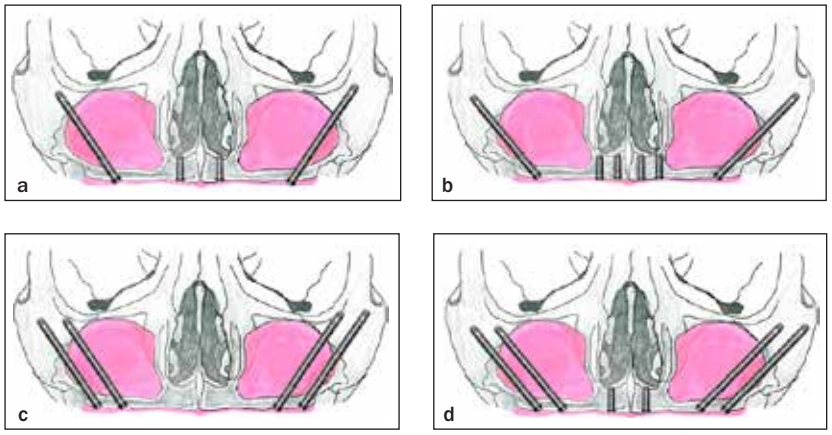


Fig 5 Examples of diversity of surgical approaches using zygomatic implants in study participants with Cawood-Howell bone class IV to VI. *(a)* Two trans-sinus zygomatic and two conventional implants[87]; *(b)* four trans-sinus zygomatic[86]; *(c)* two extrasinus zygomatic and four conventional implants[64]; *(d)* four extrasinus zygomatic implants and two conventional implants.[68]

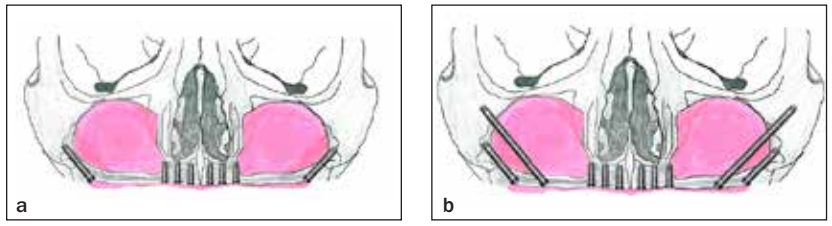


Fig 6 Examples of the use of pterygomaxillary implants in study participants with Cawood-Howell bone class IV to VI. *(a)* Two Brånemark pterygomaxillary and six conventional Brånemark implants[96]; *(b)* two Brånemark pterygomaxillary, six Brånemark conventional implants, and two zygomatic implants, also known as the "teeth-in-an-hour" concept.[95]

remained for data extraction, primarily with the intent to compare the intrapatient outcome of the zygoma vs conventional implants (Table 8).[58–87]

The studies selected for data extraction were published between 2002[87] and 2014[58–60] and included study participant cohorts that encompassed partially edentate or fully edentulous maxilla. Most of the studies reported that there was general or posterior atrophy, but few described the actual Cawood-Howell classifications.[13] None of the studies included participants with terminal teeth, who received immediate postextraction implants. In some reports, it was often difficult to judge whether they described outcomes of the same or different study cohorts.

Between 1990[85] and 2013,[60] 1,359 study participants received 6,394 conventional and zygoma implants. The study settings were single private (n = 15), university (n = 6), not reported (n = 4), public (n = 4), or multicenter (n = 1). The study cohorts ranged between 11 and 352[61] participants with 48 to 1,542[61] implants,

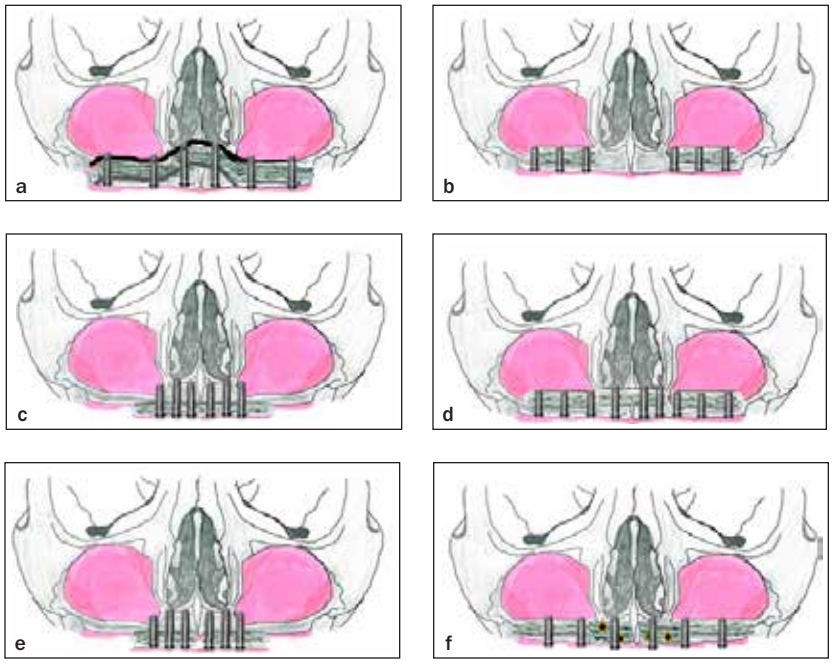


Fig 7 Examples of the diversity of surgical approaches for bone augmentation with simultaneous or delayed implant placement in study participants with Cawood-Howell bone class IV to VI. *(a)* Le Fort I fracture with interpositional fixation and immediate or delayed placement of six Brånemark implants.[109] *(b)* Full-arch onlay block with six immediate Brånemark implants.[104] *(c)* Segmental block onlay with delayed Brånemark implants. *(d)* Segmental inlay blocks in sinus with six immediate loading Brånemark implants.[112] *(e)* Right segmental inlay blocks in sinuses and nasally with nine immediate loading Brånemark implants.[106] *(f)* Segmental blocks in sinus and horizontal onlay anteriorly with Brånemark implants placed 4 to 7 months later.[102]

followed up from 2 to 10 years. The implant system used was almost universally manufactured by Nobel Biocare (n = 30). Other systems were Defcon (n = 1), Phibo (n = 1), and one unreported implant manufacturer. Separate outcomes as a function of implant features, eg, turned vs oxidized implant surface, were not presented in any of the reports.

Studies Reporting the Effects of Implants Placed in Pterygoid Bone or Other Bony Buttresses With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 6). The literature search identified 13 reports, of which 9 were selected for data extraction, primarily with the intent to compare the outcome of the pterygomaxillary vs conventional implants (Table 9).[88–96]

The studies selected for data extraction were published between 1999[96] and 2013,[88] and included study participant cohorts that encompassed partially edentate or fully edentulous maxilla. Most studies reported that there was general or posterior atrophy. Two studies included participants with terminal teeth,[89,95] who received immediate postextraction implants. In some reports, it was often difficult to judge whether they described outcomes of the same or different study cohorts.

A total of 1,814 study participants received 6,808 implants between 1985[89,90] and 2010.[89,90] The study settings were a single private practice in the United States (n = 4), or from a single university in Spain (n = 4) and one private practice. The study cohorts had a range of 18 to 981[89] participants with 117 to 1,817[96] implants, followed up from 2 to 25 years.[89] The implant systems were manufactured by Nobel Biocare (n = 5), Defcon (n = 2), and one each by Astra Tech, Biomet 3i, Phibo, and Straumann. Four studies reported outcomes as a function of implant design.[89,90,95,96]

Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting An Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 7). The literature search identified 165 reports, of which 92 were not included because either the observation period was less than 2 years or the study population was less than 10. Fifty-five of the 57 excluded articles did not report outcomes as a function of implant design aspects specific to a rehabilitated edentulous maxilla. Sixteen reports remained for data extraction (Table 10).[97–112]

The studies selected for data extraction were published between 1994[112] and 2013,[97,98] and included cohorts that encompassed all categories of participant situations, or included only participants with a fully edentulous maxilla. Most articles described the study participants' atrophic maxilla according to the Cawood-Howell classification.[13] None of the studies included participants with terminal teeth, who received immediate postextraction implants. In some reports, it was often difficult to judge whether they described outcomes of the same or different study participant cohorts.

A total of 937 study participants received 5,667 implants between 1984[105,106,112] and 2009.[97] The study

Table 6 Characteristics of Studies Designed With an Objective to Assess Effects of Implant Design (/Feature) on Outcomes

Study	Patient Situation	Year Placed	Setting
Jungner et al (2014-2012e)[18]	Edentulous (31p, 148i) Partial edentate (39p, 103i), Single (33p, 36i), mandible, maxilla	2001–2002	Private practice, Umeå, Sweden
Vervaeke et al (2015-2013e)[19]	Terminal/edentulous mandible (52p, 269i), maxilla (39p,250i)	2002–2008	University clinic, Milano, Italy
Testori et al (2014-2013e)[20]	Edentulous(736i), partial dentate (419i), single (165i), mandible (563i), maxilla (757i)	2004–2007	Private practice
Ravald et al (2013)[21]	Edentulous mandible (32p, 165i), maxilla (34p, 206i)	1993–1995	Public health, Linköping, Sweden
Van Assche et al (2012-2011e)[22]	Edentulous maxilla	NR	University clinic, Leuven, Belgium
Cosyn et al (2012-2010e)[23]	All categories	2004–2007	University hospital, Ghent, Belgium
Kallus et al (2009-2008e)[24]	Edentulous mandible (358i), maxilla (222i)	NR	Private practice, Stockholm, Sweden
Li et al (2009)[25]	Terminal/edentulous mandible (63p, 371i), maxilla (48p, 319i)	2001–2007	Private practice, Hong Kong
Alsaadi et al (2008)[26]	All categories	NR	University clinic, Leuven, Belgium
Nelson et al (2008)[27]	Edentulous mandible/maxilla (418i), partial dentate mandible/maxilla (114i)	2000–2005	University clinic, Berlin, Germany
Maló et al (2007)[28]	Edentulous (54i), partial dentate (296i), single (58i), mandible (278i), maxilla (130i)	1996–2004	Private practice, Lisbon, Portugal
Hjalmarsson and Smedberg (2005)[29]	Edentulous mandible maxilla	1999–2000	Public health, Stockholm, Sweden
Degidi et al (2005)[30]	Terminal/edentulous maxilla	1995–1999	Private practice, Bologna, Italy
Schwartz-Arad et al (2004)[31]	Terminal/edentulous mandible (22p, 150i), maxilla (31p, 228i)	1989–1996	University clinic, Tel Aviv, Israel
Morris et al (2001)[32]	All categories	1991–NR	Multicenter (30): Veterans Affairs Medical Centers, USA
Friberg et al (1997)[33]	Edentulous mandible (69p, 363i), maxilla (33p, 200i)	1987–1990	Multicenter (3): public health, Sweden
Olsson et al (1995)[34]	Edentulous mandible (70p, 363i), maxilla (33p, 200i)	1987–1990	Multicenter (3): public health, Göteborg/Skövde/Umeå, Sweden

Ø = diameter; L = length; NR = not reported; TiU=TiUnite, HA= hydroxyapatite; p = patients; i = implants.

settings were public hospitals (n = 8), university (n = 5), or multicenter (n = 3). The study cohorts had a range of 10 to 224[97] participants with 60 to 1,120[102] implants, followed up for 2 to 14 years.[97] The implant systems were manufactured by Nobel Biocare (n = 11), Astra Tech (n = 2), Friatec/Friadent (n = 1), and Straumann (n = 1). One report did not specify the name of the implant manufacturer and another listed four systems with no further details about the performance of each.

Studies Designed With no A Priori Stated Objective to Assess a Particular Implant Design Feature.[113–123] The authors identified these reports amongst the remaining 522 reports, of which 253 were not included because either the observation period was less than 2 years or the study population was less than 10**.** Of the 259 excluded articles, 252 did not report outcomes as a function of implant design aspects specific to a rehabilitated edentulous maxilla. Ten reports remained for data extraction (Table 11).[113–123]

The studies selected for data extraction were published between 1994[123] and 2011,[113,114] and included study cohorts that encompassed participants with an edentulous maxilla. Two studies[113–115] included study participants with an atrophic maxilla described according to the Lekholm and Zarb bone classification system.[124] None of the studies included participants

No. Patients	No. Implants	Time Range (Mean) (y)	Implant System(s)
103	287	5–8 (7)	Brånemark-Mk3-turned (133i)/-Mk3-TiU (154i)
80	519	4–9 (7)	3i, ø: 3.25/3.75/4/5 mm; L: 8.5/10/11.5/13/15 mm
376	1,320	0–6 (3)	Osseospeed, ø: 3.5/4.0/4.5/5.0 mm; L: 8–17 mm
66	371	12–15 (7)	Astra-TiO (184i), ø: 3.5 mm; L: 9–19 mm vs Brånemark-Mk2 (187i), ø: 3.75/4.0 mm; L: 10–18 mm
12	72	2	StraumannStdPlus-SLActive, ø: 3.3/4.1 mm; L: 6/10/12/14 mm
461	1,180	1–4 (2.5)	3i (125i), Astra (174i), NobelB (442i), Dentsply (183i), Straumann (266i), ø: 3–6.0 mm; L: 6–18 mm
60	580	5	Brånemark-Mk2 (290i) (Lifecore), Restore(359i), ø/L: NR
111	690	1–6 (2)	Brånemark-Mk3 (256i)/Mk4/NobelSpeedy(64i) Replace Select Taper/ NobelReplace(359i)/Straigtht(11i)
412	1,514	2	Brånemark-turned (1316i)/TiU (198i), ø: 3.3/3.75/4/5 mm; L: 10 mm (107/1514 < 10 mm)
117	532	2–5 (3.75)	Camlog-Rootline(410i)/Screwline(53i) vs Straumann-solidscrew(69i), ø: 3.3–6.0 mm; L: 8–16 mm
237	408	1–9 (5)	Brånemark-Mk2/Mk3/Mk4/NobelSpeedyShorty-Turned (272i)/TiU (136i), ø: 3.75/4.0 mm; L: 7/8.5 mm
46	276	3	Astra (135i), Brånemark (141i)
45	388	5	NR, ø: 3.8–5.5 mm; L: 10 mm
44	381	1–8.5 (3)	"HA-coated"/"cpTi,"ø: NR; L: 13 mm
829	2,955	4	BioVent (MdE:319i+MxP:172i+MdP:420i), CoreVent (MdE:291i+MdP:328i), MicroVent-HA (MxE:247i+MxP:249i), ScrewVent-HA (MxE:185i)/CPTi(MxE:199i /tiA(MdE:294i)
103	563	5	Brånemark-Std (275i)/Mk2(288i), ø: 3.75/4.0 mm; L: 7–20 mm
103	563	3	Brånemark-Std (275i)/Mk2 (288i), ø: 3.75/4.0 mm; L: 7–18 mm

with terminal teeth, who received immediate postextraction implants. The articles by Jemt et al[113,114,116,122] described the same study cohort in combinations with other cohorts.

In total, 795 study participants received 4,382 implants between 1985[122,123] and 2004.[113,114,118] The study settings were public health clinic (n = 5), not reported (n = 3), private practice (n = 1), or multicenter (n = 1). The study cohorts had 25 to 165[113,114] participants with 59 to 1,120 implants,[113,114] followed up for 2 to 15 years.[116] The implant systems were manufactured by Nobel Biocare (n = 6), Calcitek (n = 1), Biomet 3i (n = 1), and Straumann (n = 1). One report listed six systems with no further details about the performance of each.

Risk of Bias Within Studies

The scientific quality as well as risk of potential bias of the studies included varied considerably. In this systematic review, the risk of bias was trichotomized roughly as high, medium, or low. The reader should consider these labels relative only within this review, and they are not comparable to stricter criteria used in other reviews, such as the Cochrane reviews.

Studies Designed With an Objective to Assess Effects of Implant Design (or Feature) on Outcomes (Fig 3).[18–34]

Table 7 Characteristics of Studies Reporting the Effects of Tilted Implants to Enable Placement of Longer Implants

Study	Patient Situation	Year Placed	Setting
Agliardi et al (2014-2012e)[35]	Terminal (44i)/edentulous maxilla posterior atrophy	2005–2008	NR
Agnini et al (2014-2012e)[36]	Terminal/edentulous mandible (16p), maxilla (20p)	2006–2010	University clinic, Foggia, Italy
Pera et al (2014)[37]	Terminal > edentulous maxilla	2005–2006	University clinic, Genova, Italy
Pozzi et al (2015–2013e)[38]	Edentulous mandible (61p), maxilla (34p)	2003–2012	University clinic, Milano, Italy
Maló et al (2013)[39]	Terminal/edentulous mandible (48p, 192i), maxilla (38p, 152i)	2008–2011	University clinic, Beijing, China
Testori et al (2013)[40]	Edentulous maxilla atrophy height < 5 mm-bone	2005–2010	Private practice, Lisbon, Portugal
Di et al (2013)[41]	Edentulous (32p)/partial dentate (3p), maxilla atrophy CH5	NR	NR
Maló et al (2012–2011e)[42]	Terminal/edentulous maxilla	2002–2006	Private practice, Lisbon, Portugal
Francetti et al (2012–2010e)[43]	Terminal/edentulous mandible (33p, 132i), maxilla (16p, 64i), LZ-A/B/C	2004–2008	Multicenter (2); NR
Mozzati et al (2012)[44]	Terminal/edentulous mandible (20p, 80i), maxilla (24p, 96i), posterior atrophy	2007–2007	University clinic, Milano, Italy
Crespi et al (2012)[45]	Terminal/edentulous maxilla	2001–2009	University clinic, Torino, Italy
Cavalli et al (2012)[46]	Terminal/edentulous maxilla, posterior atrophy	2007–2011	NR
Maló et al (2012)[47]	Terminal (18i)/edentulous mandible (94i), maxilla (133i)	2003-2009	Private practice, Lisbon, Portugal
Maló et al (2011)[48]	Terminal (31p, 45i)/edentulous maxilla posterior atrophy-levels 1–4	1998–2006	Private practice, Lisbon, Portugal
Agliardi et al (2010)[49]	Edentulous mandible (93p, 404i), maxilla (61p, 288i), atrophy	2004–2009	Private practice, Bollate, Italy
Degidi et al (2010)[50]	Edentulous maxilla	2005–2006	Private practice, Bologna, Italy
Pomares (2009)[51]	Terminal/edentulous mandible (9p, 36i), maxilla (19p, 91i)	2004–2006	Private practice, Alicante, Spain
Agliardi et al (2009)[52]	Terminal/edentulous maxilla	2005–2007	NR
Rosen and Gynther (2007)[53]	Edentulous maxilla atrophy CH5/6	1998–NR	University clinic, Stockholm, Sweden
Capelli et al (2007)[54]	Edentulous mandible (24p, 96i), maxilla (41p, 246i) atrophy	2002–2006	Multicenter (4); private practices, Italy
Fortin et al (2002)[55]	Edentulous maxilla	1991–1994	Private practice, Quebec, Canada
Krekmanov et al (2000)[56]	Edentulous/partial dentate mandible (25p, 78i), maxilla (22p, 138i)	NR	Public health, Västerås, Sweden
Mattsson et al (1999)[57]	Edentulous maxilla atrophy CH5/6	1998–NR	University clinic, Stockholm, Sweden

Ø = diameter; L = length; NR = not reported; CH = Cawood & Howell; LZ = Lekholm-Zarb classification.

Two studies were designed as randomized controlled trials (RCTs),[21,32] four as a prospective study with concurrent controls,[22,31,33,34] and 11 as retrospective case series, including one comparing the outcomes with a historical cohort (Table 12). Six of the 17 studies reported approval of an ethics committee.[19,20,23,27,30–32,34] Funding was declared in four reports.[21,22,30,32] The reported statistics were predominantly some form of time-to-event univariate statistical test, for example, Kaplan-Meier or actuarial life table, occasionally supplemented with a multivariate test, such as linear mixed models or Cox regression tests. The risk of bias varied from low (n = 1)[21] to medium (n = 9)[19,20,23,27,30–34] to high (n = 7).

Studies Reporting the Effects of Tilted Implants to Enable Placement of Longer Implants (Fig 4).[35–57] One study was designed as an RCT, but the comparison arms were not focused on implant design features. All other articles were prospective (n = 12) or retrospective (n = 10) case series (Table 13). Eight articles described an approval from an ethics committee, though only five

No. Patients	No. Implants	Time Range (Mean) (y)	Implant System(s)
32	192	3–6.5 (4.5)	Brånemark-Mk4-TiU (30i), NobelSpeedyGroovy (162i), ø: 4.0 mm; L: 11.5/13/15 mm
30	272	1.5–5.5 (3.5)	(Zimmer) Spline(84i), ScrewVent-taper (188i)
37	164	6	Osseotite (108i)/NT(56i)+/Coronal etching, ø: 4.0 mm; L: > 13 mm
86	344	1–9 (5.5)	NR
69	344	1–4.5 (3)	Brånemark-Mk2-TiU (52i), NobelSpeedyGroovy (202i), ø: NR; L: 10–12 mm
70	280	3	NobelSpeedy, ø: 4 mm; L: 10/13/15/18 mm
35	190	0–10 (5)	NR, ø: 4 mm; L: 13/15 mm
242	968	5	Brånemark-Mk3 (21i)/Mk4-TiU (82i)U, NobelSpeedy (865i), ø: mm; L: 10–18 mm
47	196	2.5–5.5 (4)	Brånemark-Mk4-TiU (92i-all md.), NobelSpeedyReplace (104i), ø: 4.0 mm; L: 10–18 mm
36	176	3	(Sweden&Martina) PAD, ø: 3.75/4.0 mm; L: 13/15 mm
65	334	2	NR (“ext.hex”), ø: 4.0 mm; L: 11.5/13/15/18 mm
34	136	1–6 (3)	Brånemark-Mk4-TiU NobelSpeedyGroovy
142	227	1–3 (2)	Brånemark-Mk3-TiU /-Mk4-TiU NobelSpeedy, ø: 3.3/4.0 mm; L > 10 mm
221	995	5	Brånemark-Mk2 /-Mk3 /-Mk4 NobelSpeedy, ø: 3.3/4.0 mm; L:10–18 mm
173	616	1–5 (3.5)	Brånemark-Mk4-TiU(92i), NobelSpeedyGroovy (600i), ø: 4.0 mm; L: 8.5/10/11.5/13/15/18 mm
30	210	3	XiVEPlus, ø: 3.4/3.8 mm; L: 10–16 mm
20	127	2	NobelSpeedyMk3Groovy, ø: 4.0 mm; L ≥ 13 mm
20	120	1.5–3.5 (2)	Brånemark-Mk4-TiU (30i) NobelSpeedyGroovy (90i), ø: 4.0 mm; L: 11.5/13/15 mm
19	103	8–12 (10)	Brånemark-Mk2, ø: 3.75 mm; L: 7/10–18 mm
65	342	0–4.5 (2)	Osseotite-NT, NR
45	245	5	Brånemark, ø: 3.75 mm; L: 7/8.5/10/12/13/15/18 mm
47	206	3–5 (4)	Brånemark (NR)
15	68	3–4.5 (4)	Brånemark-Mk2, ø: 3.75 mm; L: 7/10–18 mm

included name and number.[36,39–42,44,48,52] Study funding was declared in three reports.[41,51,55] The reported statistics were predominantly simple parametric or nonparametric statistical hypothesis tests comparing the axial vs tilted implants (n = 7) with or without some additional form of time-to-event univariate statistical test, such as the Kaplan-Meier or actuarial life table. Two studies described the use of a multivariate test.[37,48] The risk of bias was considered either medium (n = 5)[36,37,41,43,48] or high (n = 18).

Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 5).[58–87] All studies were prospective (n = 10) or retrospective (n = 22) case series (Table 14). The reported statistics were purely descriptive (n = 13), of which four reported 100% survival of the zygoma implants, using statistical hypothesis tests (n = 3) and/or some form of time-to-event univariate statistical test, such as the

Table 8 Characteristics of Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of A Particular Implant Design Feature on One or more Treatment Outcomes

Study	Patient Situation	Year Placed	Setting
Yates et al (2014-2013e)[58]	Edentulous maxilla, atrophy, height < 6 mm-bone	2000–2006	NR
Aparicio et al (2014-2012e)[59]	Edentulous maxilla, atrophy	1998–2002	Private practice, Barcelona, Spain
Fernández et al (2014)[60]	Edentulous, partial dentate, maxilla	2009–2013	University Hospital, Bogotá, Colombia
Maló et al (2015-2013e)[61]	Edentulous maxilla, atrophy, CH5/6/>6	2006–2012	Private practice, Lisbon, Portugal
Davó et al (2013)[62]	Edentulous maxilla, atrophy CH4/5/6	2006–2009	Private practice, Alicante, Spain
Davó and Pons (2013)[63]	Edentulous (37p), partial dentate (5p), maxilla atrophy	2004–2006	Private practice, Alicante, Spain
Maló et al (2012)[64]	Edentulous maxilla, atrophy CH5/6	2006–2009	Private practice, Lisbon, Portugal
Miglioranca et al (2012)[65]	Edentulous maxilla, atrophy	2003–2006	Private practice, São Paulo, Brazil
Balshi et al (2012)[66]	Edentulous maxilla	NR	Private practice, Fort Washington, PA, USA
Aparicio et al (2010–2008e)[67]	Edentulous maxilla, atrophy	NR	Private practice, Barcelona, Spain
Aparicio et al (2010-2008e)[68]	Edentulous/partial dentate, maxilla atrophy	2004–2005	Private practice, Barcelona, Spain
Bedrossian (2010)[69]	Edentulous maxilla, atrophy	2003–2005	NR
Stiévenart & Malevez (2010)[70]	Edentulous maxilla, atrophy, LZ-D/E	NR	NR
Davó (2009)[71]	Edentulous maxilla, atrophy	1999–2003	Private practice, Alicante, Spain
Balshi et al (2009)[72]	Edentulous maxilla, atrophy	NR	Private practice, Fort Washington, PA, USA
Pi Urgell et al (2008)[73]	Edentulous/partial dentate, maxilla atrophy	2004–2006	Private practice, Alicante, Spain
Davó et al (2008)[74]	Edentulous maxilla, atrophy	NR	Private practice, Alicante, Spain
Davó et al (2008)[75]	Edentulous maxilla, atrophy CH4/5	1998–2004	Private practice, Barcelona, Spain
Kahnberg et al (2007)[76]	Edentulous maxilla, atrophy	NR	University Clinic, Bahia, Brazil
Duarte et al (2007)[77]	Edentulous/partial dentate, maxilla atrophy	1997–1999	Multicentre (18): Private/Public/ University International
Peñarrocha et al (2007)[78]	Edentulous maxilla, atrophy	2000–2005	University Clinic, Valencia, Spain
Peñarrocha et al (2007)[79]	Edentulous maxilla, atrophy	1998–2004	University Clinic, Valencia, Spain
Bedrossian et al (2006)[80]	Edentulous maxilla, atrophy	1999–2001	Public Health, Bergen, Norway
Farzad et al (2006)[81]	Edentulous maxilla, atrophy LZ-B/C	2003–2004	University Clinic, San Francisco, CA, USA
Ahlgren et al (2006)[82]	Edentulous maxilla, atrophy	2000–2002	Public Health, Västerås, Sweden
Aparicio et al (2006)[83]	Edentulous (66p), partial dentate (3p), maxilla atrophy	NR	Private practice, Barcelona, Spain
Becktor et al (2005)[84]	Edentulous maxilla_atrophy_CH5/6	1998–2002	Public Health, Halmstad, Sweden
Malevez et al (2004)[85]	Edentulous maxilla, atrophy	1990–1995	University Clinic, Göteborg, Sweden
Brånemark et al (2004)[86]	Edentulous maxilla, atrophy	1997–2001	University Clinic, Brussels, Belgium
Bedrossian et al (2002)[87]	Edentulous maxilla, atrophy	NR	NR

Ø = diameter; L = length; NR = not reported; LZ = Lekholm-Zarb classification; CH = Cawood & Howell; alv = alveolar; cor = coronal; TiU = TiUnite; ITI = International Team for Implantology.

No. Patients	No. Implants	Time Range (Mean) (y)	Implant System(s)
25	43	5–10 (6)	Brånemark-Zygomatic-turned, ø: 4–4.5 mm; L: 8 mm
22	172	10	Brånemark-Mk3/pter(29i), (131i), ø: 3.3–4 mm; L: 7–18 mm + Brånemark-zygomatic-turned (41i), L: 30–50 mm
80	244	0.5–4 (~2)	NR
352	1,542	0.5–7 (2.5)	NobelSpeedy(795i) + (NobelB) Zygoma-TiU
17	68	3	Brånemark-zygomatic, L: 30–52.5 mm
42	221	5	Brånemark-TiU (108i), Replace (32i), ø: 3.75/4/4.3/5 mm; L: 10–16 mm + Brånemark-Zygomatic turned (44i) /-TiU (37i), L: 40–52.5 mm
39	169	3	Nobel-TiU (77i) + (NobelB) Zygoma-TiU Prototype1/Prototype2 (92i), ø: 5 mm
25	114	8	NobelReplace-taper (74i) + Brånemark-Zygomatic (40i)
77	173	1–10	Brånemark-Mk3/pter (391i) + Zygoma-turned (76i)/-TiU (34i), ø: 4.0 mm; L: 30–52.5 mm
25	176	2–5	NobelB-TiU (129i), ø: 3.75/4.0 mm; L: 7–18 mm + (NobelB) Zygomatic-turned (47i), L: 35–52.5 mm
20	140	3–4 (3.5)	NobelB-TiU (104i), ø: 3.75/4.0 mm; L: 7–18 mm + Brånemark-Zygomatic-turned (36i), L: 35–52.5 mm
36	172	0.5–7	Brånemark-Mk4(54i), NobelSpeedy (44i), ø: 4.0 mm; L: 7–13 mm + Brånemark-Zygomatic-turned (74i), L: 30–-52.5 mm
20	80	0.5–3.5	Brånemark-Zygomatic, L: 30–52.5 mm
24	154	5	Brånemark-Mk3-turned (79i)/-TiU (30i), ø: 3.75/4.0 mm; L: 10–15 mm + Brånemark-Zygomatic-turned (45i), L: 40–50 mm
56	501	0.5–5	Brånemark-Mk3/pter(391i) + Zygoma-turned(76i)/-TiU(34i), ø: mm; L:30–52.5 mm
42	221	1–3.5 (2)	Brånemark-TiU (108i) Replace (32i), ø:3.75/4/4.3/5 mm; L:10–16 mm + Brånemark-Zygomatic-turned(44i)/TiU (37i), L:40–52 mm
36	196	1–3.5 (2)	Brånemark(125i) + Brånemark-Zygoma-turned (44i)/TiU (27i)
54	325	0–6 (3)	Brånemark-std(221i) + (NobelB)-Zygoma(101i), ø: 4 mm-apex/4.5 cor; L:30–52.5 mm
12	48	2.5 & 0.5 (NR)	Brånemark-Zygomatic-turned, ø: 4–5 mm
60	145	3	Brånemark/Zygomatic(103i), ø: 4.0 mm apex/5.0 mm alv; L: 35–50 mm
21	129	1–4 (2)	Defcon/(Straumann), ITI (89i) + Brånemark-Zygomatic (40i)
46	321	1–3.5 (2)	Defcon (122i) (Straumann), ITI (155i) + Brånemark-Zygomatic (44i); L: 30–42.5 mm
13	55	1–4 (~2)	Brånemark-Mk2/-Mk3/-TiU (30i) + Brånemark-Zygomatic (25i); L: 35–50 mm
14	83	1–3 (2)	Brånemark-Mk4-TiU(55i), ø: 4.0 mm; L: 7–13 mm + Brånemark-Zygomatic(28i); L: 35–52.5 mm
11	64	1.5–4 (3)	Brånemark(42i) + Brånemark-Zygomatic(22i)
69	435	0.5–5	Brånemark-Mk3/pter(84i) (304i), ø: 3.75/4.0 mm; L: 7–18 mm + Brånemark-Zygomatic(131i), ø: 4.0 mm apex/5.0 mm alv; L: 35–52.5 mm
16	105	0.9–5.5 (4)	Astra/Brånemark(74i) + Brånemark-Zygomatic(31i); L: 30–50 mm
28	158	5–10	Brånemark (106i) + Brånemark-BOC/Expro-Zygoma (52i), ø: 4.0 mm apex/4.5 mm (cor); L: 30–50 mm
55	297	0.5–4 (2.5)	Brånemark-Std(194i), ø: 3.75 mm + Brånemark-Zygomatic(103i), ø: 4.0 apex/5.0 mm alv; L:35–50 mm
22	124	3	Brånemark-Mk3 (80i), ø: 3.75 mm; L: 10/13 mm + Brånemark-Zygomatic(44i); L: 40–50 mm

Table 9 Characteristics of Studies Reporting the Effects of Implants Placed in Pterygoid Bone or Other Bony Buttresses With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes

Lead author	Patient Situation	Year Placed	Setting
Peñarrocha-Oltra et al (2013)[88]	Edentulous maxilla, atrophy CH5	2000–2004	University clinic, Valencia, Spain
Balshi et al (2013)[89]	Terminal/edentulous maxilla	1985–2011	Private practice, Fort Washington, PA, USA
Balshi et al (2013)[90]	Edentulous/partial dentate/single maxilla posterior	1985–2011	Private practice, Fort Washington, PA, USA
Rodriguez et al (2012)[91]	Edentulous partial dentate, maxilla < 8 mm bone-to-sinus	1997–2010	Private practice, Barcelona, Spain
Peñarrocha et al (2012)[92]	Edentulous maxilla atrophy CH4/5	2002–2010	University clinic, Valencia, Spain
Peñarrocha et al (2009)[93]	Edentulous maxilla, atrophy CH4/5	2000–2004	University clinic, Valencia, Spain
Peñarrocha et al (2009)[94]	Edentulous (23p), Partial dentate (22p), maxilla atrophy CH4/5	2000–2006	University clinic, Valencia, Spain
Balshi et al (2005)[95]	Terminal/edentulous maxilla	1999–2004	Private practice, Fort Washington, PA, USA
Balshi et al (1999)[96]	Edentulous maxilla	NR	Private practice, Fort Washington, PA, USA

Ø = diameter; L = length; CH = Cawood & Howell; NR = not reported; ITI = International Team for Implantology; TiU = TiUnite.

Table 10 Characteristics of Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes

Study	Patient Situation	Year Placed	Setting
Zinser et al (2013–2012e)[97]	Edentulous (278i), partial dentate (642i), single(124i) maxilla posterior atrophy CH2-6	1995–2009	Public health, Amstelveen, The Netherlands
Dasmah et al (2013–2012e)[98]	Edentulous maxilla, atrophy CH6	1999–2001	Public health, Stockholm, Sweden
Sjöström et al (2007)[99]	Edentulous maxilla, atrophy CH2-6	NR	University clinic, Umeå, Sweden
Chiapasco et al (2007)[100]	Edentulous maxilla, atrophy CH6	1995–2004	Multicenter (3): University, Milano, Italy
Hallman et al (2005)[101]	Edentulous maxilla atrophy CH6	Brånemark: 1993–1995; Astra: 1995–1997	Public health, Gävle, Sweden
Becktor et al (2004)[102]	Edentulous maxilla, atrophy CH3/4(22p), 5/6(41p)	1990–1996	Public health, Halmstad, Sweden
Pinholt (2003)[103]	Edentulous (11p) partial dentate (14p), maxilla atrophy; LZ-D/E	Brånemark: 1996–1998; Straumann: 1998–2000	Public health, Vejle, Denmark
Becktor et al (2002)[104]	Edentulous maxilla, atrophy CH3-6	1990–1996	Multicenter (2): Public health, Rochester, USA, & Halmstad, Sweden
Lekholm et al (1999)[105]	Edentulous (28p), partial dentate (4p), maxilla compromised	1984–1997	Public health, Rochester, MN, USA
Keller et al (1999)[106]	Edentulous partial dentate, maxilla	1984–1996	Public health, Rochester, MN, USA
Keller et al (1999)[107]	Edentulous maxilla, atrophy, LZ-D	1991–NR	Multicenter (23): Scandinavia
Watzek et al (1998)[108]	Edentulous maxilla, posterior atrophy CH6	1989–1995	University clinic, Wien, Austria

Ø = diameter, L = length; CH = Cawood & Howell; NR = not reported; ITI = International Team for Implantology; LZ = Lekholm-Zarb classification.

No. Patients	No. Implants	Time Range (Mean) (y)	Implant System(s)
33	222	5	(Phibo) TSA-Avantblast
981	1,608	1–25 (10+)	Astra(7i) Brånemark-std /-Mk2 /-Ebon /-Mk3 /-Mk4 /-turned /-TiU(1601i), ø: 3.75/4.0/5.0 mm; L: 7–18 mm
	992	1–10 (6)	Brånemark-pterygoid, ø: 4 mm; L:7-13/15–18 mm
392	454	0–14 (6)	Osseotite-pterygoid, ø: 3.75/4.0 mm; L: 15/18/20 mm
18	117	1–7 (3)	(Sentmenat)Phibo, ø:3.5/4.1/4.2/5.5; L:10/11.5/13 mm (NobelB) Zygoma(4i); L:35/45 mm
74	490	2–4 (3)	(Impladent) Defcon-Avantblast, ø: 3.6/4.2 mm; L: 10/11.5/13/14.5 mm (NobelB) Zygoma (36i)
45	268	1–5 (3)	(Impladent) Defcon-Avantblast(25p, 37i), (Straumann), ITI (20p, 31i), ø: 3.6/4.2 mm; L: 10/11.5/13/14.5 mm/pterygoid(68i)
82	840	0.5–4.5 (2.5)	Brånemark-Mk3-TiU (28p, 251i), ø: 3.75/4 mm; L: 7-15 mm /-Mk4-TiU (136p, 379i), ø: 4 mm; L: 7–18 mm /Zygoma-turned (46i); L: 30–50 mm
189	1,817	1.5–6(4.5)	Brånemark-std /selftap, ø: 3.75/(4.0/5.0) mm; L: (10/13)/15/(18) mm

No. Patients	No. Implants	Time Range (Mean) (y)	Implant System(s)
224	1,045	14	"Additive" & "ablative," ø: 3.3/3.8/4/4.4/4.5/5 mm; L: 11/12/13/14/15/16 mm
19	152	5	Astra-TiO, ø: 3.5 mm; L: 9/11/13/15/17 mm
29	222	3	Brånemark-Std (171i)/Mk2 (21i), ø: 3.75 mm; L: 10–18 mm
39	281	1–9 (4)	Brånemark, (Friadent) Frialit, IMZ, (Straumann) ITI
22	156	5	Astra-TiO (11p, 72i), ø: NR; L: 8/9/11/13/15 mm; Brånemark-Mk3-turned (11p, 84i), ø: NR; L: 7/10/13/15 mm
182	1,120	2–9 (6.5)	Brånemark, ø: 3.75/4/5 mm; L: 6/7/8/10/13/15/18 mm
25	158	2–5.5 (NR)	Brånemark-std/Mk2/Mk3-turned (12p, 78i), ø: NR; L: 8.5–18 mm and (Straumann) ITI-SLA (13p, 80i), ø: NR; L: 8–16 mm
90	643	2–9 (5)	Brånemark-Std /-Con /-Mk2, ø: 3.75/4.0/5.0 mm; L: 7/8/10/13/15/18/20 mm
32	204	1–11 (5)	Brånemark-Std /-Con /-Mk2, ø: 3.75/4.0 mm; L: 15/18 mm
54	248	1–11 (5)	Brånemark-Std /-Con /-Mk2, ø: 3.75/4.0 mm; L: 10/13/15/18/20 mm
150	781	3	Brånemark-Std /-Con /-Mk2, ø: 3.75/4.0 mm; L: 15/18 mm
20	155	1–6	(Friatec) Frialen(70i) (Friatec) IMZ(85i)

Table 10 ***Continued*** **Characteristics of Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes**

Study	Patient Situation	Year Placed	Setting
Nyström et al (1997)[109]	Edentulous maxilla, atrophy CH5/6	NR	University clinic, Umeå, Sweden
Köndell et al (1996)[110]	Edentulous maxilla, atrophy < 7 mm-bone-post	NR	University clinic, Stockholm, Sweden
Neukam (1996)[111]	Edentulous maxilla, atrophy, LZ-D/E	1987–1993	University clinic, Erlangen-Nurnburg, Germany
Keller et al (1994)[112]	Edentulous partial dentate, maxilla atrophy	1984–NR	Public health, Rochester, MN, USA

Ø = diameter, L = length; CH = Cawood & Howell; NR = not reported; ITI = International Team for Implantology; LZ = Lekholm-Zarb classification.

Table 11 Characteristics of Studies Designed With no A Priori Stated Objective to Assess a Particular Implant Design Feature

Study	Patient Situation	Year Placed	Setting
Jemt et al (2011)[113,114]	Edentulous maxilla LZ-B/C	Turned: 1986–1987; oxidized: 2001–2004	Public health, Göteborg, Sweden
Friberg and Jemt (2008-2007e)[115]	Edentulous maxilla wide (n = 33p, 226i) vs atrophy narrow LZ-C/D (n = 42p, 279i)	1993–1997	Public health, Göteborg, Sweden
Jemt and Johansson (2006)[116]	Edentulous maxilla	1986–1987	Public health, Göteborg, Sweden
Widbom et al (2005)[117]	Edentulous maxilla	1993–2002	Public health, Skövde, Sweden
Ibañez et al (2005)[118]	Edentulous mandible (126i) maxilla (217i)	1998–2004	Multicenter (3): University clinic & private practices, Cordoba, Spain
Degidi and Piattelli (2003)[119]	Edentulous mandible (39p) maxilla (14p), partial dentate, mandible post (23p), maxilla post (15p), single (58i)	1996–2001	Private practice, Bologna, Italy
Kiener et al (2001)[120]	Edentulous maxilla	1991–1998	NR
Watson et al (1998)[121]	Edentulous mandible (30p, 90i), maxilla (14p, 43i)	1990–1994	NR
Jemt and Lekholm (1995)[122]	Edentulous maxilla & maxilla, atrophy severe/intermediate	1985–1988	NR
Palmqvist et al (1994)[123]	Edentulous maxilla	1985–1992	Public health, Örebro, Sweden

LZ = Lekholm-Zarb classification; Ø = diameter; L = length; NR = not reported; ITI = International Team for Implantology.

Kaplan-Meier or actuarial life table. No studies described the use of a multivariate test. Only 7 of the 30 articles described approval from an ethics committee,[59–64,74] and three studies specified the source of funding.[70,74,75,86] The risk of bias was considered either medium (n = 1)[59] or high (n = 29).

Studies Reporting the Effects of Implants Placed in Pterygoid Bone or Other Bony Buttresses With or Without Additional Alveolar Implants Reporting An Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 6).[88–96] All studies were retrospective case series (n = 9) (Table 15). The reported statistics were descriptive (n = 5), statistical hypothesis tests (n = 2), and/or a time-to-event univariate statistical test (n = 4). No studies described the use of a multivariate test. One article reported approval from an ethics committee[88] and none specified the source of funding. The risk of bias was considered high for all the studies.

Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 7).[97–112] Three studies were designed as comparative prospective studies.[98,101,103] One of these focused on comparing block vs particulate bone augmentation, rather than implant design features.[98] The two other studies compared implant designs, but in succession, which risks introducing bias.[101,103] The remaining studies were

No. Patients	No. Implants	Time Range (Mean) (y)	Implant System(s)
10	60	1–3	Brånemark-Mk2, ø: 3.75 mm; L: 13/15/18 mm
14	75	5	Brånemark-selftap, ø: 3.75 mm; L: 7–15 mm
43	284	3–6	Brånemark, ø: NR; L: 7/10/12/13/15/18 mm
20	83	1–6 (2)	Brånemark-Std /-Con /-Mk2, ø: 3.75/4.0 mm; L: 10/13/15/18/20 mm

No. Patients	No. Implants	Time Range (Mean) (y)	Implant System(s)
165	1,120	5	Brånemark-Std/-Mk2 /-Mk3 /-Mk4 (450i+360i)/-TiU(310i), ø: 3.75/4.0 mm; L: 7/8.5/10/11.5/13/15/18/20 mm
75	506	7	Brånemark-Std/-selftap/-Mk2/-Mk3-turned, ø: 3.75/4.0/5.0 mm; L: 6/7/8.5/10/11.5/13/15/18/20 mm (72 ≤ 8.5 mm)
76	450	15	Brånemark-Std, ø: 3.75 mm; L: 7–18 mm (106i/430 < 10 mm)
27	145	4–9 (5.5)	Brånemark-Mk2; L: 7–18 mm
41	343	0.5–6 (2.5)	Osseotite/-NT/-XP, ø: 3.75/4.0/≥ 5.0 mm; L: ≤ 10/> 10 mm (74 ≤ 10 mm)
152	646	0.5–5 (2)	Frialit2 (144i), Frialoc (37i), IMZ (51i), Brånemark (73i), Maestro (242i), Restore (97i)
41	173	1–5 (3)	(Straumann) ITI, ø: 3.3/4.1/4.8 mm; L: 6/8/10/12 mm
43	139	3–6 (4)	(Calcitek) Integral-HA, ø: 3.25/4.0 mm; L: 8/10/13/15 mm
150	801	5	Brånemark-Std/-selftap/-con, ø: 3.75 mm; L: 7/10/≥ 13 mm, (298/801 < 10 mm)
25	59	1–5 (3)	Brånemark, ø: 3.75 mm; L: 7/10/13/15/18/20 mm

prospective (n = 2) or retrospective (n = 9) case series (Table 16). The reported statistics were predominantly descriptive (n = 7), statistical hypothesis tests (n = 4), and/or some form of time-to-event univariate statistical test, such as the Kaplan-Meier or actuarial life table (n = 6). Four reports applied a multivariate statistical test for data analysis.[97,99,104,111] Only one article described approval from an ethics committee, vaguely termed the "Local Research Ethics committee."[99] None of the reports described a source of funding for the study. The risk of bias was considered either medium (n = 3)[99,104,111] or high (n = 13).

Studies Designed With no A Priori Stated Objective to Assess a Particular Implant Design Feature.[113–123] The studies were prospective (n = 3) or retrospective (n = 7) case series (Table 17). The reported statistics were predominantly descriptive (n = 2), statistical hypothesis tests (n = 3), and/or some form of time-to-event univariate statistical test, such as the Kaplan-Meier or actuarial life table (n = 7). Three studies described the use of a multivariate test.[117,122,123] None of the studies described approval from an ethics committee. Three reports described a source of funding.[119,121,122] The risk of bias was considered high in all studies.

Results of Individual Studies

Studies Designed With an Objective to Assess Effects of Implant Design (or Feature) on Outcomes

Table 12 Bias Assessment of Studies Designed to Assess Effects of Implant Design or Feature on Outcomes

Study	Study Objective
Jungner et al (2014–2012e)[18]	To compare the clinical performance of turned and oxidized implants after more than 5 years of loading
Vervaeke et al (2015–2013e)[19]	To identify predictors affecting implant treatment outcomes using multivariate tests that correct for confounding
Testori et al (2014–2013e)[20]	*(1)* To assess the reliability of immediate implant and immediate loading protocols in the edentulous jaws, and *(2)* to investigate the role of patient-related, implant-related, and surgery-related secondary variables in the occurrence of implant failure
Ravald et al (2013)[21]	To study the long-term outcome of implant survival rate, soft and hard tissue conditions, and prosthetic status in a group of individuals treated with either Astra Tech tioblast or Brånemark turned implants supporting a full-arch bridge
Van Assche et al (2012–2011e)[22]	To investigate the outcome of short implants additionally placed with longer implants to support a maxillary overdenture
Cosyn et al (2012–2010e)[23]	To explore factors associated with failure of surface-modified implants using data obtained in a university postgraduate training center
Kallus et al (2009–2008e)[24]	To compare survival rates and marginal bone resorption of the Lifecore Restore Implant System with the benchmark Nobel Biocare MK II Implant System
Li et al (2009)[25]	To describe immediate functional loading of completely edentulous maxillas and mandibles with fixed provisional prostheses and to compare cumulative survival rates between maxillas and mandibles
Alsaadi et al (2008)[26]	To evaluate the success rate of two different implant systems with sandblasted and acid-etched modified surfaces loaded after reduced healing times
Nelson et al (2008)[27]	To assess the influence of systemic and local bone and intraoral factors on the occurrence of implant loss from abutment connection up to 2 years
Maló et al (2007)[28]	To report on the placement of short Brånemark implants, testing the hypothesis that short implants in atrophied jaws might give similar long-term implant survival rates as longer implants used in larger bone volumes
Hjalmarsson and Smedberg (2005)[29]	To compare the prosthesis retention screw stability (ie, preload) and the clinical outcome after prosthesis connection in patients treated with traditional frameworks vs frameworks produced with the Cresco Ti Precision method
Degidi et al (2005)[30]	To evaluate the outcome of implants immediately loaded with a cross-arch fixed temporary restoration in the edentulous upper jaw in a consecutive study population
Schwartz-Arad et al (2004)[31]	To examine the cervical bone loss and its correlation with implant characteristics and anatomic factors, 1 to 8 years after implantation of immediate and delayed implants
Morris et al (2001)[32]	To separately examine a subset of data from the extensive DICRG database to determine what relationship, if any, exists between implant design and survival; six implant designs were randomized to five restorative applications and subsequently evaluated
Friberg et al (1997)[33]	To compare the clinical and radiographic evaluations of MK II self-tapping implants with standard implants of the Brånemark system after 5 years
Olsson et al (1995)[34]	To evaluate for over 3 years a modified self-tapping implant (Mk II) with improved cutting characteristics used in both maxillae and mandibles

REB = Research Ethics Board; ANOVA = analysis of variance; NR = not reported; ND = none declared;
IRCCS = National Institute for Research and Treatment (Italy); RCT = randomized controlled trial; EC = Ethics committee;
CCT = clinical controlled trial; DICRG = Dental Implant Clinical Research Group; HA = hydroxyapatite.

Study Design	Statistics	REB	Funding	Bias Risk
Retrospective case series	ANOVA	NR	ND	High
Retrospective case series	Mann-Whitney + log rank + Cox regression + linear mixed effect	Ghent University Hospital, Belgium	ND	Medium
Retrospective case series	Mann-Whitney + Kaplan-Meier + Cox Regression	IRCCS scientific review board	ND	Medium
RCT, two arms (Astra vs Brånemark)	Wilcoxon + life table	EC of Linköping University, Sweden	Astra Tech AB, Sweden & Research Council of Public Dental Services, Östergötland, Sweden	Low
CCT prospective study w/concurrent controls, split (short distally vs long anterior)	ANOVA + linear mixed models, including Dunnett-multiple tests	NR	Institut Straumann, Switzerland	High
Retrospective case series	Fisher exact + Kaplan-Meier + log rank + Cox regression + logistic regression	University Hospital Ghent, Belgium	ND	Medium
Retrospective case series (Lifecore) w/ historical controls (Nobel Biocare)	χ^2/Fisher exact + Kaplan-Meier	NR	ND	High
Retrospective case series	Fisher exact/*t* test	NR	ND	High
Retrospective case series	χ^2/*t* test + Kaplan-Meier	NR	ND	High
Retrospective case series	Logistic regression	NR	ND	Medium
Retrospective case series	χ^2 + life table	NR	ND	High
Retrospective case series	ANOVA/Fisher exact/ Kruskal Wallis	NR	ND	High
Retrospective case series	Kaplan-Meier + log rank + Cox regression	NR	Ministry of Education, Italy & National Research Council, Italy & Research Association for Dentistry, Italy	Medium
CCT prospective study w/ concurrent controls (Implant characteristics)	χ^2/*t* test + Kaplan-Meier + linear regression	NR	ND	Medium
RCT–split, 2 × 3 + 2 arms (edentulous max: HA-coated grooved vs HA-coated screw vs cpTi-screw/edentulous mandible: HA-coated cylinder vs Ti-alloy-basket vs Ti-alloy screw/partial edentulous; max. post HA-coated cylinder vs HA-coated grooved)	Kaplan-Meier + log rank + Breslow	NR	US Government	Medium (high dropout rate)
CCT prospective study w/ concurrent controls, split (with and without tapping)	Life table	NR	ND	Medium
CCT prospective study w/concurrent controls Split (Self-tapping vs pretapping implant)	Life table	NR	ND (one coauthor is NobelPharma employee)	Medium

Table 13 Bias Assessment of Studies Reporting the Effects of Tilted Implants to Enable Placement DICRG f Longer Implants

Study	Study Objective
Agliardi et al (2014-2012e)[35]	To prospectively evaluate the clinical and radiographic outcomes of immediate full-arch fixed maxillary prosthesis supported by two axial and four tilted implants after 3 years of loading
Agnini et al (2014-2012e)[36]	To evaluate full-arch fixed-dental restorations supported by immediate loaded axial and tilted implants in a single-cohort study; survival rate of axial and tilted implants was compared
Pera et al (2014)[37]	To report the 6-year outcomes for patients rehabilitated with an immediate loading protocol of the maxilla (Columbus Bridge Protocol)
Pozzi et al (2015-2013e)[38]	To retrospectively evaluate the implant and prosthetic survival and success rates of zirconia-based, implant-supported, screw-retained, cross-arch restorations up to 5 years after placement
Maló et al (2013)[39]	To report the outcome of trans-sinus tilted implants for the rehabilitation of the complete edentulous atrophic maxilla using the all-on-four concept with immediate loading
Testori et al (2013)[40]	To evaluate tilted trans-sinus implants for rehabilitation of the atrophic maxilla
Di et al (2013)[41]	To evaluate the outcome and special characteristics of immediate implant rehabilitation using the all-on-four treatment concept in completely or potentially completely edentulous Chinese patients
Maló et al (2012-2011e)[42]	To report on the medium- and long-term outcomes of a protocol for immediate function of four implants (all-on-four, Nobel Biocare) supporting a fixed prosthesis in the completely edentulous maxilla
Francetti et al (2012-2010e)[43]	To assess clinical outcomes and peri-implant bone level changes around tilted and axial implants supporting full-arch fixed immediate rehabilitations up to 60 months of loading
Mozzati et al (2012)[44]	To conduct an immediate postextraction implant placement with immediate loading in the maxilla
Crespi et al (2012)[45]	To compare definitive acrylic resin prostheses with or without a cast metal framework that were immediately loaded and supported by axial and tilted implants in completely edentulous patients after 3 years of function
Cavalli et al (2012)[46]	To assess the treatment outcome of immediately loaded full-arch fixed bridges anchored to both tilted and axially placed implants in the edentulous maxilla and to evaluate the incidence of biological and prosthetic complications
Maló et al (2012)[47]	To document complete rehabilitations in both jaws through the so-called all-on-four concept (ie, four implants with the posterior implants placed at an angle) using immediate function implants inserted in "nonideal" conditions (eg, implants inserted with dehiscences or fenestrations, in periodontally compromised sites, or in fresh extraction sockets)
Maló et al (2011)[48]	To report the long-term outcome of immediately loaded implants in the rehabilitations of completely edentulous maxillae with different classifications
Agliardi et al (2010)[49]	To evalute the clinical and radiographic outcomes of immediately loaded full-arch fixed prostheses supported by a combination of axially and nonaxially positioned implants in a large cohort of patients with completely edentulous jaws, up to 5 years of function
Degidi et al (2010)[50]	To evaluate the concept of intraoral welding as a suitable technique for the fabrication of a restoration for the edentulous atrophic maxilla on the day of placement of axial and tilted implants
Pomares (2009)[51]	To present clinical results of an implant placement protocol using 4 or 6 implants supporting immediately loaded fixed prostheses
Agliardi et al (2009)[52]	To report the preliminary results of a single cohort prospective study that sought to evaluate a new surgical protocol for the immediate rehabilitation of edentulous maxilla without using a bone grafting
Rosen and Gynther (2007)[53]	To evaluate retrospectively the surgical outcome of tilted implants in severely resorbed edentulous maxillas as an alternative to bone grafting and the prosthodontic outcome of posterior extension bridges on tilted implants
Capelli et al (2007)[54]	To assess the treatment outcome of immediately loaded full-arch fixed bridges anchored to both tilted and axially placed implants for the rehabilitation of fully edentulous maxillae and to compare the outcome of axial vs tilted implants
Fortin et al (2002)[55]	To develop a surgical and prosthetic implant treatment protocol for completely edentulous maxillae in which optimal lip support and phonetics is achieved in combination with substantial implant anchorage without bone grafting
Krekmanov et al (2000)[56]	To modify the method for implant placement in the posterior part of the jaws to extend fixed implant-connected prostheses further distally, and to reduce the length of cantilevers in complete-arch prostheses without transpositioning the mandibular nerve or performing bone grafting in the maxilla
Mattsson et al (1999)[57]	To describe the surgical technique for implant treatment in severely resorbed edentulous maxillae without any alveolar reconstruction before or combined with implant placement

REB = Research Ethics Board; ANOVA = analysis of variance; NR = not reported; ND = none declared; EC = Ethics committee; GEE = general estimation equation; RCT = randomized controlled trial; IRCCS = National Institute for Research and Treatment (Italy); IRB = institutional review board.

Study Design	Statistics	REB	Funding	Bias Risk
Prospective case series	ANOVA/Fisher exact/*t* test	NR	ND	High
Prospective case series	ANOVA/*t* test	Universita di Foggia EC	ND	Medium
Prospective case series	Friedman/Wilcoxon/ ANOVA + GEE	NR	ND	Medium
Retrospective case series	Fisher exact	NR	ND	High
Retrospective case series	Life table	Ethics Committee for Health, Lisboa, Portugal	ND	High
Retrospective case series	Life table	IRCCS ethics and scientific committee	ND	High
Prospective case series	Life table + log rank	Beijing Municipal Health Bureau 2008-99	National Program on Key Basic Research (973 Program) China	Medium
Retrospective case series	Kaplan-Meier	Independent ethical committee	ND	High
Prospective case series	ANOVA/paired *t*	NR	ND	Medium
Retrospective case series	Descriptive	Local ethics committee	ND	High
RCT, two arms (acrylic resin framework ± metal framework)	*t* test	NR	ND	High
Retrospective case series	Life table	NR	ND	High
Prospective case series	Kaplan-Meier	NR	ND	High
Retrospective case series	Kaplan-Meier + logistic regression	Ethics Committee for Health, Lisboa, Portugal	ND	Medium
Prospective case series	χ^2/*t* test + life table	NR	ND	High
Prospective case series	*t* test	NR	ND	High
Retrospective case series	No statistical tests	NR	Nobel Biocare research manager, Italy	High
Prospective case series	Life table	IRB	ND	High
Retrospective case series	Life table	NR	ND	High
Prospective case series	*t* test life table	NR	ND	High
Retrospective case series	Life table	NR	Nobel Biocare, Sweden	High
Prospective case series	Life table	NR	ND	High
Prospective case series	Descriptive	NR	ND	High

Table 14 Bias Assessment of Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes

Lead author	Study Objective
Yates et al (2014-2013e)[58]	To analyze and report the 5–10 year survival rates of endosseous zygomatic implants used in the rehabilitation of the atrophic maxilla
Aparicio et al (2014-2012e)[59]	To report on long-term outcomes in the rehabilitation of the atrophic maxilla using zygomatic and regular implants
Fernández et al (2014)[60]	To describe the surgical techniques, success rate, prosthetic rehabilitation, complications, and demographics of patients undergoing zygomatic implant surgery
Maló et al (2015-2013e)[61]	To report rehabilitation outcomes in 352 patients with complete edentulous atrophied maxillae using 747 zygomatic implants in immediate function inserted through the extramaxillary technique
Davó et al (2013)[62]	To assess the long-term outcome of immediately loaded zygomatic implants placed in atrophic maxillae
Davo and Pons (2013)[63]	To assess the clinical 3-year outcome of prostheses supported by four immediately loaded zygomatic implants
Maló et al (2012)[64]	To report retrospectively on the 3-year follow-up results in the rehabilitation of completely edentulous atrophied maxillae using extramaxillary zygomatic implants
Migliorança et al (2012)[65]	To evaluate the long-term success rate of immediate occlusal loading of extrasinus zygomatic implants after an 8-year follow-up
Balshi et al (2012)[66]	To view and measure the BIC of zygomatic implants in the zygomatic bone
Aparicio et al (2010-2008e)[67]	To report on the clinical outcomes of immediate early loading of zygomatic implants for prosthetic rehabilitation of edentulous and severely resorbed maxillary cases
Aparicio et al (2010-2008e)[68]	To report on the preliminary experiences with zygomatic implants placed with an extrasinus approach to have the implant head emerging at or near the top of the alveolar crest
Bedrossian (2010)[69]	To report on the 7-year follow-up of patients treated with zygomatic implants in conjunction with two to four anterior maxillary implants placed into immediate function and restored with a definitive fixed prosthesis
Stiévenart and Malevez (2010)[70]	To evaluate the results of a consecutive cohort of 20 patients (mean age, 56 years) with extremely resorbed maxillas provided with four zygomatic implants
Davó (2009)[71]	To evaluate the prosthetic rehabilitation success rate and the survival rates of machined surface zygomatic implants and conventional implants placed using a two-stage protocol
Balshi et al (2009)[72]	To determine the clinical effectiveness of the zygomatic implant in oral implant reconstruction under an immediate loading protocol
Pi Urgell et al (2008)[73]	To evaluate the survival of 101 zygomatic implants placed in upper maxilla presenting important bone reabsorption, with a follow-up of 1–72 months
Davó et al (2008)[74]	To evaluate the success rate of immediately loaded zygomatic implants placed in atrophic maxillae
Davó et al (2008)[75]	To evaluate the maxillary sinus in a cohort of patients by means of clinical criteria and CT performed before surgery and after zygomatic implant placement (immediate function protocol)
Kahnberg et al (2007)[76]	To evaluate the treatment outcome with zygoma implants with regard to implant survival, patient satisfaction, and function of prosthesis replacement after 3 years
Duarte et al (2007)[77]	To establish a new surgical/prosthetic protocol for the treatment of extremely atrophic maxillae using four zygomatic implants in an immediate loading system
Peñarrocha et al (2007)[78]	To describe the management of patients with extreme maxillary atrophy; their treatment consisted of maxillary fixed prostheses supported by conventional implants placed in residual anatomic structures in conjunction with zygomatic implants positioned using the sinus slot technique of Stella and Warner
Peñarrocha et al (2007)[79]	To evaluate the satisfaction of patients with maxillary fixed prostheses supported by conventional and/or zygomatic implants
Bedrossian et al (2006)[80]	To evaluate a protocol for immediate function (within 2 hours) of two zygomatic and four standard implants (Nobel Biocare) supporting a fixed prosthesis in the completely edentulous maxilla
Farzad et al (2006)[81]	To describe the experiences of 11 consecutively treated patients who received zygomatic implants

REB = Research Ethics Board; ANOVA = analysis of variance; NR = not reported; ND = none declared; BIC = bone-to-implant contact; CT = computed tomography.

Study Design	Statistics	REB	Funding	Risk of Bias
Retrospective case series	Fisher exact + Kaplan-Meier	NR	ND	High
Prospective case series	Life table	University of Barcelona EC	ND	Medium
Retrospective case series	Descriptive	"ERC guidelines of Universidad el Bosque"	ND	High
Retrospective case series	Kaplan-Meier	Ethics committee for health, Lisboa, 002/2012	ND	High
Prospective case series	Descriptive	Review board of the hospital	ND	High
Prospective case series	Descriptive	Medimar Int Hospital RB 3/2006	ND	High
Retrospective case series	Friedman/Wilcoxon + life table	Ethics committee for health, Lisboa, 003/2009	ND	High
Prospective case series	Descriptive	NR	ND	High
Retrospective case series	Life table	NR	ND	High
Retrospective case series	Life table	NR	ND	High
Retrospective case series	No statistical tests	NR	ND	High
Prospective case series	Life table	NR	ND	High
Retrospective case series	Life table	NR	Nobel Biocare	High
Retrospective case series	No statistical tests	NR	ND	High
Retrospective case series	Life table	NR	ND	High
Retrospective case series	Descriptive	NR	ND	High
Retrospective case series	No statistical tests	Review board of the hospital	Nobel Biocare research manager, Italy	High
Prospective case series	No statistical tests	NR	Nobel Biocare research manager, Italy	High
Retrospective case series	Descriptive	NR	ND (one coauthor is employee of Nobel Biocare AB, Sweden)	High
Prospective case series	Descriptive	NR	ND	High
Retrospective case series	Descriptive (100% survival)	NR	ND	High
Retrospective case series	*t* test + Pearson correlation	NR	ND	High
Retrospective case series	Life table	NR	ND	High
Retrospective case series	Wilcoxon	NR	ND	High

Table 14 ***Continued*** **Bias Assessment of Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes**

Lead author	Study Objective
Ahlgren et al (2006)[82]	*(1)* To evaluate indications, surgical problems, complications, and treatment outcomes related to the placement of zygomatic implants, and *(2)* to determine any prosthetic difficulties and complications
Aparicio et al (2006)[83]	To report on the clinical outcome of using zygomatic and regular implants for prosthetic rehabilitation of the severely atrophic edentulous maxilla
Becktor et al (2005)[84]	To evaluate the clinical outcome of zygomatic implant treatment and consider if treatment with zygomatic implants could be an alternative to bone grafting and implant procedures in patients with edentulous maxillae
Malevez et al (2004)[85]	To evaluate retrospectively in consecutive patients, after a period of 6–48 months follow-up of prosthetic loading, the survival rate of 103 zygomatic implants inserted into 55 edentulous severely resorbed upper jaws
Brånemark et al (2004)[86]	To report the outcome of the first patients with a follow-up time of at least 5 years in whom zygoma fixtures were used in the treatment of the compromised edentulous maxilla and compared with bone grafting procedures
Bedrossian et al (2002)[87]	To present a preliminary report on 22 patients followed for 34 months who received the Brånemark Zygomaticus implant in conjunction with premaxillary standard implants for the reconstruction of resorbed edentulous maxillae

REB = Research Ethics Board; ANOVA = analysis of variance; NR = not reported; ND = none declared; BIC = bone-to-implant contact; CT = computed tomography.

(Fig 3).[18–34] Only 1 of the 17 papers reported patient-centered outcomes (Table 18). The prevailing reported outcome was incidence of adverse biological and technical events, clinical success or survival, and degree of bone loss. Radiographic techniques varied from standardized periapical radiographs to nonstandardized orthopantograms. Some studies also reported indices of periodontal tissues, secondary stability using resonance frequency analysis technology or periotest values. Based on the surrogate and clinical outcomes, it can be proposed that in the fully edentulous maxilla the choice of implant system does not appear to influence outcome (n = 8 reports). Moreover, the surface may influence outcome (n = 4 reports); the length appears not to influence outcome (n = 7 reports). Implants of wider diameter (n = 2 reports) may appear to perform not as well or similarly as implants of regular diameter (n = 4 reports). The healing period varied extensively after extraction and surgery procedures, as did the healing period before implant loading, the number of implants needed to support the supraconstruction, and the composition and design of the supraconstruction. We considered meta-analyses of the extracted data as inappropriate and therefore abandoned further statistical analyses of the extracted data.

Studies Reporting the Effects of Tilted Implants to Enable Placement of Longer Implants (Fig 4).[35–57] A relatively high proportion of the clinical studies (13 of 23) reported patient-centered outcomes, using a Likert-type scale, dichotomous or a visual analogue scale (Table 19), though these were about the treatment in general and none were pertinent to issues about implant length. The prevailing outcome reported was the incidence of adverse biological and technical events, clinical success or survival, and degree of bone loss. Radiographic techniques varied from standardized periapical radiographs to nonstandardized orthopantograms. Some studies also reported indices of periodontal tissues. Based on the surrogate and clinical outcomes, it can be proposed that the clinical performance of axial and tilted implants in the fully edentulous maxilla appear comparable. Moreover, different designs from the same manufacturer do not appear to influence outcome, or this was simply not reported when more than one implant design was used. There was extensive variation in the healing period after extraction and surgery, and before implant loading; number of implants needed to support the supraconstruction; and the composition and design of the supraconstruction. Formal meta-analyses can be performed for comparing tilted with axial implants, and have been published elsewhere (Table 2a).

Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 5).[58–87] Two studies reported quality of life data using the Oral Health Impact Profile (OHIP)-14 scale,[59,63] and four studies described other patient-centered outcomes (Table 20).[76,79–81] Questions about study participant satisfaction did not pertain to implant design effects, but rather to the general treatment outcomes. The prevailing reported outcome

Study Design	Statistics	REB	Funding	Risk of Bias
Retrospective case series	No statistical tests	NR	ND	High
Prospective case series	Descriptive (100% survival)	NR	ND	High
Retrospective case series	No statistical tests	NR	ND	High
Retrospective case series	Descriptive (100% survival)	NR	ND	High
Prospective case series	Descriptive	NR	Hilary Orton Memorial Foundation	High
Prospective case series	Descriptive (100% survival)	NR	ND	High

was incidence of adverse biological events during or immediately after surgery and implant survival. The degree of bone loss is seldom reported, because there are no radiographic techniques that can adequately depict such loss. Nonstandardized orthopantograms, cone beam computer tomography scans, and conventional radiographs using Waters' projection have been attempted. Some studies also reported indices of periodontal tissues and secondary stability using resonance frequency analysis technology. A wide variation was observed in the healing period after extraction, surgery procedures, healing period before implant loading, number of implants to support the supraconstruction, and composition and design of the supraconstruction.

Appraising the potential effects of the implant design on outcomes related to zygoma implants is complex because of inadequate descriptions of the implant brand. The company Brånemark Integration manufactured a product named "Z-fixture" for a period, which many have confused with a product named "Brånemark system zygoma implant" manufactured by Nobel Biocare. One early generation of the zygoma implants included a cervical hole meant for the abutment screw that potentially could allow direct communication from the oral cavity to the sinus if the abutment screw did not completely obliterate the canal. The second generation of such implants contained no such holes. The third generation avoids threads in the coronal one third of the implant, whereas the fourth generation incorporates engaging threads and a narrow apical tip. So far, no studies have compared any of these designs one to one. A few studies that included both turned and oxidized zygoma implants did not report whether there were differences in outcomes between the two.[62,66,72,74,75,82]

When appraising the possible effects of zygoma implant design on outcomes it is important to be aware that at least four different surgical techniques have been described and an implant design used for one technique may not be optimal for another. The original protocol described a trans-sinus placement.[86] An alternative extrasinus approach could be used when large buccal concavity in the sinus area otherwise would displace the zygoma implant head very far palatinally.[68] A third approach named the sinus slot technique creates a different angulation of the zygoma implant, which places the implant head on the top of the alveolar crest while avoiding penetrating the sinus membrane.[73] The last alternative is to anchor the implant solely in the zygomatic bone, remaining mostly outside the maxilla.[64]

Studies Reporting the Effects of Implants Placed in Pterygoid Bone or Other Bony Buttresses With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 6).[88–96] One study reported quality-of-life data using the OHIP-14 scale,[88] while two more described other patient-centered outcomes (Table 21).[93,94] The prevailing reported outcome was incidence of adverse biological and technical events, clinical success or survival, and degree of bone loss, based on orthopantograms. Based on the surrogate and clinical outcomes, it appears that the clinical performance of

Table 15 Bias Assessment of Studies Reporting the Effects of Implants Placed in Pterygoid Bone or Other Bony Buttresses With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes

Study	Study Objective
Peñarrocha-Oltra et al (2013)[88]	To evaluate the 5-year outcome of a previously reported case series of patients with severely atrophic maxillae treated with palatally positioned implants and fixed full-arch rehabilitations
Balshi et al (2013)[89]	To determine if there is a statistically significant difference in the survival rates between different sized implants placed in the pterygomaxillary region
Balshi et al (2013)[90]	To determine if there is a significant difference in implant survival rates between implants in the pterygomaxillary region: implant placement with two-stage, single-stage, and guided surgery protocols
Rodríguez et al (2012)[91]	To review a series of 454 pterygoid implants placed more vertically than the previous standard angle (45 degrees) over a functional loading period ranging from 2 months to 14 years with a mean follow-up period of 6 years
Peñarrocha et al (2012)[92]	To assess the success and marginal bone loss, after 1 year of loading, of implants placed in anatomic buttresses of atrophic maxillae to rehabilitate patients with combination syndrome
Peñarrocha et al (2009)[93]	To evaluate implant-supported restorations supported by palatally positioned implants as an alternative treatment for rehabilitation of the atrophic maxilla and to assess the satisfaction of patients with the results
Peñarrocha et al (2009)[94]	To evaluate the success rate of implants placed in the pterygomaxillary region using drills and osteotomes with a minimum of 12 months' follow-up
Balshi et al (2005)[95]	To calculate the survival rate of Brånemark implants with ti-unite surfaces in edentulous maxillary sites, including the pterygomaxillary region, restored with complete fixed maxillary prostheses
Balshi et al (1999)[96]	To examine all patients whose dentition had been restored with a complete maxillary prosthesis supported by Brånemark implants in pterygomaxillary sites and to address the biomechanical aspects of implant size, position, and bone quality with patient age, gender, smoking habits, and medications

REB = Research Ethics Board; MANOVA = multivariate analysis of variance; NR = not reported; ND = none declared.

Table 16 Bias Assessment of Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes

Lead author	Study Objective
Zinser et al (2013-2012e)[97]	To assess the predictors of implant failure after grafted maxillary sinus
Dasmah et al (2013-2011e)[98]	To conduct a 5-year follow-up analysis with focus on bone-level alteration in block vs particulate onlay bone grafts
Sjöström et al (2007)[99]	To conduct a 3-year follow-up with respect to clinical, radiologic, and RFA parameters of implant stability in 29 patients with atrophic edentulous maxillae reconstructed with free autogenous iliac bone graft and titanium implants
Chiapasco et al (2007)[100]	To report the clinical outcome of osseointegrated implants placed in extremely atrophied edentulous maxillae after Le Fort I osteotomy and interpositional autogenous iliac bone grafts
Hallman et al (2005)[101]	To compare two different implant systems used after interpositional bone grafting of the severely resorbed maxilla with a modified augmentation technique using fibrin glue
Becktor et al (2004)[102]	To analyze and compare the survival rates of endosseous implants placed in the edentulous maxillae of patients in whom bone augmentation was undertaken prior to or in conjunction with implant placement with survival rates in patients who did not undergo bone augmentation
Pinholt (2003)[103]	To observe the clinical outcome of Brånemark machine-surfaced implants in a comparative evaluation with ITI SLA implants inserted into severely atrophied maxillae reconstructed with autogenous bone graft
Becktor et al (2002)[104]	To analyze the influence of the mandibular dentition on implant performance in the maxilla before definitive prosthesis attachment when reconstruction is possible only with the use of autogenous bone-grafting techniques

REB = Research Ethics Board; NR = not reported; ND = none declared; CCT = clinical controlled trial; REC = Regional Ethics committee; ISQ = implant stability quotient; GEE = general estimation equation; RFA = radiofrequency analysis; ANOVA = analysis of variance; ITI = International Team for Implantology.

Study Design	Statistics	REB	Funding	Risk of Bias
Retrospective case series	Descriptive	U Valencia Ethics Board H1330446292077	ND	High
Retrospective case series	Life table	NR	ND	High
Retrospective case series	Life table + MANOVA	NR	ND	High
Retrospective case series	Descriptive	NR	ND	High
Retrospective case series	Kruskal Wallis/ Mann-Whitney *U*	NR	ND	High
Retrospective case series	Descriptive	NR	ND	High
Retrospective case series	Descriptive	NR	ND	High
Retrospective case series	Life table	NR	ND	High
Retrospective case series	Descriptive	NR	ND	High

Study Design	Statistics	REB	Funding	Risk of bias
Retrospective case series	Kaplan-Meier + Cox regression	NR	ND	High
CCT prospective study with concurrent controls, split	Wilcoxon	NR	ND	High
Prospective case series	Life table + logistic regression (ISQ: Mann-Whitney/ Spearman rho)	The local REC	ND	Medium
Prospective case series	Life table	NR	ND	High
CCT prospective study (Astra) with historical controls (Brånemark)	χ^2/Mann Whitney *U*	NR	ND	High
Retrospective case series	χ^2/Wilcoxon + life table	NR	ND	High
CCT prospective study (Straumann) with historical controls (Brånemark)	Descriptive	NR	ND	High
Retrospective study with concurrent controls	Logistic regression + GEE	NR	ND	Medium

Table 16 ***Continued*** **Bias Assessment of Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes**

Lead author	Study Objective
Lekholm et al (1999)[105]	*(1)* To study the extent to which different bone grafting procedures are performed, *(2)* to evaluate the treatment results obtained after 3 years of function, and *(3)* to assess possible complications occurring during treatment and follow-up
Keller et al (1999)[106]	To present a retrospective study of patients with advanced horizontal and vertical bone loss and complete or partial edentulism who were treated with an autogenous rigidly fixed block onlay bone graft
Keller et al (1999)[107]	To present a continuation of a study of medical, surgical, and prosthetic records of patients with advanced maxillary bone resorption in whom autogenous inlay bone grafts were placed in the maxillary antrum or nasal floor
Watzek et al (1998)[108]	To examine *(1)* whether the concept of sinus floor augmentation can also be recommended in the treatment of patients with extreme maxillary resorption, and *(2)* whether the concept of placing implants mainly in maxillary posterior regions is suitable for this group of patients
Nyström et al (1997)[109]	To present the results from 10 consecutive patients who, because of insufficient bone volume for conventional implant placement in the maxilla, were treated with an interpositional bone graft and Le Fort I osteotomy
Köndell et al (1996)[110]	To evaluate the treatment of patients with severely resorbed edentulous maxillae with immediate autogenous rib grafts and titanium implants in a one-stage procedure with the onlay technique
Neukam (1996)[111]	To report a retrospective study of 43 patients with extreme severe maxillary ridge resorption who had received onlay grafts from the iliac crest with simultaneous placement of osseointegrated implants
Keller et al (1994)[112]	To describe a one-stage antral and nasal inlay composite bone-grafting procedure and to present preliminary statistical data for 30 recipient sites in 20 patients

REB = Research Ethics Board; NR = not reported; ND = none declared; CCT = clinical controlled trial; REC = Regional Ethics committee; ISQ = implant stability quotient; GEE = general estimation equation; RFA = radiofrequency analysis; ANOVA = analysis of variance; ITI = International Team for Implantology.

Table 17 Bias Assessment of Studies Designed With no A Priori Stated Objective to Assess a Particular Implant Design Feature

Lead Author	Study Objective
Jemt et al (2011)[113,114]	To report and compare the treatment outcomes of two patient cohorts from the same clinic, rehabilitated with fixed implant prostheses in the edentulous maxilla from 1986 to 1987 (early) and 2001 to 2004 (late)
Friberg and Jemt (2008-2007e)[115]	To retrospectively evaluate and compare the outcome of implants placed in edentulous maxillae with either wide or narrow jaw shapes; the marginal bone loss and implant cumulative survival rates were calculated and analyzed with special reference to smoking habits
Jemt and Johansson (2006)[116]	To report 15-year patient-based data in relation to follow-up after treatment with fixed prostheses supported by implants in the edentulous upper jaw
Widbom et al (2005)[117]	To retroactively evaluate outcome in two groups of patients treated with implant-supported maxillary overdentures; various factors related to the treatment were compared among subjects in the two groups
Ibañez et al (2005)[118]	To determine whether, with proper care selection and adherence to established principles, immediate occlusal loading of double acid-etched surface implants could be considered for clinical use in both arches after strict evaluation and longer follow-up
Degidi and Piattelli (2003)[119]	To evaluate clinical implants subjected to immediate functional loading and to immediate nonfunctional loading in various anatomic configurations
Kiener et al (2001)[120]	To report on prosthetic complications and maintenance of maxillary overdentures supported by ITI implants
Watson et al (1998)[121]	*(1)* To evaluate the long-term effectiveness of Calcitek cylindrical HA-coated implants to support maxillary or mandibular overdentures; *(2)* to compare the maxillary and mandibular success and survival rates of implants and prostheses; and *(3)* to report on the maintenance requirements associated with overdenture treatment with this system
Jemt and Lekholm (1995)[122]	To compare the 5-year treatment result of the Brånemark implant technique, when used in different maxillary shape situations and when using various prosthetic solutions, to determine if the outcome is predictable based on the presurgical jaw shape assessment
Palmqvist et al (1994)[123]	To retrospectively compare the outcomes of implant-supported maxillary overdentures in planned and emergency cases

REB = Research Ethics Board; NR = not reported; ND = none declared; HA = hydroxyapatite; ITI = International Team for Implantology.

Study Design	Statistics	REB	Funding	Risk of bias
Retrospective case series	Descriptive	NR	ND	High
Retrospective case series	Descriptive	NR	ND	High
Retrospective case series	Descriptive	NR	ND	High
Retrospective study with concurrent controls	ANOVA + Kaplan-Meier + log rank	NR	ND	High
Retrospective case series	Descriptive	NR	ND	High
Prospective case series	Descriptive	NR	ND	High
Retrospective case series	Kaplan-Meier + log rank +Cox regression	NR	ND	Medium
Prospective case series	Descriptive	NR	ND	High

Study Design	Statistics	REB	Funding	Risk of Bias
Retrospective study with historical controls	χ^2/t test + life table	NR	ND	High
Retrospective case series	χ^2/t test + Fisher permutation + life table	NR	ND	High
Prospective case series	χ^2/t test + life table	NR	ND	High
Retrospective case series	Life table + Cox regression	NR	ND	High
Prospective case series	Descriptive	NR	ND	High
Retrospective case series	Life table	NR	Apollonia, Italy; Biohorizons, USA; Friadent, Germany; Lifecore, USA; & Nobel Biocare, Sweden	High
Retrospective case series	Kaplan-Meier	NR	ND	High
Prospective case series	Life table	NR	Calcitek & Leeds General Infirmary Trust, UK	High
Retrospective case series	*t* test + life table + Cox regression	NR	Nobelpharma, Sweden	High
Prospective case series	Kaplan-Meier + logistic regression	NR	ND	High

Table 18 Results of Studies Designed to Assess Effects of Implant Design or Feature On Outcomes

Study	Presurgery	Surgery Details	Postsurgery
Jungner et al (2012e)[18]	Healed; no grafting	Two protocols: If stable, then 1-stage (32p, 59i), otherwise, 2-stage (57p, 174i)	Two protocols: *(1)* If stable ant mandible, then loading 13–32 days (14p, 54i); *(2)* healing 4–36 (av 17) weeks
Vervaeke et al (2015-2013e)[19]	No periodontitis	"According to manufacturers guidelines" 2 protocols: 1/2-stage	Two protocols: *(1)* If good stability, immediate impression, temp PMMA + metal < 24 h -> > 3 months perm; *(2)* healing
Testori et al (2014-2013e)[20]	Two protocols: *(1)* healed; *(2)* postextraction	AB, two protocols: 1/2-stage	Two protocols: *(1)* Stability > 32 Ncm, immediate impression, temp FDP < 48 h; otherwise, healing 2–6 months
Ravald et al (2013)[21]	Healed 3–6 months	2-stage	Healing mandible 4 months, maxilla 6.5 months
Van Assche et al (2012-2011e)[22]	Healed 6 months	AB, distal sites underprepared, 15+ NCm	Healing 6+ weeks, bar + denture -> 6 months, egg-shaped, bar new CoCr
Cosyn et al (2012-2010e)[23]	Three protocols: *(1)* postextraction (6%) or within 6 weeks (7%); *(2)* healed (87%), no periodontitis; *(3)* augmented-onlay/inlay (18%)	Two protocols: *(1)* (43%), *(2)* (57%)-stage	Two protocols: *(1)* Immediate
Kallus et al (2009-2008e)[24]	Healed 6 months	NR	Healing mandible 4 months, maxilla 6 months
Li et al (2009)[25]	Two protocols: *(1)* healed; *(2)* postextraction	AB, "standard protocol," 20–50 NCm	Immediate abutment, PMMA FDP -->
Alsaadi et al (2008)[26]	NR	NR	NR
Nelson et al (2008)[27]	Some augmented; some healed	Not AB, GA/La flap, 1-stage	Immediate reline –mandible > 6 weeks, maxilla 12 weeks; if > 35 Ncm then rehabilitation
Maló et al (2007)[28]	NR	AB, LA, Flap, Ø: undercontour, 0.8 mm supra, 32+ NCm	Immediate final abutment; two protocols: *(1)* immediate (16p/23i), *(2)* healing 4–6 months
Hjalmarsson and Smedberg (2005)[29]	NR	NR	NR
Degidi et al (2005)[30]	Two protocols: *(1)* postextract (23p, 175i); *(2)* healed (20p, 213i)	AB, LA, flap, Max ant/post Spread	Immediate PMMA FDP --> 4–6 months permanent
Schwartz-Arad et al (2004)[31]	Two protocols: *(1)* Postextract (144i); *(2)* healed (237i)	AB, maximal implant lengths, 2-stage	Immediate soft, reline --> healing time NR
Morris et al (2001)[32]	NR	AB	NR
Friberg et al (1997)[33]	Healed 3–4 months	2-stage	Healing 6 months
Olsson et al (1995)[34]	Healed 6 months	1 exp + 1 ctr implant in each contralateral quadrant, 2-stage	Healing mandible 4 months, maxilla 6 months

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; mc = Metal-Ceramic; OPGX = orthopantomogram; PMMA = polymethyl methacrylate; VAS = visual analogue scale; Adverse*: Adverse biological and technical outcomes.

Prosthesis	Outcome	Patient-Outcome	Findings
Crown (36i) pFDP (103i) fFDP (148i)	PAX bone, perioindex, implant removed	NR	Surface influence the outcome. Oxidized marginally better than turned
Crown pFDP fFDP	PAX/OPX bone SuccSurv	NR	Multivariate analyses indicated no effect of implant length, diameter, or design on survival or bone loss
4-8i FDP cement/ screw	Adverse* PAX bone SuccSurv	NR	The multivariate analyses indicated no effect of implant length, diameter, or design on survival or bone loss, contrasting the univariate estimates
5/6i-ga/TiA/mc-10/12u-FDP screw	Adverse* PAX bone Perioindices	NR	Implant system does not influence outcome; (corrects somewhat earlier data of same cohort by Engquist et al, 2002, & Åstrand et al, 1999 & 2004)
4i + 2 post short egg-shape bar CoCr overdenture	Adverse PAX bone Perioindices Stability-ptv/RFA SuccSurv	NR	Multivariate analyses indicated that implant length does not influence outcome; no differences were noted between the two short posterior implants vs the other implants supporting the FDP
Crown pFDP fFDP overdenture	PAX/OPX bone, SuccSurv	NR	Multivariate analyses indicated no effect of implant length or diameter on outcome. Surfaces/systems not compared
6i-FDP-ns	PAX bone, SuccSurv	NR	Implant system does not influence outcome
4/6i-FDP	OPX bone, SuccSurv	NR	No differences noted between designs lengths and diameter
Crown pFDP fFDP	PAX bone, stability-ptv SuccSurv	NR	Multivariate analyses indicated more bone loss around ø5mm than others. Trend for more loss with machined surfaces. No effect of length
FDP overdenture	Adverse OPGX bone, perioindices, SuccSurv	NR	Implant design does not influence outcome. (No implants were lost following the abutment connection)
Crown (58), pFDP (296i), total FDP (54i)	Adverse* PAX bone, SuccSurv	NR	Implant surface influence outcome; all the failed implants (n = 13) were turned and not microrough; possible learning curve effect; concurrent use of short and long implants to support FDP
4/8i-Au/Ti-FDP screw (24p) OR 4/8i-Au/Ti-FDP-cresco(26p)	Adverse* bone, perioindices, preload	Satisfaction VAS	No difference noted between two implant systems
6-12i-12u-mcFDP cement	PAX bone, SuccSurv	NR	Multivariate analyses indicated that implant diameter influenced outcome; implants with diameter more than 5.25 mm had a hazard rate of 3.1 compared to < 5.25 mm
mc-FDP	OPX bone	NR	Multivariate analyses indicated that implant length does not influence bone loss; implant coating may have a marginal effect on outcome
Crown/FDP 5-6i-ball/ bar-overdenture	PAX/OPX bone, perioindices, stability-ptv, SuccSurv	NR	Implant surface may influence outcome; cp titanium screw have worse outcomes compared to hydroxyapatite screw and cylinders
ga-FDP screw	PAX bone	NR	No difference between two designs, one with and one without tapping
4-6i FDP	*(1)* SurgComplic/Success 2; *(2)* adverse* PAX bone	NR	Implant design does not influence outcome

Table 19 Results of Studies Reporting the Effects of Tilted Implants to Enable Placement of Longer Implants

Study	Presurgery	Surgery Details	Postsurgery
Agliardi et al (2014-2012e)[35]	Two protocols: *(1)* postextraction-pal + autograft, *(2)* healed	AB, LA, flap, post tilt 30°– 45°, medial i, tilt 30°– 45°, axial, underprepared; 30+ Ncm	Immediate permanent abutment, suture, impression, PMMA-FDP 4–6 months > permanent
Agnini et al (2014-2012e)[36]	Two protocols: *(1)* postextraction autograft + allograft, no membrane, *(2)* healed	AB, LA, flap, two protocols: *(1)* if 9 mm bone then 6–8 axial imp, *(2)* If < 7 mm bone 2 tilted + 2 axial. If required, autograft + allograft/xenograft + Membrane	Immediate impression, healing abutment, suture, PMMA-FDP 6 months > permanent
Pera et al (2014)[37]	Postextraction	Underprepared, posterior angled if required, > 40 Ncm	Immediate abutment + impression > PMMA within 36 h > 4 months healing
Pozzi et al (2015-2013e)[38]	Two protocols: *(1)* postextraction (44i), *(2)* healed (126i)	NR, 30 Ncm, peri-implant autograft	Immediate prefabricated PMMA w/metal screws > 3–4 months > permanent
Maló et al (2012-2011e)[39]	Healed	AB, LA, flap, fenestration, trans-sinus, post tilt < 45°, 32+ Ncm	Immediate impression, PMMA screws 6 months > permanent
Testori et al (2013)[40]	NR	AB, LA, flap, fenestration, trans-sinus, post tilt < 30°, xenograft	Healing 6 months > permanent
Di et al (2013)[41]	Two protocols: *(1)* postextraction, *(2)* healed	AB, LA, flap, fenestration, post tilt < 45°, 35 Ncm	Immediate impression, PMMA screws 6 months > permanent
Maló et al (2012)[42]	Two protocols: *(1)* postextraction, *(2)* healed	AB, LA, flap, fenestration, post tilt 35°–45°, underprepared, 35+ Ncm	Immediate impression, PMMA screws 6 months > permanent
Francetti et al (2012-2010e)[43]	Two protocols: *(1)* postextraction, *(2)* healed	LA, flap, fenestration, post tilt 30°, 40–50 Ncm	Two protocols: *(1)* If > 40–50 Ncm then immediate abutment (straight/30° multiunit) + pickup pvs-impression, PMMA-FDP 4–6 months permanent
Mozzati et al (2012)[44]	Two protocols: *(1)* postextraction (210i), *(2)* healed (124i)	AB, LA, bone remodel, flap, post tilt 30°, "nanocrystalline paste" (35p, 108i), 40 Ncm	Immediate PMMA-screw > 6+ months healing > permanent
Crespi et al (2012)[45]	Two protocols: *(1)* postextraction, *(2)* healed	AB, LA, flap, post tilt 25°– 35° (4 mm–13/15 mm), axial (3.75/4–13 mm), underprepared	Two protocols: (1) If > 40 Ncm then immediate abutment (17/30°) + pickup preimpression + bite registration, prefab PMMA ± metal-FDP+ >
Cavalli et al (2012)[46]	Two protocols: *(1)* postextraction, *(2)* healed	AB, LA, flap, post tilt 30°, 40–50 Ncm	Immediate permanent abutment, suture, compression, PMMA-FDP 6 months > permanent
Maló et al (2012)[47]	Two protocols: *(1)* postextraction, *(2)* healed	AB LA, flap fenestration, post tilt 35°– 45°, underprepared 35+ Ncm	Immediate impression, PMMA screws 6 months > permanent
Maló et al (2011)[48]	Two protocols: *(1)* postextraction, *(2)* healed	AB LA, flap fenestration, post tilt 35°– 45°, underprepared 35+ Ncm	Immediate impression, PMMA screws 6 months > permanent
Agliardi et al (2010)[49]	Healed	AB, LA, flap post tilt 30°– 45°, underprepared 30+ Ncm	Immediate permanent abutment, suture, impression, PMMA-FDP 4–6 months > permanent

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; ø = diameter; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; PMMA = polymethyl methacrylate; VAS = visual analogue scale; ZrO: Zirconium-oxide; CAD/CAM = computer-aided design/computer-assisted manufacture; Au/Ti: Gold alloy or Titanium.
*Adverse biological and technical outcomes.

Prosthesis	Outcome	Patient Outcome	Findings
4 tilt + 2i-CAD/CAM TiA-12u-FDP-Procera	Adverse* PAX bone, perioindices SuccSurv	Satisfaction-5-Likert	Tilted, axial implants performance comparable, effects of different implant systems were NR
2 tilt + 2i/6-8i-mc/ac/Tia-FDP/CAD-ZrO/TiO-FDP	Adverse* PAX bone	NR	Tilted, axial implants performance comparable for one system, but worse for tilted when alternative system described, could be an effect of unbalanced intraoral distribution/restorations
4-6-FDP screw	PAX bone	NR	Tilted, axial implants performance comparable, multivariate stats indicated that roughness of implant neck does not influence outcome
2 tilt + 2-8i-CAD-ZrOFDP	Adverse* OPGX bone, perioindices, SuccSurv	Satisfaction-VAS	Implant system does not influence outcome, no implants were lost, (however only 2 vs 10 patients had implants in the edentulous maxilla)
2 tilt + 2i-12u-FDP	Adverse* OPG/PAX bone, SuccSurv	"Complaints"	The axial implants performed slightly better than the tilted
2 tilt + 2/4i-12u-TiaFDP screw	Adverse* PAX bone, SuccSurv	Satisfaction-4-Likert	Tilted, axial implants performance comparable
2 tilt + 2i-12u-gaFDP	Adverse* OPGX bone, SuccSurv	Satisfaction-5-Likert	Tilted, axial implants performance comparable
2 tilt + 2i-TiC-FDP-Procera/TiA-FDP	Adverse* OPG/PAX bone, SuccSurv	"Complaints"	Tilted, axial implants performance comparable, implant design influence outcome, one implant system had higher failure rate than the others
2 tilt + 2i-12u-mcFDP-Procera-screw	Adverse* PAX bone, SuccSurv	NR	Tilted, axial implants performance comparable
2 tilt + 2/4i-mcFDP	Adverse* PAX bone, perioindices, SuccSurv	Satisfaction-Y/N	Tilted, axial implants performance comparable
2 tilt + 2i-10/12u-ga-FDP screw	Adverse* PAX bone, SuccSurv	NR	Axial implants performed slightly better than tilted
2 tilt + 2i-12u-CAD-TiA-FDP-Procera	Adverse* PAX bone, perioindex, SuccSurv	NR	Implant system does not influence outcome, no implants were lost
2 tilt + 2i-TiC-FDP-Procera/TiA-FDP	Adverse* OPG/PAX bone, SuccSurv	"Complaints"	Tilted, axial implants performance comparable, implant system does not influence outcome
2 tilt + 2i-TiC-FDP-Procera/TiA FDP	Adverse* OPG/PAX bone, SuccSurv	"Complaints"	Tilted, axial implants performance comparable, multivariate stats indicated that implant system does not influence outcome
2 tilt + 2i- CAD/CAM TiA-FDP-canti-Procera	Adverse* PAX bone, perioindices	NR	Tilted, axial implants performance comparable, effects of different implant systems were NR

Table 19 ***Continued*** **Results of Studies Reporting the Effects of Tilted Implants to Enable Placement of Longer Implants**

Study	Presurgery	Surgery Details	Postsurgery
Degidi et al (2010)[50]	Healed	AB, LA, flap post tilt 30°– 45°, no bone grafting, minimum 25 Ncm/ISQ 60 for study inclusion	Immediate abutment, prefabricated PMMA FDP, welded framework, ø: 2 mm bar, removed & sandblasted, permanent
Pomares (2009)[51]	Two protocols: *(1)* postextraction, *(2)* healed	LA, MaloSurgGuide, if poor bone 6 implants, otherwise 4	Immediate abutment + impression > temp PMMA > 7 days > healing 5–15 months > permanent
Agliardi et al (2009)[52]	Two protocols: *(1)* postextraction (40i), *(2)* healed (80i)	AB, LA, flap post tilt 30°–45°, medial. tilt 30°– 45°, axial, underprepared, 30+ Ncm	Immediate permanent abutment, suture, impression, PMMA-FDP 4–6 months > permanent
Rosen & Gynther (2007)[53]	NR	No AB, LA, fenestration, post tilt > 30°, if thin, palatal w/2-5 exposed threads, no graft, no membrane, 2-stage	Healing 6 months > permanent
Capelli et al (2007)[54]	Healed	AB, LA, flap fenestration, post tilt 25°– 35°, 1-stage crestal/subcrestal	Two protocols: *(1)* If > 30+ Ncm then immediate PMMA-FDP, 3 months permanent
Fortin et al (2002)[55]	Healed	30+ Ncm	Healing 3/6 months > permanent
Krekmanov et al (2000)[56]	Healed	AB, LA, flap fenestration, post tilt 30°–35°, anterior tilt varies	Healing 3/6 months > permanent
Mattsson et al (1999)[57]	NR	No AB, LA, fenestration, post tilt > 30°, if thin, palatal w/2-5 exposed threads, no graft, no membrane, 2-stage	Healing 6 months > permanent

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; ø = diameter; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; PMMA = polymethyl methacrylate; VAS = visual analogue scale; ZrO: Zirconium-oxide; CAD/CAM = computer-aided design/computer-assisted manufacture; Au/Ti: Gold alloy or Titanium.
*Adverse biological and technical outcomes.

Table 20 **Results of Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes**

Study	Presurgery	Surgery Details	Postsurgery
Yates et al (2014-2013e)[58]	Healed	GA, SinusSlot, suture, 2-stage	Healing 6 months
Aparicio et al (2014-2012e)[59]	Healed	AB, GA, flap vertical rectangular sinus window, trans-sinus implant, 2-stage	Healing 5–6 months
Fernández et al (2014)[60]	Healed	AB, GA, flap, two protocols: *(1)* vertical rectangular sinus window, trans-sinus implant (51p), *(2)* no window (29p) 2-stage	NR
Maló et al (2015-2013e)[61]	NR	AB, GA/LA, flap, three protocols? XtraMaxillary, ≥ 30 Ncm	Immediate impression, PMMA screws same day > 6 months > permanent
Davó et al (2013)[62]	Healed postextraction	AB, GA, flap, three protocols: *(1)* vertical rectangular sinus window, trans-sinus implant (66i), *(2)* SinusSlot (15i), *(3)* "minimal invasive" SinusSlot XtraSinus	Immediate impression, metal-reinforced PMMA 24–48 hours > healing 6 months
Davo and Pons (2013)[63]	Healed	AB, GA, flap, vertical rectangular sinus,window, trans-sinus implant, > 35 Ncm, suture	Immediate impression, metal-reinforced PMMA 24–48 hours > healing 6 months
Maló et al (2012)[64]	Healed	AB, GA (32p), LA (7p) flap XtraMaxillary ≥ 30 Ncm	Immediate PMMA temp same day > 6 months

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; CAD/CAM = computer-aided design/computer-assisted manufacture; BIC = bone-to-implant contact; ptv = Periotest; zyg = zygomatic; pter = pterygoid; PMMA = polymethyl methacrylate; VAS = visual analogue scale; OHIP = Oral Health Impact Profile.
*Adverse biological and technical outcomes.

Prosthesis	Outcome	Patient Outcome	Findings
4 tilt + 3i-10/12u-weld-bar-ga FDP screw	Adverse* PAX bone, perioindices, SuccSurv	NR	Tilted implants performed slightly better than axial
2 tilt + 2i- CAD/CAM TiA-FDP-canti-Procera	Adverse* OPG/PAX bone, SuccSurv	NR	Tilted, axial implants performance comparable
4 tilt + 2i-10/12u- CAD/CAM TiA-12u-FDP-Procera	Adverse* PAX bone, perioindices, SuccSurv	Satisfaction-5-Likert	Implant system does not influence outcome, no implants were lost
2 tilt + 4i-12u-CoCr/AgPd/TiaFDP-canti-screw	Adverse* OPG/PAX bone, perioindices, SuccSurv	Satisfaction-Y/N	Tilted, axial implants performance comparable
2 tilt + 2/4i-12u-TiA-FDP screw	Adverse* PAX bone, SuccSurv	Satisfaction-Y/N	Tilted, axial implants performance comparable
2 tilt + 1-5i-bar-Marius bridge	Adverse* SuccSurv	Satisfaction-Y/N	Tilted, axial implants performance comparable
6 tilt-Ga/TiA-FDP	Adverse* bite force, SuccSurv	NR	Tilted implants performed slightly better than axial
2 tilt + 4i-12u-CoCr/AgPd/TiA FDP-canti screw	Adverse* SuccSurv	NR	Tilted, axial implants performance comparable

Prosthesis	Outcome	Patient Outcome	Findings
2-4i + 1/2 zyg-FDP screw, overdenture	SuccSurv	NR	
2-5i + 2 zyg-FDP, cement (3)/ screw (19)	Adverse* Stability-Ptv SuccSurv	Sinusitis-Y/N OHIP-Edent	
NR	Adverse* SuccSurv	NR	
1-4i + 2/4 zyg-FDP	Adverse* SuccSurv	NR	
2-6i + 2/4 zyg-FDP screw	Adverse* SuccSurv	NR	Performance of different conventional implants and turned vs oxidized zygoma implants NR
4 zyg-FDP screw (15p), overdenture (2p)	Adverse* SuccSurv	OHIP-14	
1-4i + 2/4 zyg-Tia/ga-FDP	Adverse* PAX bone, perioindices, SuccSurv	NR	Performance of different prototype zygoma implants NR

Table 20 ***Continued*** **Results of Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes**

Study	Presurgery	Surgery Details	Postsurgery
Migliorança et al (2012)[65]	Healed	AB, GA + LA, flap XtraSinus, ≥ 35 Ncm, abutment, suture	Two protocols: *(1)* If > 40 Ncm then immediate impression, temp PMMA 6 months, *(2)* healing 6 months
Balshi et al (2012)[66]	Healed	AB, GA, flap, vertical rectangular sinus window, PrP-prep + trans-sinus implant	Immediate autopolymer PMMA in denture < 2 hours > 3 months
Aparicio et al (2010-2008e)[67]	Healed	AB, GA, flap, two protocols: *(1)* vertical rectangular sinus window, trans-sinus implant (7p), *(2)* XtraSinus (18p)	Two protocols: *(1)* immediate temp PMMA < 24 hours > 4–6 months, *(2)* immediate impression, suturing, denture relief, submerged healing 6 months, permanent FDP < 5 days
Aparicio et al (2010-2008e)[68]	Healed	AB, GA, flap, XtraSinus	Immediate impression, suturing, denture relief, two protocols: *(1)* immediate temp PMMA < 24 hours > 4–6 months, *(2)* permanent FDP < 5 days
Bedrossian (2010)[69]	Healed	AB, GA + LA, flap, vertical rectangular sinus window, trans-sinus implant	Immediate autopolymer PMMA in denture > 6 months permanent
Stiévenart and Malevez (2010)[70]	Healed	AB, GA + LA, flap, vertical rectangular sinus window, trans-sinus implant. 2 protocols: *(1)* 2-stage (10p), *(2)* 1-stage (10p) + immediate/ early load	Two protocols: *(1)* healing 2–5 months, *(2)* immediate temp PMMA < 1–14 days
Davó (2009)[71]	Healed postextraction	AB, GA, flap, vertical rectangular sinus window, trans-sinus implant, 2-stage	Healing 6 months
Balshi et al (2009)[72]	Healed	AB, GA, flap, vertical rectangular sinus window, PrP-prep + trans-sinus implant	Immediate autopolymer PMMA in denture < 2 hours > 3 months
Pi Urgell et al (2008)[73]	Healed	AB, GA + LA, flap, SinusSlot. Suture. 2-stage	Healing 6–12 months
Davó et al (2008)[74]	Healed postextraction	AB, GA. flap, 3 protocols: *(1)* vertical rectangular sinus window, trans-sinus implant (66i), *(2)* SinusSlot (15i), *(3)* "minimal invasive" SinusSlot XtraSinus	Immediate impression, metal-reinforced PMMA 24–48 hours > healing 6 months
Davó et al (2008)[75]	Healed postextraction	AB, GA, flap, two protocols: *(1)* vertical rectangular sinus window, trans-sinus implant (61i), *(2)* SinusSlot (10i)	Immediate impression, metal-reinforced PMMA 24–48 hours > healing 6 months
Kahnberg et al (2007)[76]	Healed	AB, GA, flap, autograft + vertical rectangular sinus window, trans-sinus implant, 2-stage	Healing 6 months
Duarte et al (2007)[77]	Healed	AB, GA, flap, vertical rectangular sinus window, trans-sinus implant	Immediate abutment, autopolymer surgery guide, impression, permanent next day
Peñarrocha et al (2007)[78]	Healed	AB, GA + LA, flap, SinusSlot, suture, 2-stage	Healing 2 months
Peñarrocha et al (2007)[79]	Healed	AB, GA + LA, flap, two protocols: *(1)* conventional imp, 2-stage (23p), *(2)* conventional + SinusSlot (23p), 2-stage	Healing 2 months
Bedrossian et al (2006)[80]	Healed 12+ months	AB, GA + LA, flap, vertical rectangular sinus window, trans-sinus implant, 40 Ncm	Immediate autopolymer PMMA in denture > 6 months permanent
Farzad et al (2006)[81]	Healed	AB, GA, flap, vertical rectangular sinus window, trans-sinus implant, immediate impression, suturing, denture relief	Healing 6–11 months

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; CAD/CAM = computer-aided design/computer-assisted manufacture; BIC = bone-to-implant contact; ptv = Periotest; zyg = zygomatic; pter = pterygoid; PMMA = polymethyl methacrylate; VAS = visual analogue scale; OHIP = Oral Health Impact Profile.
*Adverse biological and technical outcomes.

Prosthesis	Outcome	Patient Outcome	Findings
2-4i + 2 zyg-10u-FDP screw	Adverse* SuccSurv	NR	
2-4i + 2 zyg + 2p ter-ga/mcFDP	Adverse* BIC, SuccSurv	NR	Performance of turned vs oxidized zygoma implants NR
2-5i + 2 zyg-mcFDP	Adverse* SuccSurv	NR	
3-4i + 2 zyg-FDP	Adverse* SuccSurv	NR	
2-4i + 2 zyg-FDP	Adverse* SuccSurv	NR	Performance of different conventional implants NR
4 zyg-Tia-FDP-Procera	Adverse* SuccSurv	NR	
3-6i + 2 zyg-ga-FDP screw (19p), overdenture (3p)	Adverse* SuccSurv	NR	Performance of turned vs oxidized conventional implants NR
2-6i + 2 zyg + 2 pter-ga/mcFDP	Adverse* SuccSurv	NR	Performance of turned vs oxidized zygoma implants NR
4i + 2 zyg-FDP/overdenture	Adverse* SuccSurv	NR	
2-6i + 2/4 zyg-FDP screw	Adverse* SuccSurv	NR	Performance of different conventional implants and turned vs oxidized zygoma implants NR
2-6i + 1/2/4 zyg-FDP screw	Adverse* SuccSurv	NR	Performance of turned vs oxidized zygoma implants NR
2-4i + 2 zyg-FDP/overdenture	Adverse* SuccSurv	Satisfaction	
4 zyg-ga-FDP screw	Adverse* SuccSurv	NR	
3-6i + 1/2 zyg-FDP screw/cem	Adverse* SuccSurv	NR	Performance of different conventional implants NR
3-6i + ½ zyg-FDP screw/cem	Adverse* SuccSurv	Satisfaction-VAS	Performance of different conventional implants NR
2-4i + 2 zyg-FDP	Adverse* SuccSurv	Satisfaction	
2-4i + 2 zyg-Tia-FDP-Procera	Adverse* Stability-RFA, SuccSurv	Satisfaction-VAS	

Table 20 ***Continued*** **Results of Studies Reporting the Effects of Implants Placed in Zygomatic Bone With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes**

Study	Presurgery	Surgery Details	Postsurgery
Ahlgren et al (2006)[82]	Failed implant surgery, cleft palate, graft refusal	AB, GA, flap, onlay graft (2p), vertical rectangular sinus window, trans-sinus implant, 2-stage	Healing 5–6 months
Aparicio et al (2006)[83]	Healed	AB, GA, flap, vertical rectangular sinus window, trans-sinus implant, 2-stage	Healing 5–6 months
Becktor et al (2005)[84]	Healed	AB, GA, flap, vertical rectangular sinus window, trans-sinus implant, 2-stage	Healing 5–8 months
Malevez et al (2004)[85]	Healed graft (n = 7) > 4–6 months	AB, GA, flap, vertical rectangular sinus window, trans-sinus implant, 2-stage	Healing 6 months
Brånemark et al (2004)[86]	Healed	AB, GA, flap, autograft (17p), vertical rectangular sinus window, trans-sinus implant	Immediate impression, suturing, healing 6 months
Bedrossian et al (2002)[87]	Healed	AB, GA + LA, flap, vertical rectangular sinus window, trans-sinus implant	Immediate impression, suturing, denture relief, healing 6 months

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; CAD/CAM = computer-aided design/computer-assisted manufacture; BIC = bone-to-implant contact; ptv = Periotest; zyg = zygomatic; pter = pterygoid; PMMA = polymethyl methacrylate; VAS = visual analogue scale; OHIP = Oral Health Impact Profile.
*Adverse biological and technical outcomes.

Table 21 **Results of Studies Reporting the Effects of Implants Placed in Pterygoid Bone or Other Bony Buttresses With or Without Additional Alveolar Implants Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes**

Study	Presurgery	Surgery Details	Postsurgery
Peñarrocha-Oltra et al (2013)[88]	Healed	LA, flap, ≥ 4 imp placed tilted & palatal w/2–5 exposed threads covered w/autograft + xenograft, 2-stage	Healing 2 + 1–2 months
Balshi et al (2013b)[89]	NR	NR	NR
Balshi et al (2013)[90]	Two protocols: *(1)* postextraction, *(2)* healed	Three protocols: *(1)* 1-stage-freehand, *(2)* 1-stage-CAD guide, *(3)* 2-stage freehand	Two protocols, pending primary stability: *(1)* immediate abutment, suture, temp PMMA (since 2000)/CAD/CAM planned (since 2004), teeth in a day vs *(2)* healing 6–8 months
Rodríguez et al (2012)[91]	NR	AB, LA, flap, pter-med, 10°–15°/mes-dis 70°, 2-stage	Healing 4 months (2–7 months)
Peñarrocha et al (2012)[92]	Healed	GA + LA, drill/osteotome, palatal positions (35i), autograft-articles + xenograft-bovine covered, pterymax (10i), XtraSinus-zygomatic(4i)/frontomax buttress (30i), nasopalatal (6i); 2-stage	Healing 3 months
Peñarrocha et al (2009)[93]	Healed	GA + LA drill/osteotome, palatal positions, autograft-articles + xenograft-bovine covered, XtraSinus-zygomatic, 2-stage	Softlined denture, healing 2 + 1 months
Peñarrocha et al (2009)[94]	Healed	GA + LA, drill/osteotome, flap, 2-stage	Healing 3 months
Balshi et al (2005)[95]	Two protocols: *(1)* postextraction, *(2)* healed	NR	Two protocols, pending primary stability: *(1)* immediate abutment, suture, temp PMMA, teeth in a day (522i), healing 5–6 months > perm. FDP, *(2)* healing 4–6 months (318i)
Balshi et al (1999)[96]	NR	LA 2-stage	Healing 5–6 months

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; CAD/CAM = computer-aided design/computer-assisted manufacture; BIC = bone-to-implant contact; zyg = zygomatic; pter = pterygoid; PMMA = polymethyl methacrylate; VAS = visual analogue scale; OHIP = Oral Health Impact Profile; CAD/CAM = computer-aided design/computer-assisted manufacture.
*Adverse biological and technical outcomes.

Prosthesis	Outcome	Patient Outcome	Findings
2-5i + 2 zyg-FDP/overdenture	Adverse* SuccSurv	NR	Performance of turned vs oxidized conventional implants NR
2-4i + 2/4 zyg-ga-FDP-cem	Adverse* Stability-Ptv SuccSurv	NR	
1-6i + 2 zyg-ga FDP	Adverse* SuccSurv	NR	Performance of different conventional implants NR
2-4i + 2 zyg-FDP	Adverse* Perioindices, SuccSurv	NR	
2-5i + 1-4 zyg-FDP screw	Adverse* SuccSurv	NR	
2-4i + 2 zyg-ma/ga-FDP	Adverse* SuccSurv	NR	

Prosthesis	Outcome	Patient-Outcome	Findings
6-8i-mcFDP-cement/ga-FDP screw/2 tilt + 2i-bar, overdenture	Adverse* OPGX bone, perioindices	OHIP-14 Satisfaction-VAS	(Long) tilted and palatally placed vs conventional implant comparable outcomes
NR	Adverse*	NR	The 7–13 mm long pter implants performed worse than the 15–18 mm
6i + 2 pter + 2zyg-12u-mcFDP screw	Osseointegration	NR	Titanium oxide surface performed better than machined Brånemark implants
6i + 2 pter-12u-mcFDP screw, part-FDP	*(1)* SurgSucc *(2)* adverse*	NR	Pterygoid and conventional implant comparable outcomes
tilt-10/12u-FDP/overdenture	Adverse* SuccSurv (Buser)	NR	Pterygoid & palatal and conventional implant comparable outcomes
6i + 2 pter ± zyg mc/ga-FDP screw	Adverse* OPX bone SuccSurv	Satisfaction-VAS	Palatal and conventional implant comparable outcomes
6i + 2 pter-FDP screw/cement	Adverse* OPX bone, SuccSurv	Satisfaction-VAS	Pterygoid and conventional implant comparable outcomes
6i + 2 pter + 2 zyg-12u-mcFDP screw	Osseointegration	NR	No difference between Mark III and Mark IV Brånemark implants
6-8i + 2 pter-12u-mcFDP screw	Adverse biol OPX bone	NR	No difference between standard and self-tapping Brånemark implants

Table 22 Results of Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes

Lead author	Presurgery	Surgery Details	Postsurgery
Zinser et al (2013-2012e)[97]	Two protocols, 1 & 2 stage, AB, GA/LA, sinus later autograft-iliac/chin/ramus/ symphysis ± iliac-block-hor/vert onlay + membrane collagen > 3 months (autograft) 5 months (autograft + allograft)/6 months (allograft + xenograft)	AB, GA/LA, as for 2-stage procedure	3 months (autograft) 6 months (allograft + xenograft)/3–4 months if 2-stage
Dasmah et al (2013-2011e)[98]	AB, GA, LA flap, two protocols: (R) autograft_iliac_block-onlay vs (L) iliac particulate onlay + PrP + sinus lateral iliac particulate inlay (R) + PrP (L) – > 6 months	NR	Healing 6 months, stability-RFA
Sjöström et al (2007)[99]	AB, GA, two protocols: *(1)* Le Fort I fracture, autograft iliac interpositional (n = 5), *(2)* ant onlay + nasal floor inlay (24p) + sinus (6p)/post onlay (18p) > 6 months	AB, LA, 2-stage	Healing 6–8 months
Chiapasco et al (2007)[100]	AB, GA, Le Fort I fracture, autograft iliac block interposition > 4–8 months	NR	Healing 4–8 months
Hallman et al (2005)[101]	GA, Le Fort I fracture, autograft iliac block interposition midline + sinus iliac particulate > 6 months	AB, LA, 2-stage	Healing 6 months
Becktor et al (2004)[102]	AB, GA, three protocols (1990–94/1994–1996): *(1)* (1994–1996), autograft iliac block hor-vert onlay/sinus inlay (24p)-> 4–7 months	AB, GA, *(1,2)* (1990–1994). Autograft iliac block hor-vert onlay/inlay + 7–15 mm-i (40p, 260i) vs *(3)* nongrafted (118p/683i), 2-stage	Healing 5-12 months (av 9) graft group/5–14 months (av 7) nongraft group
Pinholt (2003)[103]	AB, GA + LA sinus lateral autograft-iliac (/symphysis/ramus) corttrab-block + particulate + edentulous: block secured to lateral crest > 4.5 months	AB, flap, 2-stage	Healing 8 months
Becktor et al (2002)[104]	GA, four protocols *(1)* 2-stage, *(2–4)* 1-stage, 1. Autograft iliac segment block + particulates onlay + sinus lateral inlay, resilient denture (24p) > 4–7 months	GA, three protocols: *(1)* segment block-inlay nasal floor + sinus lateral + 9 imp, *(2)* segment block onlay + 3 × 3 imp, *(3)* full block onlay + 8 imp, all autograft iliac block + particulates, 4(1): 2 × 3 implants, 2-stage, resilient denture (66p)	Healing 5–12 months
Lekholm et al (1999)[105]	Five protocols: *(1,2)* autograft onlay (general & local, *(3)* Autograft_sinus inlay, *(4)* onlay + sinus inlay, *(5)* Le Fort + autograft > 4–5 months (25p)	Same five protocols: *(1)* +2 × 3 imp (33p) (21p local), *(3)* +2 imp (55p), *(4)* +2 + 2 × 3 imp (13p), *(5)* 3 + 2 × 3 imp (23p) (125p, 624i) in grafted bone + 157 nongrafted	NR
Keller et al (1999)[106]	GA, Le Fort I fracture, autograft iliac block interposition midline + sinus Iliac particulate > 6 months (4p, 21i)	GA, Le Fort I fracture, autograft iliac block interposition midline + sinus iliac particulate, 2-stage, resilient denture (21p, 183i)	Healing 6 months
Keller et al (1999)[107]	GA, three protocols × 2/1-stage. *(1)* LeFort I fracture, autograft iliac block nasal floor + sinus iliac particulate (37p), *(2,3)* Le Fort I/crestal flap, autograft iliac corticocanc block + particulates nasal floor/sinus lat, resilient denture > 6 months (31p)	*(2,3)* As for 2-stage, 2 × 3 implants, 2-stage, resilient denture (87p)	Healing 6 months

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; R = right side; L = left side; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; CAD/CAM = computer-aided design/computer-assisted manufacture; BIC = bone-to-implant contact; PMMA = polymethyl methacrylate; VAS = visual analogue scale; HA = hydroxyapatite.
*Adverse biological and technical outcomes.

Prosthesis	Outcome	Patient Outcome	Findings
Crown (124), FDP (642i), overdenture (279i)	*(1)* SurgComplic/Success *(2)* PA/OPGX bone SuccSurv	NR	Multivariate analyses indicated that implant design or surface does not influence outcome
8i-mc-FDP screw	PAX bone SuccSurv	NR	Implant length does not influence outcome
6-8i-FDP	*(1)* SurgComplic/Success *(2)* adverse* PAX bone stability-RFA, SuccSurv	NR	Multivariate analyses indicated that implant length does not influence outcome within 10–13 mm vs 15–18 mm
4-10i-FDP/ overdenture (19p/20p)	*(1)* Surgery success (98) *(2)* PAX bone perioindex SuccSurv	Satisfaction-Likert-3p	Implant length does not influence outcome when chosen to engage the grafted bone; effects of different implant systems were NR
5-8i-mc-FDP screw	*(1)* SurgComplic/Success *(2)* PAX bone SuccSurv	Satisfaction-VAS	Implant system influences outcome; however, possible effect of learning curve since first patients received implant brand A and the following group brand B
ga-FDP bar overdenture	*(1)* Surgery success *(2)* PAX bone, perioindex, SuccSurv	NR	Implant length influences outcome. 15-mm implants perform better than 10-mm, which perform better than 6–8 mm; however, tables include implants placed both in grafted and in nongrafted cohort
10i-FDP/7-8i overdenture	*(1)* Surg Complic/Success *(2)* histology *(3)* adverse* PAX/OPGX bone	NR	Implant system influences outcome; however, possible effect of learning curve since first patients received implant brand A and the following group brand B; complex and incoherent data matrix
FDP (68p), overdenture (4p)	*(1)* SurgComplic/Success *(2)* "Failure"	NR	Multivariate analyses indicated that implant length influences outcome. 15/18/20-mm long implants perform better than 10/13 mm, which perform better than 7/8 mm
FDP overdenture	Adverse biol SurgSucc (NR)	NR	Implant design influences outcome; one design showed less success than other designs from same manufacturer
3-6i bar ball overdenture	*(1)* SurgComplic/Success *(2)* SuccSurv	NR	Implant length influences outcome; 18 & 20 mm implants performed better than 10/13/15 mm; however, potential influence by implant design
FDP (45p) fix remove (10p), overdenture (14p)	*(1)* SurgComplic/Success *(2)* SuccSurv	NR	Implant length may influence outcome, but no data presented to support statement; long implants preferred to stabilize graft

Table 22 ***Continued*** **Results of Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes**

Lead author	Presurgery	Surgery Details	Postsurgery
Watzek et al (1998)[108]	GA, three protocols: *(1)* sinus graft lateral autograft iliac cancellous vs *(2)* iliac + allograft HA/xenograft bovine > 3–8 months (auto)/6 months (allo)	AB	Healing 6 months
Nyström et al (1997)[109]	GA, Le Fort I fracture, autograft iliac block-interposition midline + sinus iliac particulate > 6 months	LA, 6 implants, 2-stage	Healing 6 months
Köndell et al (1996)[110]	Healed 6–38 years, edentulous	GA, autograft rib 2 × 5 cm inlay nasal + sinus + 2 × 2–3 implants, 2-stage	Healing 6–11 months
Neukam (1996)[111]	NR	Autograft iliac onlay, 2-stage	Healing 2–16 months
Keller et al (1994)[112]	NR	GA, Le Fort I/crestal flap, nasal floor/sinus lateral autograft iliac corticocanc-block + particulates + 2 × 3 implants, 2-stage, resilient denture	Healing 6 months

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; R = right side; L = left side; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; CAD/CAM = computer-aided design/computer-assisted manufacture; BIC = bone-to-implant contact; PMMA = polymethyl methacrylate; VAS = visual analogue scale; HA = hydroxyapatite.
*Adverse biological and technical outcomes.

Table 23 **Results of Studies Designed With no A Priori Stated Objective to Assess a Particular Implant Design or Feature**

Study	Presurgery	Surgery Details	Postsurgery
Jemt et al (2011)[113,114]	Healed minimum 3 (Md) or 6–8 (Mx) months	Flap, 2-stage	Healing 5–8 months
Friberg and Jemt (2008-2007e)[115]	Healed 4 months–40 years	All narrow crests height reduced, no grafting	NR
Jemt and Johansson (2006)[116]	Healed 13.3 years	Flap, 2-stage	Healing 3–6 months
Widbom et al (2005)[117]	NR	NR	NR
Ibanez et al (2005)[118]	NR	AB, flap, flapless (10p)	Three protocols: : *(1)* immediate abutments + Prefab PMMA FDP-> healing 2–3 (Md) 6–12 (Mx) months, permanent, vs *(2)* immediate abutment metal-reinforced PMMA FDP 4–24 hours, vs *(3)* impression, permanent mc-FDP < 48 hours
Degidi and Piattelli (2003)[119]	Two protocols: *(1)* postextraction (187i) vs *(2)* healed (235i)	Flap, two protocols: 1-stage or 2-stage	Four protocols: *(1)* healing 8–10 weeks, *(2–4)* prefab FDP, exp *(1)* occluding same day (n = 422), exp *(2)* nonoccluding same day (n = 224), exp *(3)* permanent crown within 3 weeks

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; CAD/CAM = computer-aided design/computer-assisted manufacture; BIC = bone-to-implant contact; PMMA = polymethyl methacrylate; VAS = visual analogue scale.

Prosthesis	Outcome	Patient Outcome	Findings
6-8i bar overdenture FDP	*(1)* SurgComplic/Success *(2)* adverse* OPGX bone	NR	Implant system does not influence outcome; two systems were comparable
6i-FDP	*(1)* SurgComplic/Success *(2)* SuccSurv	NR	Implant length may influence outcome, but no data presented to support statement; long implants preferred to stabilize graft
ga-FDP-canti Ceka-bar overdenture	*(1)* SurgComplic/Success *(2)* PA/OPGX bone SuccSurv	NR	Implant length influences outcome when placed in ribs; 10-mm implants performed better than 13-mm as well as 7-mm implants
FDP	*(1)* SurgComplic/Success *(2)* Adverse* PAX bone	NR	Multivariate analyses indicated that implant length influences outcome; 10+ mm implants performed better than 6–7-mm implants
NR	*(1)* SurgComplic/Success *(2)* SuccSurv	NR	Implant length may influence outcome, but no data presented to support statement; 18 mm preferred to stabilize graft

Prosthesis	Outcome	Patient Outcome	Findings
4-8i-10/12u-ga-FDP screw canti	Adverse* PAX bone SuccSurv	NR	Implant surface does not influence outcome; early failure less prevalent with oxidized surface, but turned perform as well as oxidized on longer term
NR	Adverse* PAX bone SuccSurv	NR	Implant length influences outcome; short implants performed worse than long in narrow jaws; however, this may be a secondary effect of crest height
4-8i-10/12u-ga-FDP screw canti	Adverse* PAX bone SuccSurv	NR	Implant length influences outcome; 7-mm turned implants in soft bone fail more than others
2-4i-bar overdenture	Adverse* SuccSurv	NR	Multivariate analyses indicated no effect of implant length on outcome
6-10i-mcFDP screw	Adverse* PAX bone Stability-RFA SuccSurv	NR	Implant design or length does not influence outcome
Crown-mix 8-11i-FDP mix bar overdenture	PAX bone SuccSurv	NR	Implant system may influence outcome; of 6 different implant systems used, all failures (n = 8) were one particular system; the data matrix is complex and incoherent; marg bone loss was only reported for 91/646 implants

Table 23 *Continued* **Results of Studies Designed With No A Priori Stated Objective to Assess a Particular Implant Design or Feature**

Study	Presurgery	Surgery Details	Postsurgery
Kiener et al (2001)[120]	Healed	1-stage, membrane	NR
Watson et al (1998)[121]	Healed	AB, widest and longest i. as possible, 2-stage	Healing 3 (Md), 6 (Mx) months
Jemt and Lekholm (1995)[122]	Subgroup *(1)* autograft_ iliac block onlay (14p, 83i) > 6–18 months	Subgroups (3): *(1)* atrophic, no graft (33p, 127i), *(2)* intermediate atrophy (25p, 142i), *(3)* fixed P(76p, 449i)	Healing 5–14 months
Palmqvist et al (1994)[123]	NR	Two protocols: *(1)* "planned case" 2–4 implants, *(2)* lost implant + change of plan: 4–6 implants	NR

AB = antibiotics; GA = general anesthesia; LA = local anesthesia; NR = not reported; mc = metal ceramic; ac = all ceramic; ga = gold-acrylic; CoCr = cobolt-chrome; u = unit; PAX = periapical radiographs; OPX = panoramic radiographs; SuccSurv = clinical success or survival; ptv/RFA = periotest/radiofrequency analysis; pFDP = partial fixed dental prosthesis; fFDP = full fixed dental prosthesis; TiA = Titanium-Acrylic; OPGX = orthopantomogram; CAD/CAM = computer-aided design/computer-assisted manufacture; BIC = bone-to-implant contact; PMMA = polymethyl methacrylate; VAS = visual analogue scale.

implants placed in bony buttresses in the fully edentulous maxilla as well as in the pterygomaxillary bone, appear comparable. Several reports that describe implant placements in the pterygomaxillary bone combine these with zygoma implants (Table 20). One investigation center reported that different designs from the same manufacturer may not influence outcome (n = 2),[95,96] in contrast to influence of the surface (n = 1)[90] and the implant length (n = 1).[89] Extensive variation was seen in the healing period after extraction, surgery procedures, healing period before implant loading, number of implants needed to support the supraconstruction, and composition and design of the supraconstruction. We considered meta-analyses of the extracted data as inappropriate, and therefore abandoned further statistical analyses of the extracted data.

Studies Designed to Report Effects of Bone Augmentation With Simultaneous or Delayed Implant Placement Reporting an Effect of a Particular Implant Design Feature on One or More Treatment Outcomes (Fig 7).[97–112] Two of 16 clinical studies reported patient-centered outcomes (Table 22).[100,101] The prevailing reported outcome was the incidence of adverse biological events during or immediately after surgery, late adverse biological and technical events, clinical success or survival, and degree of bone loss. Some studies also reported indices of periodontal tissues. Based on the surrogate and clinical outcomes, it can be proposed that in the fully edentulous maxilla, the choice of implant system may not (n = 2) influence outcome.[97,108] Two studies reported differences between implant designs, but both compared implant system A during a learning curve vs design B afterwards.[101,103] Moreover, different designs from the same manufacturer may influence outcome (n = 1),[105] whereas the length may (n = 8) or may not (n = 3) influence outcome. Extensive variation was seen in the healing period after extraction, surgery procedures, healing period before implant loading, number of implants needed to support the supraconstruction, and the composition and design of the supraconstruction. We considered meta-analyses of the extracted data as inappropriate, and therefore abandoned further statistical analyses of the extracted data. The conclusions about the effect of implant length on outcome were all from studies applying a one-stage approach with extensive grafting and implants placed to stabilize the graft (n = 8).[102,104,106,107,109–112] The three studies found no such effect with a two-stage approach, with a 4- to 8-month healing period in between.[98–100]

Studies Designed With No A Priori Stated Objective to Assess a Particular Implant Design Feature.[113–123] None of the nine clinical studies reported patient-centered outcomes (Table 23). The prevailing reported outcome was incidence of adverse biological and technical events, clinical success or survival, and degree of bone loss, measured on periapical radiographs. Based on the surrogate and clinical outcomes, it can be proposed that in the fully edentulous maxilla the choice of implant system appears to influence outcome (n = 1).[119] Moreover, outcomes may or may not (n = 2)[117,118] be influenced by *(1)* different designs from the same manufacturer (n = 1); *(2)* the surface (n = 1)[113–114]; and *(3)* wide (n = 1)[121] and short implants (n = 5).[115,116,120,122,123] Extensive variation was noted in the healing period after extraction, surgery procedures, healing period before implant loading, number of implants to support the supraconstruction, and the composition and design of the supraconstruction. The authors considered meta-analyses of the extracted data as inappropriate and therefore abandoned further statistical analyses of the extracted data.

Prosthesis	Outcome	Patient Outcome	Findings
4-6i-ball/dolder bar, overdenture	Adverse* maintenance	NR	Implant length influences outcome; ≤ 10 mm failed more than 12 mm
Ball/hader bar, overdenture	PAX bone maintenance, perioindices, stability-ptv, SuccSurv	NR	Implant length may influence outcome; highest failure rates were short and wide implants
4-8i-10/12u-ga-FDP screw-canti/4-6i-bar, overdenture	Adverse* PAX bone SuccSurv	NR	Implant length influences outcome; 7-mm turned implants in soft bone fail more than others and especially when there is severe height resorption
2-4i-ball/round-dolder bar, overdenture	Adverse* maintenance	NR	Multivariate analyses indicated that implant length influences outcome; 7-mm turned implants fail more than others

DISCUSSION

Summary of the Evidence

Arguably, the present authors identified far more clinical studies aimed at appraising possible effects of implant design on outcomes in the fully edentulous maxilla in comparison with other systematic reviews (Tables 2a and 2b). Unfortunately, the great majority of the primary reports aimed at appraising possible effects of implant design on outcomes lump their observed data, probably to obtain more statistical power. The consequence is that the readers cannot judge outcomes specifically related to the various clinical conditions, such as for the fully edentulous maxilla. Moreover, many reports present inadequate statistics generally associated with incorrect choice of statistical unit.[124–126] Multivariable linear or logistic regression models were occasionally applied in the reports, but often with clear violations of statistical assumptions generally associated with multiple within-subject factors.[127–129]

The general impression of the evidence available is that there is a lack of compelling data to state that one particular implant system or design feature stands out amidst others, when applied to restoring the fully edentulous maxilla with implant-retained prosthetics.

Limitations at the Study and Outcome Level

Characteristics of the Study Groups and Participant Inclusion and Exclusion Criteria. Although the term "edentulous maxilla" is easy to understand, it is more difficult to categorize into groups based on difficulties of rehabilitating facial form and oral functions. There are multiple variants and codification sets of the edentulous maxilla. The most well known is a classification system developed by the American College of Prosthodontics,[2] which emphasizes the restoration of form and function with conventional dentures in patients with increasing complexity depending on specific general and local elements. Several systems for describing jaw size and consistency have also been proposed in the implant literature.[13,124, 130–132] Further attempts to evaluate the risks associated with implant treatment have resulted in the Straightforward-Advanced-Complex (SAC) classification system developed by the International Team for Implantology (www.iti.org). The difficulties with the use of these classifications are to identify which of the many criteria used are prognostic factors for the treatment outcome, because these criteria are not necessarily risk factors.

Although not presented in this systematic review, a vast spectrum of study inclusion and exclusion criteria were identified. The most common inclusion and exclusion criteria were *(1)* participant level—maximum or minimum age, general health condition, past drug or alcohol abuse, extent of smoking, bruxism or clenching history, past radiation therapy, compliance, and commitment to follow-up; *(2)* intraoral condition—state of edentulousness, adequate bone height and width, bone quality, maxillomandibular discrepancy or lack of vertical space, no local pathology, no sinus inflammation, level of oral hygiene, healed alveolar ridge, augmentation or grafting; *(3)* surgical—minimum primary stability, minimum keratinized mucosa. Although most articles described a few or multiple criteria, it is likely that many reports have underreported the range of criteria. It is therefore uncertain how the potential effects of implant design on outcomes in the fully edentulous maxilla should be interpreted in light of the described or lack of described inclusion and exclusion criteria.

Description of the Intervention

The surgical protocols may significantly affect outcomes of studies comparing implant design aspects and therefore, protocols need to be appraised in the context of our data interpretation. Similarly, different settings and operators with different levels of skills and experience will probably influence outcomes of studies comparing implant design aspects. In particular, reports have shown that the level of surgical experience may influence the percentage of implants that fail.[133,134] Although some articles report these details, most do not.

In this regard, it is essential to consider the years when implants were placed and be reminded of the surgical principles at the time. Investigators designing studies in the 1980s followed the rather strict principle that implant parallelism was essential, which trumped implant angulation even in the presence of bone. Another argument was that costs would increase significantly, because angulated abutments would be required.[113,114] At the time, the clinician would strive to place a parallel, for instance, 7-mm implant, with a turned surface. Today, a clinician would angulate the implant to increase implant length beyond 7 mm in almost any direction. Comparing incidences of adverse outcomes in contemporary studies with historical data applying different standard operating procedures is therefore fraught with interpretational fallacies. It was not until around the turn of the century when data emerged that placing nonaxial loaded implants was not necessarily detrimental to the patient.[56,57] Subsequently, these concepts led to surgical protocols based on the use of two- or four-axial plus two tilted implant solutions. High-quality long-term studies of the concept are hopefully under way.

Studies that include grafting procedures in connection with implant placement may increase the risk of adverse outcomes irrespective of the implant design. The same applies to immediate placement after tooth extraction, and perhaps even the reason for extraction may have some bearing on the osseointegration process. Other clinical variables that come into play are the time of loading of the implants, implant bed preparation protocol, and/or primary stability. In fact, most studies reviewed did not have a description about implant stability.

The number of implants needed to support a supraconstruction, as well as the material composition and design of the supraconstruction itself, probably influences the treatment outcomes in studies aimed at comparing implant design aspects. Currently, however, no published study findings can provide clinical guidance.

Some investigators and authors of systematic reviews have suggested that implant lengths and diameters influence outcomes. This may or may not be correct when applied to single implants and perhaps small fixed dental prostheses. However, unless planned a priori in a study protocol, it is more likely that a narrow, wide, and/or short implant placed among "standard" size implants to support a full jaw suprastructure is a reflection of an unfavorable site for osteotomy. It follows that the higher failure rates reported with these narrow or wide and/or short implants is not a reflection of the effect of the implant design on outcomes, but rather of the effect of unfavorable local anatomic conditions.[6]

With regard to the implant surface, we may be faced with a new dimension of scientific rationale and technological strategies based on novel approaches to enhance the biological process of osseointegration.[10] A focus of implant surface design and science has been its morphology or topography, as extensively documented in the studies comparing machined/turned surfaces and so-called rough surfaces. In fact, many studies reviewed herein compared implants from different manufacturers, presumably having different surface morphology. Recent studies have uncovered the significant role of physicochemical property of titanium surfaces in determining their biological capabilities.[135–137] Physicochemical properties include hydrophilicity or hydrophobicity, the degree of hydrocarbon contamination, and electrostatic status. More importantly, these properties change with time in an unfavorable way, as evidenced in the phenomenon that newly prepared titanium surfaces are hydrophilic, whereas the same titanium surfaces stored for a certain time are hydrophobic.[138] The degraded physicochemical properties may be restored by ultraviolet light treatment, for instance, immediately before use or by photofunctionalization.[135,139] Photofunctionalization is not categorized as either an additive or subtractive modification. It simply removes hydrocarbons from the implant surface and regenerates hydrophilicity. The process, termed surface conditioning, is theoretically universal for any titanium- and titanium alloy–based implant materials, which may affect how we think of the implant design and suggest the necessity to broaden our scope. These innovative implant surfaces have not yet been evaluated clinically in patients with a fully edentulous maxilla.

Reported outcomes after clinical studies should ideally be patient-centered. Most clinical studies, however, report implant survival data, and some also include peri-implant bone loss and advent of adverse biological events, but seldom patient-centered outcomes or other variables related to treatment morbidity.

Very few studies reported outcomes comparing different implant types or particular design features, at least pertaining to patients with a fully edentulous maxilla. One important issue in implant research is that most clinical studies are financed by industry. Hence, they are mostly case series or comparisons of implant systems from the same manufacturer. This possible bias related to the conflict of interest when reporting negative results may have prevented the publication of many completed investigations. Moreover, as stated earlier, very few studies reported patient-centered outcomes.

Limitations at the Review Level

The Academy of Osseointegration made an *a priori* determination of a very broad and general PICO question. As a consequence, it is likely that other investigators aiming to replicate this systematic review will possibly identify different studies and organize the extracted data in a different manner, perhaps even leading to different conclusions. The review of such a broad subject prevents the answer to a predefined null-hypothesis, and instead leads to a narrative description of a vast number of different studies, which prevent the appropriate data extraction and meta-analysis.

The online bibliographic searches identified fewer than half of the total number of relevant clinical studies (Fig 2). This moderate yield may appear surprising, but others have claimed that online searches identify only 20% to 40% of relevant studies, regardless of expert search algorithms.[140,141] Hence, hand searching of reference lists in identified reports is always required, and the process is greatly facilitated if further combined with the use of hyperlinked online references, for example, in the online Web of Science. Nevertheless, in this review, a substantial number of the identified reports were uncovered in a personal indexed database managed by the lead author since the mid-1990s and used in systematic reviews previously.[142]

CONCLUSIONS

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. This conclusion is in line with the previous and recently updated Cochrane systematic review focused on the same topic.[143] The difference between the current systematic review and the Cochrane review is that the former reviewed only randomized clinical trials. On the other hand, the Cochrane review appraised effects in meta-analyses that merged data from a range of different clinical conditions, including single space and partially edentate situations in both jaws. In contrast, the current review appraises outcomes only in study participants with a fully edentulous maxilla.

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