The All-on-Four Treatment Concept: A Systematic Review

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ABSTRACT

Purpose: The study aims to evaluate the all-on-four treatment concept with regard to survival rates (SRs) of oral implants, applied fixed dental prostheses (FDPs) and temporal changes in proximal bone levels.

Materials and Methods: A systematic review of publications in English and German was performed using the electronic bibliographic database MEDLINE, the Cochrane Library, and Google. Hand searches were conducted of the bibliographies of related journals and systematic reviews. The authors performed evaluations of articles independently, as well as data extraction and quality assessment. Data were submitted the weighted least-squared analysis.

Results: Thirteen (487 initially identified) papers met inclusion criteria. A number of 4,804 implants were initially placed, of which 74 failed, with a majority of failures (74%) within the first 12 months. A total of 1,201 prostheses were incorporated within 48 hours after the surgery. The major prosthetic complication was the fracture of the all-acrylic FDP. The mean cumulative SR/SR ± (standard deviation) (36 months) of implants and prostheses were 99.0 ± 1.0% and 99.9 ± 0.3%, respectively. The averaged bone loss was 1.3 ± 0.4 mm (36 months). No statistically significant differences were found in outcome measures, when comparing maxillary versus mandibular arches and axially versus tilted placed implants.

Conclusion: The available data provide promising short-term results for the all-on-four treatment approach; however, current evidence is limited by the quality of available studies and the paucity of data on long-term clinical outcomes of 5 years or greater. In terms of an evidence-based dentistry, the authors recommend further studies designed as randomized controlled clinical trials and reported according to the CONSORT statement.

KEY WORDS: all on four, dental implants, systematic review, treatment concept

INTRODUCTION

Severe atrophy of the alveolar ridge often develops following tooth loss, with increasing severity over time in the edentulous jaw. Several prosthetic treatment options exist for this particular situation: complete dentures, removable implant-retained prostheses, or fixed implant-supported prostheses.[1] However, implant-retained or fixed implant-supported prostheses provide a higher degree of patient satisfaction than removable prostheses.[2,3] Additionally, several authors described greater survival rates (SRs) for fixed prostheses.[4,5]

An extensive surgical bone augmentation procedure is often necessary to achieve sufficient bone support to place standard implants (10–12 mm length, ~3.5 mm diameter) in the posterior severely atrophic jaw. Augmentation surgery, regardless of reconstructive procedure, carriers a higher risk of patient morbidity and complications (e.g., infection, loss of graft material) as well as higher costs and longer time intervals to complete the treatment.[6] To avoid grafting procedures and to utilize preexisting bone in the most effective way, angled implants (tilting of implants) is a well-documented alternative, with no apparent clinically significant difference in success rates compared with axially placed implants.[7] One particular treatment option is marketed

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as the All-on-4™ concept (Nobel Biocare, Goteborg, Sweden). To the authors' knowledge, Maló and colleagues[8] should be credited with the first description of this concept in 2003; however, Brånemark and colleagues already described similar approaches.[9]

The principle of the all-on-four concept is to use four implants in the anterior part of complete edentulous jaws to support a provisional, fixed, and immediately loaded prosthesis. The two most anterior implants are placed axially, whereas the two posterior implants are placed distally angled to minimize the cantilever length and to allow the application of prostheses with up to 12 teeth.[10–12] Final prosthetic solutions can either be fixed (FDP) or removable dental prostheses.[12]

The purpose of this systematic review was to evaluate the effectiveness and long-term success of the all-on-four treatment concept.

Objectives

1 Evaluate SRs of oral implants placed in humans either in the maxilla or mandible according to the all-on-four treatment concept.
2 Evaluate SRs of fixed dental prostheses applied on these implants.
3 Evaluate bone level changes around these implants.

MATERIALS AND METHODS

Search Method and Identification of Studies

A systematic review of literature was performed using the web-based search engine for the electronic bibliographic database MEDLINE (user interface: pubmed.gov; http://www.ncbi.nlm.nih.gov/pubmed/), Google (http://www.google.com), and the Cochrane Library (http://www.cochrane.org). Hand searches were conducted of the bibliographies of related journals and systematic reviews. The subject search used a combination of the search items (in title and/or abstract) "all on four, all-on-four, all on 4, all-on-4, tilted implants, angled implants, angulated implants, or inclined implants" and in a separate search "four implants" (in title and/or abstract). These search items were combined with the Boolean operator [NOT] for the items "biomechanical, mechanical, or finite element analysis" (in title). Publications were considered through August 3, 2012. Abstracts of relevant papers underwent a qualitative independent pre-analysis (three reviewers: SP, OB, JS). The full text of potentially qualifying articles were then reviewed and scored with respect to inclusion criteria. When necessary, authors were contacted to provide missing data or clarification.

Types of Studies

Clinical trials were considered provided the study documented a minimum follow-up period of 1 year and reported on the SRs of the implants. When reported, data were also captured on the SRs of the prostheses as well as changes in proximal implant bone levels. Furthermore, two anterior axial and two posterior tilted implants (regardless of arch) had to be placed according to the All-on-4 treatment concept. Full texts had to be available in English or German. The following exclusion criteria were defined: case reports, systematic reviews, biomechanical trials, and finite element analyses; trials including more than four implants, zygomatic implants, no tilted distal implants or additional implants supporting the provisional or final prosthesis.

Types of Participants

Only studies involving human subjects were included.

Types of Outcome Measurements

The primary outcome measure was implant failure rate (loss of function or removal). Secondary outcome measures included prosthesis failures (loss of function or removal) and marginal bone loss/bone level changes (radiological examination).

Data Collection

For each included study the following data were collected using a specially designed data abstraction form: names of the authors, year of publication, title, study design, investigated jaw(s), number and demographic data of treated patients, number and type of applied implants, tilt of distal implants, time of prosthesis delivery, inclusion and exclusion criteria, assessment of success, success criteria, follow-up period, and details of outcomes reported (implant SRs, SRs of the prostheses, marginal bone loss, and reported complications).

Quality Assessment

The quality assessment of included studies was undertaken independently by three reviewers (SP, OB, JS) using a specially designed form. The following quality criteria were examined:

1 Study design (randomized controlled clinical trial [RCT]; prospective; retrospective; none of the aforementioned)
2 Clear definition of inclusion and exclusion criteria (yes; not clearly defined but provided; no)
3 Performance of surgery (one surgeon; more than one surgeon; unspecified)
4 Success criteria/outcome measurements provided (yes; not clearly defined but provided; no)
5 Radiographic examination of marginal bone level changes (standardized technique using periapical radiographs [PAR] and an individual holder; non-standardized technique using PAR; orthopantomogramm [OPT] or a combination of OPT and PAR; unclear)
6 Evaluation of the radiological marginal bone level changes (independently; not independently; unclear)
7 Completeness of follow-ups and explanations for dropouts/withdrawals (complete; incomplete but clear explanation for dropouts/withdrawals; incomplete and unclear explanation for dropouts/withdrawals)

Collectively, these criteria provided a basis for estimating risk of bias. Studies were classified as either "low risk of bias" or "high risk of bias." Studies with a score higher than a quarter of the range of possible score were ranked as high risk of bias studies (score sum >33 for studies including the evaluation of bone level changes; score sum >24 for studies not including the evaluation of bone level changes).

Statistical Analysis

No data were available from RCTs, precluding analysis based on effect size (meta-analysis). Furthermore, data were derived from a number of small studies of low variance. Consequently, comparisons of outcome measures were based on weighted means using a variance components analysis, with α set at $p \leq .05$ (JMP Statistical Software, SAS Institute, Inc., Cary, NC, USA).

RESULTS

Search Results

The review of literature revealed a total number of 487 publications. There were no additional papers identified neither through the Google search, the Cochrane Library search, nor the hand search. Thus, further particulars consider the MEDLINE search solely. Thirty-one papers were found for the search item "all on four" [Title/Abstract], 31 papers for "all-on-four" [Title/Abstract], 11 papers for "all on 4" [Title/Abstract], 11 papers for "all-on-4" [Title/Abstract], 41 papers for "tilted implants" [Title/Abstract], 22 papers for "angled implants" [Title/Abstract], 11 papers for "angulated implants" [Title/Abstract], 9 papers for "inclined implants" [Title/Abstract], and 396 papers for "four implants" [Title/Abstract]. Search results were combined and all articles including the words "finite element analysis, mechanical, or biomechanical" in the title were removed. Thus, 71 publications remained for the proper expertise by reviewers. Forty-six trials had to be excluded after reading full texts, if available, due to missing the aforementioned inclusion criteria as well as 30 out of the "all on four-search item" group (Table 1) and 16 out of the "four implants-search item" group (Table 2). Additionally, eight relevant papers (Table 3) had to be excluded due to being duplicates or having been published twice in different journals. After a close examination of the preliminarily included 17 studies, it would seem that some studies relate to the same patient populations. For this reason, authors (Agliardi, Butura, Francetti, Galindo, and Maló) were contacted and asked to clarify the relation of their studies. After receiving clarifications from the authors, data from four studies were completely excluded and partially excluded from two studies (Table 4). The latter six studies were considered in the "Characteristics of the trial settings and investigators" paragraph as well as in the "Outcome measurements" paragraph but neither in the "Risk of bias of the included studies" paragraph nor the statistical. Finally, 13 papers remained for the detailed examination (Table 5, Figure 1).

Characteristics of Trial Settings and Investigators

A summarized overview is given in Table 6. Seven studies were conducted in Italy,[13–19] five in Portugal,[8,20–23] three in the USA,[24–26] one in Brazil,[27] and one in Germany.[28] Six studies[15–19,27] were conducted at university dental clinics and 11 studies[8,13,14,20–26,28] in private practices. Four studies[15,17–19] were performed in multiple centers. Seven trials included both jaws,[14–16,18,20,24,28] eight trials included only the mandibular arch,[8,13,17,19,22,25–27] and two trials included only the maxillary arch.[21,23] In one study, data were included from the mandibular arch,

TABLE 1 Excluded Studies and Reasons for the Exclusion (Search Items: All on Four, All-on-Four, All on 4, and All-on-4); Arranged Alphabetically by the First Author

Author	Reason	Author	Reason
Agliardi et al.[45]	Number of implants	Jensen and Adams[46]	Case report
Aparicio et al.[47]	Number of implants/study design	Jensen et al.[48]	Case report
Ata-Ali et al.[49]	Literature review	Jensen et al.[50]	Case report
Balmer and Mericske-Stern[51]	Vague documentation of results	Jensen et al.[52]	Case report
Bedrossian[53]	Zygoma implants	Khatami and Smith[54]	Case report
Bedrossian[55]	Zygoma implants	Krekmanov et al.[11]	Number of implants/study design
Butura et al.[56]	Case report	Menini et al[33]	Literature review
Cannizzaro et al.[57]	Study design/no survival rates reported	Orentlicher and Abboud[58]	Letter
Degidi et al.[59]	Number of implants	Oyama et al[60]	Study design
Del Fabbro et al.[7]	Literature review	Penarrocha et al[61]	Study design/overdentures
Di et al.[62]	Language	Penarrocha et al[63]	Study design/zygoma implants/ overdentures
Ferreira et al.[64]	Case report, zygoma implants	Penarrocha-Oltra et al.[65]	Literature review
Graves et al.[66]	Zygoma implants	Pomares[67]	Number of implants
Graves et al.[68]	Zygoma implants	Rosen and Gynther[69]	Number of implants
Jensen et al.[70]	Case report	Wu et al.[71]	Language

because the maxillary arch was not treated according to the inclusion criteria of this review.[15] One author[24] had a consultant agreement with the industry, and one study[27] was supported financially by the industry. All trials had a minimum follow-up period of one year. Five papers (29.4%) were published with Maló named as first author. The following investigators appeared as authors on multiple articles: Maló (six papers, 35.3%), Agliardi (four papers, 23.5%), Del Fabbro (four papers, 23.5%), Nobre (three papers, 17.7%), Francetti (three papers, 17.7%), Romeo (three papers, 17.7%), Lopes (two papers, 11.8%), Clerico (two papers, 11.8%), Butra (two papers, 11.8%), Galindo (two papers, 11.8%), Testori (two papers, 11.8%), Taschieri (two papers, 11.8%), and Rangert (two papers, 11.8%). All other authors were only named once.

Outcome Measurements

Implant failures were reported in all studies. Prosthesis failures were reported in all but four studies.[14,20,21,23] The latter four studies did not document or unclearly documented prosthesis failures. With the exception of three

TABLE 2 Excluded Studies and Reasons for the Exclusion (Search Item: Four Implants); Arranged Alphabetically by the First Author

Author	Reason	Author	Reason
Arvidson et al.[72]	Number of implants	Parel and Philips[73]	Number of implants
Arvidson et al.[74]	Number of implants/study design	Penarrocha-Oltra et al.[75]	Not tilted/study design
Astrand et al.[76]	Number of implants/overdentures	Pieri et al.[77]	Number of implants
Eccelente et al.[78]	Removable prosthesis	Pomares[79]	Number of implants
Ekelund et al.[80]	Number of implants	Pomares[67]	Number of implants
Friberg and Jemt[81]	Not tilted	Romanos et al[82]	Removable prosthesis
Heschl et al.[83]	Removable prosthesis	Wolfinger et al.[84]	Number of implants/study design
Li et al.[85]	Number of implants/study design	Wu et al[71]	Language

TABLE 3 Excluded Studies: Duplicates (D) and Double Publishments (DP); Arranged Alphabetically by the First Author

Author	Reason	Author	Reason
Butura et al.[86]	DP	Maló et al.[21]	D
Crespi et al.[16]	D	Maló et al.[22]	D
Galindo and Butura[26]	D	Maló et al.[23]	D
Hinze et al.[28]	D	Weinstein et al.[19]	D

studies,[22,24,25] all reported data of radiographic marginal bone level changes.

Risk of Bias of the Included Studies/Quality Assessment

With one exception,[18] all studies were considered to have a high potential risk of bias. Table 7 illustrates the assessments of the reviewers and provides an overview about the score sums. The assessed quality criteria are elucidated in the following paragraphs.

Study Design. Nine studies[13–20,27,28] were designed as prospective trials, three studies[8,21,23–26] as retrospective trials, and one study[22] as a longitudinal trial. None of the studies were designed as a RCT.

Reported Inclusion and Exclusion Criteria. All studies included in this review defined inclusion criteria. The main inclusion criteria were patients with either edentulous jaws or jaws with teeth with a poor long-term prognosis treatment planned for extraction. None of studies provided the basis for the decision to extract compromised teeth or described a maintenance program before extraction. Further inclusion criteria were:

- Edentulous jaws or jaws with compromised teeth[13,14,16–18,22,24,28]
- Dentate and edentulous patients[25]
- Edentulous patients[15,20]
- Edentulous patients wearing a prosthesis for at least 1 year[27]
- American Society of Anesthesiologists (ASA)-1/ASA-2[13–15,17,18,25]
- Atrophic posterior jaws (augmentation needed)[13–16,28]

Exclusion criteria were:

- Compromised medical history[13–18,24,28]
- History of head/neck irradiation or chemotherapy[13–15,17,18,24,25,27,28]
- Poor oral hygiene/motivation[13–18,28]
- Smoking[27] or smoking >15 cigarettes/day[16]
- Poorly controlled diabetes[13–15,17,18,25,28]
- (Severe) parafunctional habits[13–18,24,28]
- History of bisphosphonates[24,25,27]
- History of metabolic bone diseases[13,14,17,18]

TABLE 4 Excluded and Partly Excluded Papers after the Replies of Authors and Reasons for the Exclusion; Arranged Alphabetically by the First Author

Author	Title	Reason
Agliardi et al.[14]	Immediate rehabilitation of the edentulous jaws with full fixed prostheses supported by four implants: interim results of a single cohort prospective study	30 patients of Francetti et al.[17]; mandible excluded
Butura et al.[25]	Mandibular all-on-four therapy using angled implants: a three-year clinical study of 857 implants in 219 jaws	Equal patient population as reported in Butura et al.[25]; excluded
Francetti et al.[18]	Bone level changes around axial and tilted implants in full-arch fixed immediate restorations. Interim results of a prospective study	Subgroup of Francetti et al.[17]; mandible excluded
Maló et al.[8]	"All-on-Four" immediate-function concept with Branemark System implants for completely edentulous mandibles: a retrospective clinical study	Part of Maló et al.[22]; excluded
Maló et al.[23]	All-on-4 immediate-function concept with Branemark System implants for completely edentulous maxillae: a 1-year retrospective clinical study	Part of Maló et al.[21]; excluded
Weinstein et al.[19]	Immediate rehabilitation of the extremely atrophic mandible with fixed full-prosthesis supported by four implants	Subgroup of Francetti et al.[17]; excluded

TABLE 5 Included Studies Arranged Alphabetically by the First Author

Author	Title
Agliardi et al.[13]	Immediate loading of full-arch fixed prostheses supported by axial and tilted implants for the treatment of edentulous atrophic mandibles
Agliardi et al.[14]	Immediate rehabilitation of the edentulous jaws with full fixed prostheses supported by four implants: interim results of a single cohort prospective study (Note: Only data of the maxilla were included.)
Babbush et al.[24]	The all-on-four immediate function treatment concept with NobelActive implants: a retrospective study
Butura et al.[25]	Mandibular all-on-four therapy using angled implants: a three-year clinical study of 857 implants in 219 jaws
Capelli et al.[15]	Immediate rehabilitation of the completely edentulous jaw with fixed prostheses supported by either upright or tilted implants: a multicenter clinical study
Crespi et al[16]	A clinical study of edentulous patients rehabilitated according to the "all on four" immediate function protocol
Francetti et al.[17]	Immediate rehabilitation of the mandible with fixed full prosthesis supported by axial and tilted implants: interim results of a single cohort prospective study
Francetti et al.[18]	Bone level changes around axial and tilted implants in full-arch fixed immediate restorations. Interim results of a prospective study (Note: Only data of the maxilla were included.)
Hinze et al.[28]	Immediate loading of fixed provisional prostheses using four implants for the rehabilitation of the edentulous arch: a prospective clinical study
Landazuri-Del Barrio et al.[27]	A prospective study on implants installed with flapless-guided surgery using the all-on-four concept in the mandible
Maló et al.[20]	The use of computer-guided flapless implant surgery and four implants placed in immediate function to support a fixed denture: preliminary results after a mean follow-up period of thirteen months
Maló et al.[22]	A longitudinal study of the survival of All-on-4 implants in the mandible with up to 10 years of follow-up
Maló et al.[21]	"All-on-4" immediate-function concept for completely edentulous maxillae: a clinical report on the medium (3 years) and long-term (5 years) outcomes

Performance of Surgery. The description of the surgical clinician(s) was given as follows: one surgeon,[13,14,18,24,27] two surgeons,[17,22,28] surgical team,[15,25] or unspecified.[16,20,21]

Success Criteria and Outcome Measurements. Success criteria and outcome measurements were provided in all but one paper.[25] The following success criteria for implants were given: no peri-implant radiolucency,[13–18,20–22] no suppuration,[13,14,16–18,20] no pain,[13–18] no swelling,[16] implants in function,[14,21,22,28] no ongoing pathologic process,[17,18,24] no signs of peri-implantitis,[13–15,17,18,20,21] no neuropathies or persistent paraesthesia,[13–15,17,18] implants are stable/no mobility,[15,16,20–22,27,28] modified Albrektsson criteria,[24] no discomfort,[20] good esthetic outcome, and possibility to restore the placed implants.[21,22]

Success criteria for prostheses were defined as follows: prosthesis in function,[13,14,17,18,28] prosthesis is stable,[14,24] absence of mobility and pain,[14,17,18] and no fracture of the acrylic resin structure.[16] Only one study[15] defined success criteria for bone loss: no more than 1.5 mm by the end of the first year of functional loading or 0.2 mm/year in subsequent years.

Radiographic Examination and Evaluation of Marginal Bone Level Changes. All papers that evaluated marginal bone level changes reported the radiographic technique authors used to examine potential bone loss. Applied techniques were OPT and PAR using a paralleling technique,[13] OPT and PAR,[14,21] solely PAR using a paralleling technique,[15] solely OPT,[16,28] PAR using a paralleling technique and an individual x-ray holder,[17,18] and PAR using a paralleling technique and an x-ray holder.[27] The evaluation of marginal bone level changes was reported as performed by an independent radiologist,[16,20,21] an independent evaluator,[17] two independent evaluators,[21] or was not specified in the article.[13–15,27,28]

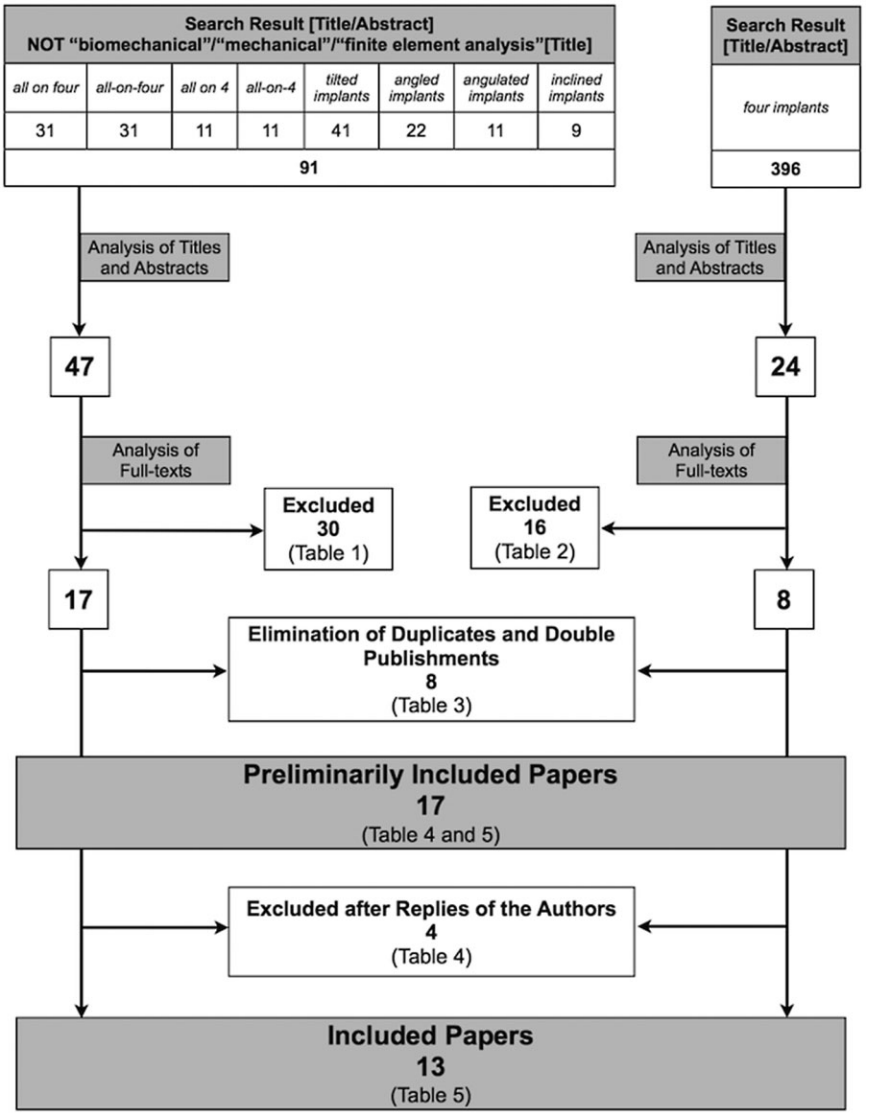

Figure 1 Search strategy and history.

Completeness of Follow-Ups and Explanations for Dropouts/Withdrawals. Only four papers[16,25,27,28] reported complete data on follow-ups. None of the studies provided clear explanations for all dropouts or clear explanations why follow-ups were not completed, except Babbush et al.[24] (two patients passed away due to natural causes, one before the 3-month visit and one before the 1-year follow-up) and Maló et al.[21] (one patient died because of causes unrelated to the implant treatment). Further explanations were not provided regarding subjects lost to follow-up.

Effects of Interventions

A total of 4,804 implants were initially placed in 1,201 jaws. Then 2,000 implants were placed in maxillae and 2,804 in mandibles. Figure 2 illustrates the number of available jaws at the selected follow-ups — 12, 24, and 36 months. The most applied implant system was the NobelSpeedy™ Groovy (Nobel Biocare) with a number of 2,403 placed implants, followed by the NobelActive™ System (Nobel Biocare; $n = 708$), the Brånemark System® MK IV (Nobel Biocare; $n = 616$), the Brånemark System® MK III (Nobel Biocare; $n = 551$), the Outlink[2] (P.A.D. System, Sweden & Martina SPA, Carare, Italy; $n = 176$), the NanoTite™ System (BIOMET 3i, Warsaw, IN, USA; $n = 148$), the OSSEOTITE® NT System (BIOMET 3i; $n = 96$), the NobelSpeedy™ Replace (Nobel Biocare; $n = 64$), and the Brånemark System® MK II (Nobel Biocare; $n = 42$) (Figure 3).

TABLE 6 Summary of Characteristics of the Preliminary Included Studies. Grey Fields Represent Entirely Excluded/Partly Excluded Studies in the Final Review

	Study							
	Agliardi et al.[13]	Agliardi et al.[14]		Babbush et al.[24]		Butura et al.[25]		
Design	Prospective	Prospective		Retrospective		Retrospective		
Jaw	Mandible	Maxilla	Mandible	Maxilla	Mandible	Mandible		
Jaws/Implants	24/96	72/288	101/404	109/436	68/272	219/876		
Jaws/Follow-up (number/months)	17/24 1/47 Mean: 32.69 ± 8.13	154/12 Mean: 26.9 ± 12.5 61/12 39/24 24/36 11/48	 93/12 58/24 29/36 7/48	174/12 81/24		219/36		
Implants (CSR/SR) (%)	CSR 100	CSR 99.19 CSR 98.36	 CSR 99.73	CSR 99.3	CSR 100	CSR 99.66 Axial SR 99.54 Tilted SR 99.77		
Prosthesis (CSR/SR) (%)	CSR 100	Not Reported		SR 100	SR 100	SR 100		
Bone loss: Implants/Follow-up (number/months)	84/12	204/12	292/12	Not Reported		Not Reported		
Bone loss/Follow-up (mm/months)	Axial 0.9 ± 0.4/12 Tilted 0.8 ± 0.5/12	0.9 ± 0.7/12	1.2 ± 0.9/12					
Radiographic technique	OPT/PAR (PT)	OPT/PAR						

	Study				
	Capelli et al.[15]		Crespi et al.[16]		Francetti et al.[17]
Design	Prospective		Prospective		Prospective
Jaw	Maxilla	Mandible	Maxilla	Mandible	Mandible
Jaws/Implants	Not included: 6 implants	24/96	24/96	20/80	62/248
Jaws/Follow-up (number/months)		24/6 23/12 21/24 20/36 3/>36 Mean: 29.1	24/36	20/36	62/12 41/24 28/36 10/48 Mean: 22.4
Implants (CSR/SR) (%)		CSR 100	Axial SR 100 Tilted SR 96.59 SR 98.96 Axial SR 100 Tilted SR 97.97	 SR 97.5 Axial SR 100 Tilted SR 95.00	CSR 100
Prosthesis (CSR/SR) (%)		SR 100	SR 100		SR 100
Bone loss: Implants/Follow-up (number/months)		64/12	96/12 96/24 96/36	80/12 80/24 80/36	120/12
Bone loss/Follow-up (mm/months)		Axial 0.82 ± 0.64/12 Tilted 0.75 ± 0.55/12	Axial 1.02 ± 0.35/12 1.08 ± 0.41/24 1.10 ± 0.45/36 Tilted 1.05 ± 0.29/12 1.07 ± 0.46/24 1.11 ± 0.32/36	Axial 1.04 ± 0.30/12 1.04 ± 0.35/24 1.06 ± 0.41/36 Tilted 1.05 ± 0.32/12 1.09 ± 0.29/24 1.12 ± 0.12/36	Axial 0.7 ± 0.4/12 Tilted 0.7 ± 0.5/12
Radiographic technique		PAR (PT)	OPT		PAR (PT + IH)

TABLE 6 *Continued*

	Study				
	Francetti et al.[18]		Galindo and Butura[26]	Hinze et al.[28]	
Design	Prospective		Retrospective	Prospective	
Jaw	Maxilla	Mandible	Mandible	Maxilla	Mandible
Jaws/Implants	16/64	132/33	183/732	19/76	18/72
Jaws/Follow-up (number/months)	16/12 16/24 7/36 Mean: 33.8	33/12 33/24 33/36 29/48 24/60 Mean: 52.8	732/12	19/12	18/12
Implants (CSR/SR) (%)	CSR 100		SR 99.86	(C)SR 96.6 Axial 95.95 Tilted 94.59	(C)SR 98.7
Prosthesis (CSR/SR) (%)	SR 100		Provisional SR 100 (6 months) Definitive SR 97.27 (8 months)	SR 100	
Bone loss: Implants/Follow-up (number/months)	64/12 64/24 28/36	132/12 132 (128)/24 116 (108)/36 96/48 48/60	731/12	Axial 71/12 Tilted 70/12	
Bone loss/Follow-up (mm/months)	Axial 0.40 ± 0.27/12 0.44 ± 0.37/24 0.85 ± 0.74/36	Axial 0.57 ± 0.42/12 0.96 ± 0.52 (0.90 ± 0.49)/24 1.15 ± 0.61 (0.92 ± 0.43)/36 0.92 ± 0.55/48 0.51 ± 0.17/60	Mean: ≤1/12	Axial 0.82 ± 0.31/12	
	Tilted 0.32 ± 0.28/12 0.63 ± 0.38/24 0.85 ± 0.34/36	Tilted 0.48 ± 0.23/12 0.70 ± 0.38 (0.67 ± 0.38)/24 0.81 ± 0.53 (0.69 ± 0.52)/36 0.81 ± 0.40/48 0.39 ± 0.18/60		Tilted 0.76 ± 0.49/12	
Radiographic technique	PAR (PT + IH)		PAR	OPT	

	Study				
	Landazuri-Del Barrio et al.[27]	Maló et al.[8]	Maló et al.[23]	Maló et al.[20]	
Design	Prospective	Retrospective	Retrospective	Prospective	
Jaw	Mandible	Mandible	Maxilla	Maxilla	Mandible
Jaws/Implants	16/64	14/56	32/128	18/72	5/20
Jaws/Follow-up (number/months)	16/12	3/12	32/12	18/12 11/24	5/12 2/24
Implants (CSR/SR) (%)	SR 100	CSR 98.2	(C)SR 97.6	CSR 97.2	CSR 100
Prosthesis (CSR/SR) (%)	(SR 93.75)	CSR 100	Unclear	Unclear	
Bone loss: Implants/Follow-up (number/months)	64/0 64/12	56/?	Axial 99/12 Tilted 98/12	51/0 36/12	
Bone loss/Follow-up (mm/months)	0.13 ± 0.03/0 0.83 ± 0.14/12	0.6 ± 0.6/?	0.9 ± 1.0/12 Axial 1.0 ±1.0/12 Tilted 0.9 ± 1.1/12	0.2 ± 0.7/0 1.9 ± 0.9/12	
Radiographic technique	PAR (PT + H)	OPT/PAR	OPT/PAR	PAR	

TABLE 6 ***Continued***

	Study		
	Maló et al.[22]	Maló et al.[21]	Weinstein et al.[19]
Design	Longitudinal	Retrospective	Prospective
Jaw	Mandible	Maxilla	Mandible
Jaws/Implants	245/980	242/968	20/80
Jaws/Follow-up (number/months)	235/12 228/24 217/36 211/48 203/60 174/72 93/84 25/96 14/108 4/120 2/132	216/12 206/24 180/36 94/48 24/60 2/72	80/24 48/36 12/48 Mean: 30.1 ± 8.6
Implants (CSR/SR) (%/months)	CSR 99.3/12 CSR 98.8/24 CSR 98.6/36 CSR 98.5/48 CSR 98.4/60 CSR 98.1/72 CSR 97.9/84 CSR 96.3/96 CSR 94.8/108 CSR 94.8/120 CSR 94.8/132	CSR 98.3/12 CSR 98.1/24 CSR 98.0/36 CSR 98.0/48 CSR 98.0/60 CSR 98.0/72	CSR 100/24 CSR 100/36 CSR 100/48
Prosthesis (CSR/SR) (%)	CSR 99.2	Unclear	CSR 100
Bone loss: Implants/Follow-up (number/months)	Not Reported	621/36 106/60	72/12
Bone loss/Follow-up (mm/months)		Axial 1.52 ± 0.31/36 Tilted 1.95 ± 0.44/60	Axial 0.6 ± 0.3/12 Tilted 0.7 ± 0.4/12
Radiographic technique		OPT/PAR	OPT/PAR

CSR, cumulative survival rate; H, holder; IH, individual holder; OPT, orthopantomogram; PAR, periapical radiographs; PT, paralleling technique; SR, survival rate.

In total, 74 implants failed (37 axially placed/37 tilted placed) during the reported follow-up intervals. The majority of implant failures (55/74, 74%) occurred within 12 months of surgical placement. Nine implants (12%) failed within 12 to 24 months, two implants (3%) within 24 to 36 months, and eight implants (11%) >36 months (range 36–99 months) (Figure 4). The following explanations and observations were provided for implant failures: mobility (19%),[14,24,28] no osseointegration (5%),[20,25] pain (4%),[16] suppuration/fistula (3%),[27] heavy bruxism (1%),[20] smoking (15%),[21,22] smoking and Hepatitis C (1%), smoking and HIV (1%),[21] smoking and hypothyroidism (1%), smoker, type 2 diabetes and history of stroke (1%),[22] diabetes (7%),[21,22] bisphosphonate medication (3%),[22] bisphosphonate medication and hypertension (7%),[21,22] hypertension (1%),[21] and heart problems (3%).[21,22] No basis for implant failures was provided in 22% of cases.[15,21,22,25,27] One implant fractured at the platform level during insertion;[27] this implant was not recognized as an implant failure. Sixty of 74 failed implants were replaced but not included in further statistical analyses. Neither of the implant failures compromised prostheses survival.

TABLE 7 Quality Assessment Questionnaire and Cumulated Results. The Corresponding Points Are Given in Parentheses (See Footnotes)

	Study Design*	Clear Definition of Inclusion and Exclusion Criteria†	Performance of Surgery‡	Success Criteria/ Outcome Measurements Provided§	Radiographic Examination of Marginal Bone Level Changes¶	Evaluation of the Radiological Marginal Bone Level Changes**	Completeness of Follow-Ups and Explanations for Dropouts/ Withdrawals††	Score Sum	Risk of Bias§§
Agliardi et al.[13]	6	4	7	3	10	9	7	46	High
Agliardi et al.[14]; only maxilla	6	4	7	3	10	9	9	48	High
Babbush et al.[24]	9	5	5	5	NR	NR	8	32	High
Butura et al.[25]	9	6	9	7	NR	NR	6	37	High
Capelli et al.[15]	6	3	7	5	7	9	7	44	High
Crespi et al.[16]	6	4	9	4	9	3	3	38	High
Francetti et al.[17]	6	3	8	3	3	3	9	35	High
Francetti et al.[18]; only maxilla	6	3	5	3	3	3	5	28	Low
Hinze et al.[28]	6	3	7	4	9	9	5	43	High
Landazuri-Del Barrio et al.[27]	6	3	5	3	3	9	5	34	High
Maló et al.[20]	6	6	8	5	8	3	5	41	High
Maló et al., 2011[22]	6	4	6	5	NR	NR	9	30	High
Maló et al., 2012[21]	9	4	9	3	9	3	7	44	High

NR, Not Reported.
*RCT (1), prospective (2), retrospective (3), none of the aforementioned (4).
†Yes (1), not clear defined, but provided (2), no (3).
‡One surgeon (1), more than one surgeon (2), unspecified (3).
§Yes (1), not clear defined, but provided (2), no (3).
¶Standardized technique using PAR and an individual Holder (1), non-standardized technique using PAR (2), OPT or combination of OPT and PAR (3), unclear (4).
**Independently (1), not independently (2), unclear (3).
††Complete (1), incomplete explanation given (2), incomplete no explanation given (3).
§§High risk of bias: score sum >33 for studies including the evaluation of bone level changes; score sum >24 for studies not including the evaluation of bone level changes.

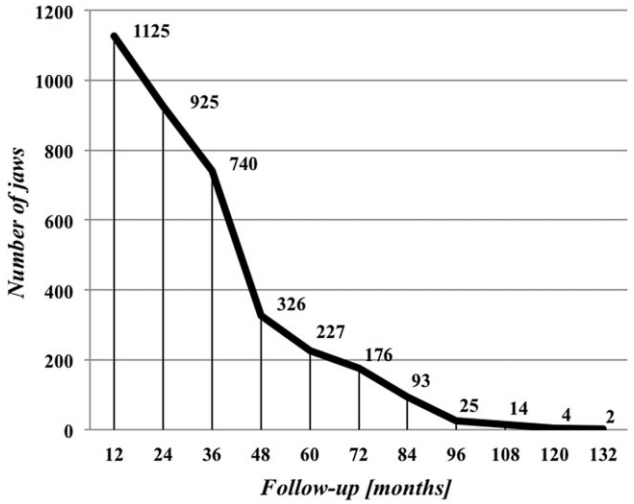

Figure 2 Available jaws at the several follow-ups.

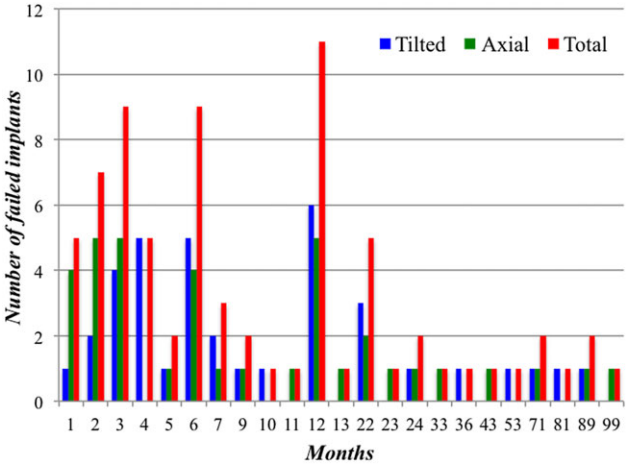

Figure 4 Overview of failed implants during the cumulative observation periods.

A number of 1,201 prostheses were incorporated within 48 hours after the surgery. Five hundred prostheses were fixed in maxillae and 701 in mandibles. Acrylic provisional fixed prostheses were used in all studies, with the following exceptions: Capelli and colleagues applied metal-framework supported acrylic provisional prostheses, Crespi and colleagues provided the final prosthesis, and Landazuri-Del Barrio and colleagues applied metal-framework supported acrylic provisional prostheses.[15,16,27] All other final prostheses were delivered 3 to 8 months following implant placement, except in Butura and colleagues (only 173 provisional prostheses were transitioned into final prostheses),[25] Maló and colleagues[20] (four prosthesis remained in acrylic resin), and Maló and colleagues[21,22] (unclear whether all prostheses were transitioned into final prosthesis). In nine papers, the final prostheses were metal-framework supported,[13–15,17,18,24,25,27,28] and in one paper,[16] either metal-framework supported or entirely made of resin. Maló and colleagues replaced the provisional prostheses according to each patient's preference either with a metal-framework supported/ceramic-veneered or metal-framework supported/resin-veneered final prosthesis; it was possible for patients to retain the provisional all-acrylic prosthesis.[20–22]

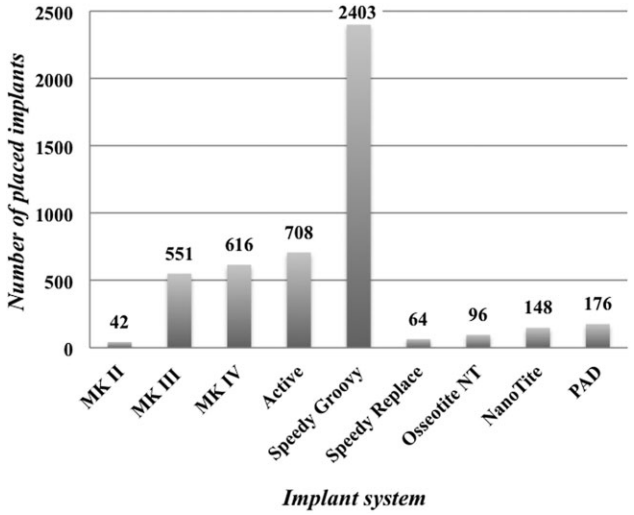

Figure 3 Applied implant systems.

In total, 57 prosthesis-related problems were reported. Most fractures occurred in all-acrylic prostheses without metal-framework. Agliardi and colleagues[14] reported fractures of 24 acrylic prostheses within 3 to 6 months, and Francetti and colleagues[17] documented the fracture of seven acrylic prostheses within 4 to 6 months of function. Both studies observed fractures primarily in men with short face morphologies and next to an anterior abutment. They related their findings to the switch from soft to hard diet and a progressive wear of the resin material.[14,17] All fractures were repairable by the clinicians. The following studies reported fractures: Crespi and colleagues[16] (two fractures, acrylic prostheses), Francetti and colleagues[18] (two acrylic prostheses and one final prosthesis after 36 months), Hinze and colleagues[28] (four fractures, acrylic veneers, four acrylic, and one final prosthesis), Landazuri-Del Bario and colleagues[27] (one fracture, final prosthesis fracture after 12 months), Maló and colleagues[20] (eight fractures, acrylic prostheses; six in heavy bruxers: four wear patterns in

the opposing dentition, two self-reported bruxers; two did not follow instructions of soft diet), Maló and colleagues[22] (two fractures), and Maló and colleagues[21] (five fractures, provisional prosthesis; four bruxers: prostheses were repaired, adjusted, and the patients got a occlusal appliance (nightguard).

None of the studies reported a correlation between implant or prosthesis failures and the opposing dentition.

In total, bone level changes of 1,575 implants (412 mandibular implants, 985 maxillary implants, 177 unclear distribution) were evaluated.[13–18,20,21,27,28] Only two studies provided baseline measurements of bone levels of 115 implants at the time of implant placement.[20,27] A total of 953 implants (412 mandibular implants, 364 maxillary implants, 177 unclear distribution) were evaluated after 12 months,[13–18,20,27,28] 240 implants (80 mandibular implants, 160 maxillary implants) after 24 months,[16,18] 825 implants (80 mandibular implants, 745 maxillary implants) after 36 months,[16,18,21] and 106 maxillary implants after 60 months.[21] A distinction between axially and tilted placed implants was only given by six authors.[13,15–18,28] In all studies, the evaluation of bone level changes was based on measurements of the distance between the implant neck (implant-abutment connection) and the first radiological visible bone-to-implant contact.

Additionally Reported Outcomes

Agliardi and colleagues reported a decrease of plaque index and bleeding on probing.[13,14] Landazurri-Del Barrio and colleagues reported a stable soft tissue situation with a reduction of pocket depths during the early phase of healing, shallow pockets (≥80%) and no significant midfacial recession in the vast majority of implants, and no changes of bone density over time.[27] A progressive decrease in plaque and bleeding index as well as beneficial cleaning conditions were reported by Francetti and colleagues due to a professional implant maintenance program (dental hygienists), less plaque retentive refined metal structures of the final prosthesis, the limited number (four) of implants, and a wider inter-implant distance.[17,18]

Two implants in two patients showed peri-implant pathology (treatment: oral hygiene program/surgical approach),[20] one patient showed a breakdown of bone in combination with mobility and radiolucency around four implants,[22] and an infection was found around one implant (same patient with abutment screw loosening and fracture of the prosthesis; treatment: resolving the prosthetic problem and non-surgical approach).[21] After 2 months, one patient had severe discomfort, pain, and swelling in the anterior maxilla due to mucositis,[16] and one patient had a light mandibular ipoesthesia after the surgery that resolved after 6 months.[17]

Occlusal screw loosening was recorded and reported differently in studies: in 3% of cases within 6 months,[16] 6% of cases after 12 months,[28] two implants before 6 months and four implants before 12 months,[27] two patients (one heavy bruxer and one noncompliant with the recommended instructions),[20] and 12 patients[22]/one patient[21] wearing provisional prostheses (treatment: retightening, controlling the occlusion and advising not to overload). Abutment screw loosening occurred in two patients (provisional prostheses) because of parafunctional habits (solution: retightening and nightguard)[22] and in two patients (provisional prostheses; treatment: retightening, controlling the occlusion and advising not to overload).[21] Screw access hole restorations were lost in 9.5% of anchors;[28] one patient showed wear of the prosthetic and abutment screw of the provisional prosthesis (treatment: replacing the prosthetic components, controlling the occlusion and advising not to overload).[21] A radiographically visible misfit was observed in 13 of 16 supra-structures.[27] In contrast, a better passive fit due to the reduced implant number (four)[17,18] and a wider inter-implant distance was reported by Francetti and colleagues.[18]

Excessive wear of the prosthesis was reported in one patient due to parafunctional habits (treatment: repairing, retightening, and nightguard).[22]

No association has been reported between smoking habits, implant type, or baseline periodontal conditions and extent of bone loss.[18] Similarly, no association was found between smoking and implant loss or smoking and on marginal bone level of tilted implants.[28] On the other hand, diabetes, bisphosphonates, smoking,[22] and systematically compromised conditions[21] were considered as risk factors for implant loss, with the implication of a great importance for follow-ups.[22] Furthermore, a reduction in patient morbidity has been reported due to a low incidence of biological complications,[28] a minimally invasive surgical approach, a less chair time, a comfortable postsurgical period, and a low level of complications.[20]

TABLE 8 Mean Number of Implants ± (SD) and Cumulative Survival Rates ± (SD) at the Several Follow-Ups (Jaw Level)

	12 Months	24 Months	36 Months
Mean number of implants			
Maxilla	81 ± 85.2	68 ± 92.8	58.8 ± 81.2
Mandible	59.8 ± 88.0	61.8 ± 94.0	100.8 ± 107.0
Combined	70.4 ± 83.3	64.6 ± 87.5	82.1 ± 93.2
Mean CSR/SR implants (%)			
Maxilla	97.5 ± 1.2	98.2 ± 1.1	98.8 ± 0.9
Mandible	99.3 ± 0.7	99.7 ± 0.6	99.2 ± 1.1
Combined	98.6 ± 1.3	99.1 ± 1.1	99.0 ± 1.0
Mean CSR/SR prostheses (%)			
Maxilla	100	N/A	100
Mandible	100	100	99.8 ± 0.4
Combined	100	100	99.9 ± 0.3

Statistical Analysis

Adequate data for statistical analyses were available for follow-ups of 12, 24, and 36 months. Results of Babbush and colleagues[24] as well as results for bone loss/bone level changes of Hinze and colleagues,[28] and Maló and colleagues[20] were not included, because of no distinguished number of arches at follow-ups. Tables 8 and 9 give the mean cumulative survival rate (CSR)/SRs of implants and prostheses and the bone loss measurements, respectively. There were no statistically significant differences, neither between SRs of implants in maxillae and mandibles, axial and tilted implants, prostheses in maxillae and mandibles, bone loss around implants in maxillae or mandibles, nor bone loss around axial or tilted implants ($p > .05$). Meta-analysis was not performed due to the homogeneity of results.

TABLE 9 Mean Number of Implants ± (SD) and Bone Losses ± (SD) in (mm) at the Several Follow-Ups (Jaw Level)

	12 Months	24 Months	36 Months
Mean number of implants			
Maxilla	108.2 ± 66.3	80 ± 22.6	248.3 ± 324.5
Mandible	82 ± 26.4	82 ± 2.8	80
Combined	96 ± 51.5	81 ± 13.2	206.3 ± 278.0
Averaged bone loss			
Maxilla	1.0 ± 0.5	0.8 ± 0.4	1.3 ± 0.5
Mandible	0.8 ± 0.4	1.0 ± 0.4	1.1 ± 0.3
Combined	0.9 ± 0.5	0.9 ± 0.4	1.3 ± 0.4
Bone loss axial implants			
Maxilla	0.8 ± 0.3	0.8 ± 0.4	1.0 ± 0.6
Mandible	0.9 ± 0.5	1.0 ± 0.4	1.1 ± 0.4
Combined	0.8 ± 0.4	0.9 ± 0.4	1.0 ± 0.5
Bone loss tilted implants			
Maxilla	0.7 ± 0.4	0.9 ± 0.4	1.0 ± 0.3
Mandible	0.8 ± 0.5	0.9 ± 0.4	1.1 ± 0.1
Combined	0.8 ± 0.4	0.9 ± 0.4	1.0 ± 0.3

DISCUSSION

A recent shift in practice paradigm has been to minimize treatment costs and patient morbidity while providing the most satisfying patient-centered treatment outcomes according to the "state of the art of the dental practice." These can be achieved by adequate treatment planning, patient selection, reduction of surgical procedures, and short treatment intervals. The all-on-four treatment concept is an attempt to address these objectives by providing relatively straightforward (simple), predictable treatment option for rehabilitating edentulous patients with a high outcome of quality of life.

Of the 487 potentially qualifying publications, only 13 papers provided sufficient information about the all-on-four approach to evaluate SRs of implants and fixed dental prostheses as well as bone level changes. Primarily, the review of literature was limited to the web-based search engine MEDLINE; this limitation seems acceptable given that a MEDLINE-based search includes the majority of peer-reviewed dental journals. Nevertheless, additional searches at Google and in the Cochrane Library were performed to identify potential relevant papers not found through MEDLINE.

The authors count 12 of 13 papers as highly biased, based on the applied quality assessment questionnaire and the following interpretations. Most of considered studies (69 %) were conducted in Italy and Portugal around a small group of investigators (Agliardi, Del Fabbro, Maló).[13–15,17,18,20–22] These authors represent experienced clinicians in applying the all-on-four approach. Two studies might be biased due to affiliations to the industry,[24,27] raising concerns of potential funding and publication bias.

None of the studies was designed as a RCT. Studies differentially selected from a healthy patient population with optimal requirements for a surgical procedure; therefore, subject selection bias is evident in the studies.

Measurement methods of marginal bone level changes were very heterogeneous, which limits direct comparisons of results across studies due to different film resolutions, acquisition angles, and inherent distortions associated with imaging technique. This latter concern is supported by a recently published study group analysis that indicates radiographs do not give an accurate reflection of peri-implant hard tissues; however, periapical radiographs appear to provide important information for monitoring changes in crestal bone,[29] especially for scientific purposes. Of the papers included in this review, 50% did not report evaluation of x-rays (detection/measurement bias).

Only 31% of the papers in this review presented results of complete follow-up periods up to 36 months. All other papers reported cumulated results. Very limited explanations were given for dropouts, withdrawals, and incomplete follow-ups. This information might be helpful for categorizing results (attrition bias).

The range of potential sources of bias in the available studies limits the meaningful interpretation of results. In total, studies reported a 1.5% failure rate out of 4,808 initially placed implants, including 37 axially placed and 37 titled implants. The majority of implants failed within the first 12 months, presumably due to a failure to osseointegrate. Clear explanations were not provided for implant losses. However, drawing conclusion on the cause-and-effect relationship of an implant loss is generally difficult. Most of the implant losses were reported in smokers and patients with bisphosphonate medication. Furthermore, due to the treatment protocol, all implants were loaded immediately following surgical placement. In a systematic review, Esposito and colleagues reported a non-statistically significant trend for higher loss rates of immediately loaded implants in comparison with conventionally loaded implants; however, implant loss rates were lower for immediately loaded implants than early loaded implants.[30]

Although an implant failure rate of 1.5% is noteworthy, this failure rate must be considered cautiously given the relatively short follow-up periods and potential risks of bias. Long-term results (5 years and more), with an adequate patient number at the follow-ups, are necessary to interpret the overall success rate of this treatment approach. Particularly noteworthy is that neither of implant failures compromised the prostheses survivals. The latter observation suggests that a further reduction in the number of implants, even to two fixtures, might support a sustainable prosthesis, as published by Cannizzaro and colleagues.[31] Again, the lack of outcome data from RCTs as well as long-term results hampers evaluation of this treatment approach.

Because of the heterogeneity and incomplete follow-ups of the included studies, the statistical analysis was restricted to a follow-up period of 36 months. Studies reported CSRs of implants and prostheses ranging from 98.6 to 99.1% and 100 to 99.9%, respectively. These SRs are significantly higher than those

recently published in a systematic review including papers *on the optimal number of implants for fixed reconstructions* by Heydecke and colleagues.[32] The authors reported overall study-specific SRs of four to over six implants (axial and tilted) between 80.3 and 98.7%, and SRs of full-arch FDPs supported by these implants ranging from 78.3 to 99.2%, with follow-ups up to 15 years.[32] Unlike in the Heydecke and colleagues' review, studies not limited to the all-on-four approach were excluded in this review. To the authors' knowledge, no RCTs are available contrasting treatment options of FDPs supported by various numbers of implants.

None of the studies found a statistically significant difference in SRs of axially and tilted placed implants. The latter finding is consistent with previously published systematic reviews on tilted implants.[7,33]

A number of 1,201 prostheses were incorporated within 48 hours after the surgery. Except for two studies, all of these prostheses were all-acrylic provisional FDPs without metal frameworks. Fractures occurred in 4.8% of these provisional restorations. Only one fracture of a final prosthesis was reported.[27] The majority of fractures were attributed to progressive wear of the resin material due to bruxism and switching from a soft diet to a hard diet. Two authors described the location of fractures next to an anterior abutment. An explanation of this observation might be a successive load of the cantilever utilizing the distal tilted implant as a fulcrum that transfers caudal faced masticatory forces of distal parts of an FDP to anterior parts. In the anterior part of the prosthesis, these forces are transformed into cranial faced forces resulting in a fracture next to the center of resistance – the anterior abutment. For that reason, it is generally recommended to integrate a metal framework into the prosthesis to strengthen resin structures, especially in patients with a history of parafunctional habits.

None of the observed implant-related and prosthesis-related problems could be linked to the opposing dentition.

Multiple approaches were used to evaluate bone level changes, hampering direct comparisons between studies. Nevertheless, all studies used same distance measurements to assess bone level changes or bone loss. Only two studies reported baseline measurements of the bone level.[20,27] The lack of baseline measurements precludes meaningful assessment of bone level changes. The depth of implants,[34] relative to the position of the implant platform, and the abutment installation[35] can influence bone levels with the effect of a bone remodeling in the first weeks of osseointegration. Thus, Mombelli and colleagues suggested that measurements of bone level changes should not be made prior implant restoration to ensure tissue homeostasis.[36] Cumulative bone loss at follow-up periods of 12, 24, and 36 months, was 0.9 ± 0.4 mm, 0.9 ± 0.4 mm, and 1.3 ± 0.4 mm, respectively, for studies in the present review. The question is: What is an acceptable bone loss? Papers from the early 1990s defined success criteria for osseointegrated implants and reported an acceptable bone lose of 1 mm in the first year, followed by an annual bone loss of 0.1 mm[37,38] or 0.2 mm.[39] Current reports of criteria do not exist. Consequently, reported cumulated bone level changes indicate no evidence for a pathological process and should be considered as acceptable. No statistically significant differences were found in the SR of implants when comparing either the maxillae and mandibles or axially placed versus tilted implants. These findings suggest that supporting bone levels are not affected by location (jaw) or vertical angulation of the implant using this particular treatment concept.

Four papers reported improvements in plaque indexes and soft tissue health[13,14,17,18,27] due to the number of implants and a wider inter-implant distance providing an increased possibility for oral hygiene. Besides these positive effects, a frequent prosthetic complication was screw loosening, most often observed in provisional prostheses and in patients with parafunctional habits. The occlusion was controlled and the screws were retightened. The predictability in achieving optimal fit of supra-structures is controversial. Landazuri-Del Barrio and colleagues[27] observed a radiographic misfit of supra-structures in 81% of restorations, whereas Francetti and colleagues[17,18] reported a better passive fit because of the implant number and wider inter-implant distances. Likewise, the influence of smoking on bone loss and implant survival remains controversial. Francetti and colleagues and Hinze and colleagues could not find a correlation between smoking habits and bone loss or implant loss.[18,28] Maló and colleagues,[22] however, described smoking as a risk factor for implant loss and emphasized the importance of a follow-up program, especially in systemically compromised patients.[21,22]

Finally, two more issues should be mentioned and respected in future study designs. None of the included papers defined evaluation criteria or provided reasons for the extraction of remaining "hopeless" teeth such as

described by several authors in previous papers.[40–44] Thus, further studies should clearly determine what constitutes a poor or guarded prognosis of the dentition. Furthermore, some anatomical conditions claim an additional extensive bone resection prior to the implant placement to accomplish adequate bone architecture for a prosthetic-oriented implant installation. This may result in a higher patient morbidity as well as a potential risk of irreversible negative impacts on the intraoral and extraoral esthetics.

In conclusion, the all-on-four treatment concept seems to be an approach for edentulous jaws according to the common demand of a cost-effective treatment concept, decreased treatment times with a lower patient morbidity, and a higher patient quality of life as compared with extended surgical approaches and removable prostheses, respectively. A careful patient selection and an experienced surgical and restorative team are essential for successful treatment outcomes. Nevertheless, there is a lack of sufficient long-term data with follow-ups of at least 5 years.

RCTs that incorporate well-defined clinical and radiographic outcome criteria are necessary to evaluate the long-term success of this treatment approach; moreover, future studies need to be reported according to the CONSORT statement.

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