Optimal number of implants for complete-arch implant-supported prostheses with a follow-up of at least 5 years: A systematic review and meta-analysis

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Complete dentures are the most common prostheses for the rehabilitation of edentulous patients and can restore both function and esthetics.[1] However, complete dentures have limitations, including instability, discomfort, and decreased masticatory efficiency, all of which can directly affect the quality of life.[2] Prostheses retained or supported by dental implants have become common for edentulous patients,[3] with implants yielding excellent survival rates after 5 and 10 years.[4]

Branemark et al[5] suggested the use of a minimum of 6 to 8 implants in the mandible and up to 14 implants in the maxilla for each complete-arch rehabilitation.[6,7] Difficulties with the placement of more than 4 implants per jaw include insufficient bone height and anatomic features such as

ABSTRACT

Statement of problem. Consensus is lacking regarding the optimal number of implants for supporting complete-arch prostheses with good survival rates and lower prosthetic complications and marginal bone loss.

Purpose. The purpose of this systematic review was to evaluate the influence of the number of implants used for complete-arch prostheses with at least 5 years of follow-up.

Material and methods. A search was performed in the PubMed/MEDLINE, Scopus, and Cochrane Library databases according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria and was registered in The International Prospective Register of Systematic Reviews (CRD42016048468). The following was the population, intervention, comparison, outcome (PICO) question: Does the number of implants influence the longevity of complete-arch prostheses?

Results. Nineteen studies including 1006 patients with a mean age of 61.44 years were selected for evaluation. The number of implants per jaw ranged between 2 and 9 in the maxilla, mandible, or both jaws. For implant survival rate in complete-arch prostheses with fewer than 5 implants per jaw, the pooled weighted event rate was 1.4% (I^2=25.26%; P=.211) and 4.2% (I^2=81.35%; P<.001) for complete arches with more than 4 implants per jaw. For the prosthesis survival rate, the pooled weighted event rate for a complete-arch with fewer than 5 implants per jaw was 1.5% (I^2=0%; P=.677) and 9% (I^2=17.33%; P=.304) for complete arches with more than 4 implants per jaw. For prosthesis complications for complete arches with fewer than 5 implants per jaw, the pooled weighted event rate was 19.9% (I^2=93.5%; P<.001) and 24.5% (I^2=88.89; P<.001) for complete arches with more than 4 implants per jaw. The mean marginal bone loss for complete arches with fewer than 5 implants per jaw was 1.22 ±0.49 mm (I^2=99.46; P<.001) and 1.46 ±0.46 mm (I^2=99.6; P <.001) for more than 4 implants per jaw.

Conclusions. The current systematic review indicated no relationship of the number of implants used to support a complete-arch prosthesis with implant survival rate, prosthesis survival rate, prosthesis complications, or marginal bone loss in studies with follow-up periods of between 5 and 15 years. (J Prosthet Dent 2019;121:766-74)

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Clinical Implications

The number of dental implants (fewer than 5 or more than 4) for complete-arch prostheses did not influence implant or prosthesis survival, bone loss, or complication rates in studies with a longer follow-up period (more than 5 years). Thus, appropriate treatment planning is more important than the number of implants placed for supporting complete-arch prostheses.

the mandibular canal or maxillary sinus. Increasing the number of implants per jaw also makes oral hygiene more difficult and increases cost.[8]

To reduce surgical morbidity and cost, reducing the number of implants for the support of complete-arch prostheses has been advocated.[9] Complete-arch prostheses with fewer than 5 implants per jaw in the maxilla and mandible are associated with fewer biological complications and with acceptable bone loss.[10] Thus, the "all-on-four" technique emerged to maximize the use of the remaining atrophic ridge. In this technique, 4 implants (2 axial anterior and 2 tilted distal) are placed to support an immediately loaded complete-arch prosthesis.[11] Malo et al[12] described this technique, with data for up to 10 years of follow-up, indicating long-term success.[12] This arrangement with angled distal implants increases the support of the prosthesis and is intended to reduce the length of the cantilever.[6]

Reducing the number of implants in a complete-arch rehabilitation slightly increases stress in the abutment and bar-retaining screws.[13] However, the biomechanics are similar in a prosthesis supported by fewer implants.[10,14] Thus, a follow-up is important for analyzing the longevity of implant-supported prostheses and the complications related to each type of prosthesis.[8]

Consensus regarding the ideal number of implants for complete-arch prostheses is currently lacking. The purpose of this systematic review was to evaluate the outcomes of complete-arch prostheses in studies with different numbers of implants and a follow-up of at least 5 years. The null hypotheses were that the number of implants per jaw would not influence implant survival rate and that prosthesis survival rate, complication rate, and marginal bone level would not be influenced by the number of implants used to support complete-arch prostheses.

MATERIAL AND METHODS

This systematic review was structured by following the criteria established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist and in accordance with models proposed in the literature.[15,16] The study was registered on the International Prospective Register of Systematic Reviews (CRD42016048468).

The studies selected for the present analysis met the criteria established by the population, intervention, comparison, outcome (PICO) question: Does the number of implants influence the longevity of complete-arch prostheses? In this question, "population" referred to edentulous patients rehabilitated using dental implants; "intervention" was complete-arch prostheses supported by fewer than 5 implants per jaw; "comparison" was complete-arch prostheses supported by more than 4 implants per jaw; and the primary "outcome" evaluated was implant survival rate. Prosthesis survival rate, complication rate, and marginal bone loss were considered secondary outcomes.

Inclusion criteria were randomized controlled trials (RCTs), prospective studies, studies published in English, studies with follow-up ≥5 years, and studies reporting the number of implants installed per jaw per patient. Exclusion criteria were retrospective studies, case series, case reports, animal studies, in vitro studies, letters to the editor, and studies that did not identify the number of implants per jaw per patient.

The searches were independently performed by 2 reviewers (J.M.L.G., C.A.A.L.); when there was disagreement, a third reviewer (E.P.P.) was consulted. The databases searched included MEDLINE/PubMed, Cochrane Central Register of Controlled Trials, and Scopus. The keywords used were (dental implant) AND (full arch OR cross arch OR fixed complete denture OR complete arch) combined with a Boolean operator. In addition, the authors conducted a manual search in specific journals (Supplementary Table 1).

One author (J.M.L.G.) collected relevant data from the articles, which were verified by another author (C.A.A.L.). An interexaminer test (kappa [κ]) was used to evaluate the agreement of the searches between the reviewers. The following values were obtained for each of the databases: (1) MEDLINE/PubMed (κ=0.88), (2) Cochrane (κ=1), and (3) SCOPUS (κ=0.96). The manual search in the journals was performed by 1 reviewer (J.M.L.G.) and independently by another reviewer (C.A.A.L.)

Two authors (J.F.S.J., S.L.D.M.) performed a risk of bias analysis on the included RCTs using the Cochrane risk of bias tool that checks for selection, performance, attrition, reporting, and other biases. For the non-RCT (prospective) studies, the Newcastle-Ottawa scale (NOS) was used. The NOS is based on 3 main concepts namely selection, comparability, and outcome for cohort studies. The scale classifies studies with a maximum of 9 stars (the highest level of study quality), whereas >6 stars indicate a low risk of bias and scores ≤5 stars indicate a high risk of bias.

The implant survival rate, prosthesis survival rate, prosthetic complications, and marginal bone loss were pooled and reported as event rates with 95% confidence intervals. Heterogeneity among the studies included in
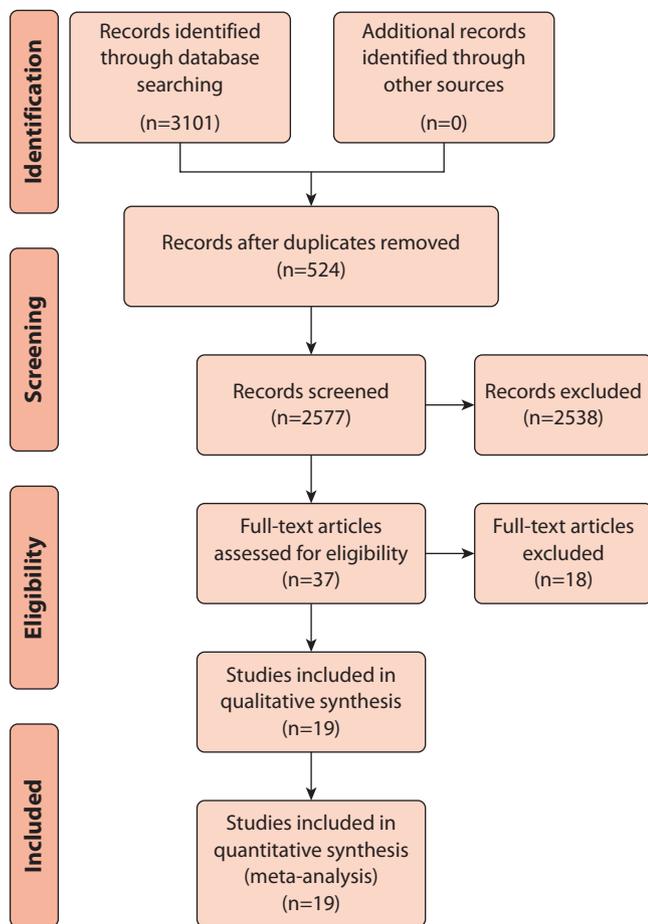
Figure 1. Study design.

Table 1. Reason for article exclusion

Reason	References
Without investigation data	Agnini et al,[47] Astrand et al,[48] Cassetta et al,[49] Crespi et al,[50] Schrott et al,[51] Zhang et al,[52] Schwartz-Arad et al,[53] Meloni et al,[54] Rosén et al,[55] Hellem et al,[56] Oliver et al,[57] and Zinsli et al.[58]
Retrospective study	Busenlechner et al[59] and Nocini et al.[60]
Same design and population	Fischer et al.[61]
Follow-up <5 years	Francetti et al,[62] Hinze et al,[63] and Pozzi et al.[64]

this analysis was formally assessed using the Cochran chi-squared test and the I^2 index, in which $P<.1$ (according to chi-squared test) and $I^2<75\%$ indicate a low degree of heterogeneity. Because the number of implants, follow-up periods, and outcomes varied, a random-effect model was used, even when no significant heterogeneity ($I^2<50\%$) was found among the studies. The analysis was performed using a comprehensive meta-analysis software program (BioStat Inc).[17]

RESULTS

The database search retrieved 3101 studies, including 1484 from PubMed/MEDLINE, 1518 from Scopus, and 99 from the Cochrane Library. Duplicate studies were removed. After evaluation of titles and abstracts, 37 full-text articles were selected for eligibility assessment (Fig. 1). After the full texts of these articles had been read, 18 were excluded (Table 1). Thus, 19 studies (6 RCTs[6,18-22] and 13 prospective studies[8,12,14,23-32]) were included (Supplementary Table 2). The mean follow-up period for a complete-arch prosthesis supported by fewer than 5 implants per jaw was 6 years and 7.63 years for more than 4 implants per jaw. A total of 1006 patients

(mean age of 61.44 years) were evaluated. The number of implants per jaw ranged between 2 and 9 in the maxilla, mandible, or both jaws. The antagonist arch had natural teeth, a removable partial denture, a tooth-supported fixed partial denture, an implant-supported prosthesis, or a complete denture.

The implant survival rate in complete-arch prostheses with fewer than 5 implants was 98.7% for both jaws, 99% for the maxilla,[6,23,26] and 98.9% for the mandible.[12,19,23-26,30] The pooled weighted event rate was 1.4% ($I^2=25.26\%$; $P=.211$) (Fig. 2). The implant survival rate in complete arches with more than 4 implants was 96.6% for both jaws, 95.61% for the maxilla,[14,18,20,21,28,29,32] and 100% for the mandible.[30,32] The pooled weighted event rate was 4.2% ($I^2=81.35\%$; $P<.001$) (Fig. 3).

The prosthesis survival rate in complete arches with fewer than 5 implants was 99.5% for both jaws, 100% for the maxilla,[6,23,27] and 99.5% for the mandible.[12,19,23-27,30] The pooled weighted event rate was 1.5% ($I^2=0\%$; $P=.677$) (Fig. 4). The prosthesis survival rate in complete arches with more than 4 implants was 89.62% for both jaws, 89.62% for the maxilla,[14,18,20-22,28,29,32] and 100% for the mandible.[22,29,31] The pooled weighted event rate was 9% ($I^2=17.33\%$; $P=.304$) (Fig. 5).

The mean prosthesis complications in a complete arch with fewer than 5 implants was 7.85 for both jaws; the pooled weighted event rate was 19.9% ($I^2=93.5\%$, $P<.001$) (Fig. 6). The mean prosthesis complications with more than 4 implants was 5.76 for both jaws. The pooled weighted event rate was 24.5% ($I^2=88.89$, $P<.001$) (Fig. 7). For marginal bone loss in complete arches with fewer than 5 implants per jaw, the pooled weighted mean was 1.22 ±0.49 mm ($I^2=99.46$; $P<.001$) (Fig. 8). For complete arches with more than 4 implants per jaw, the pooled weighted mean was 1.46 ±0.46 mm (95% confidence interval: 0.558 to 2.367; $I^2=99.6$; $P<.001$) (Fig. 9). In addition, regardless of the length of follow-up period, most studies reported a marginal bone level of <1.5 mm.

According to the Cochrane scale, the RCTs demonstrated a low risk of bias for random sequence generation and allocation concealment (selection bias). For blinding of the participants and personnel (performance bias), only 2 studies[20,21] reported on blinding of outcome assessment, and 4[6,18,19,22] reported high risk of bias in this regard. All studies were unclear in terms of incomplete outcome data.

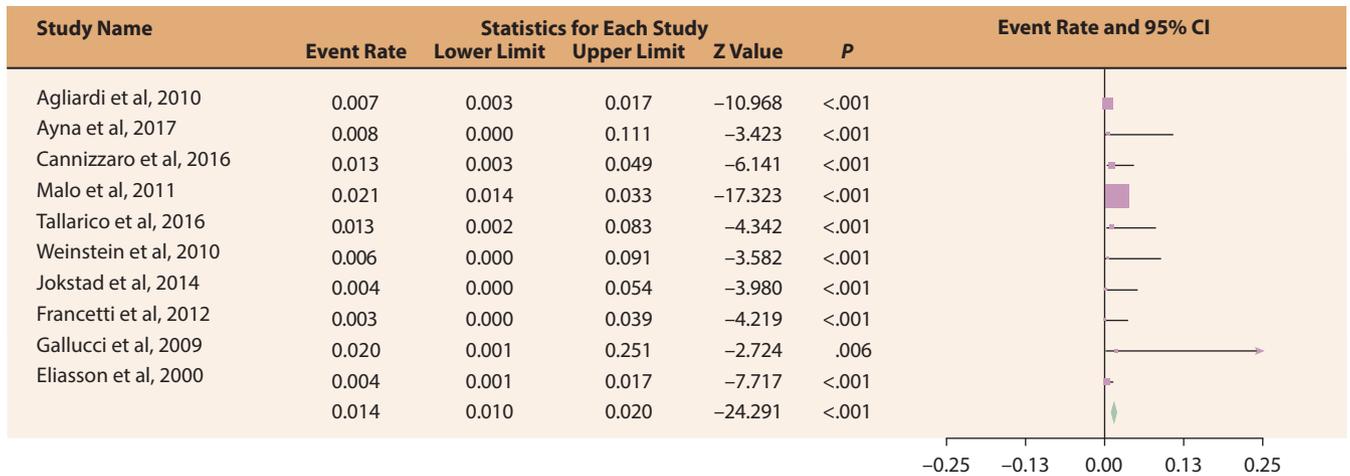| Study Name	Statistics for Each Study					Event Rate and 95% CI
	Event Rate	Lower Limit	Upper Limit	Z Value	P	
Agliardi et al, 2010	0.007	0.003	0.017	−10.968	<.001	
Ayna et al, 2017	0.008	0.000	0.111	−3.423	<.001	
Cannizzaro et al, 2016	0.013	0.003	0.049	−6.141	<.001	
Malo et al, 2011	0.021	0.014	0.033	−17.323	<.001	
Tallarico et al, 2016	0.013	0.002	0.083	−4.342	<.001	
Weinstein et al, 2010	0.006	0.000	0.091	−3.582	<.001	
Jokstad et al, 2014	0.004	0.000	0.054	−3.980	<.001	
Francetti et al, 2012	0.003	0.000	0.039	−4.219	<.001	
Gallucci et al, 2009	0.020	0.001	0.251	−2.724	.006	
Eliasson et al, 2000	0.004	0.001	0.017	−7.717	<.001	
	0.014	0.010	0.020	−24.291	<.001	

−0.25 −0.13 0.00 0.13 0.25

Figure 2. Forest plot for implant survival rate in complete-arch prostheses with fewer than 5 implants per jaw. Pooled weighted event rate: 1.4% (95% CI, 1.0%-2.0%; I^2=25.26%; P=.211). CI, confidence interval.

Study Name	Statistics for Each Study					Event Rate and 95% CI
	Event Rate	Lower Limit	Upper Limit	Z Value	P	
Fischer et al, 2012	0.088	0.047	0.161	−6.690	<.001	
Mertens et al, 2011	0.010	0.001	0.068	−4.562	<.001	
Ravald et al, 2012	0.049	0.031	0.078	−11.899	<.001	
Shigehara et al, 2015	0.003	0.000	0.041	−4.193	<.001	
Ericsson et al, 2000	0.006	0.000	0.083	−3.650	<.001	
Romanos et al, 2009	0.033	0.011	0.098	−5.734	<.001	
Gallucci et al, 2009	0.002	0.000	0.037	−4.261	<.001	
Jemt et al, 2002	0.146	0.113	0.187	−11.649	<.001	
Tallarico et al, 2016	0.050	0.023	0.107	−7.030	<.001	
Tealdo et al, 2014	0.072	0.035	0.144	−6.509	<.001	
	0.042	0.023	0.078	−9.430	<.001	

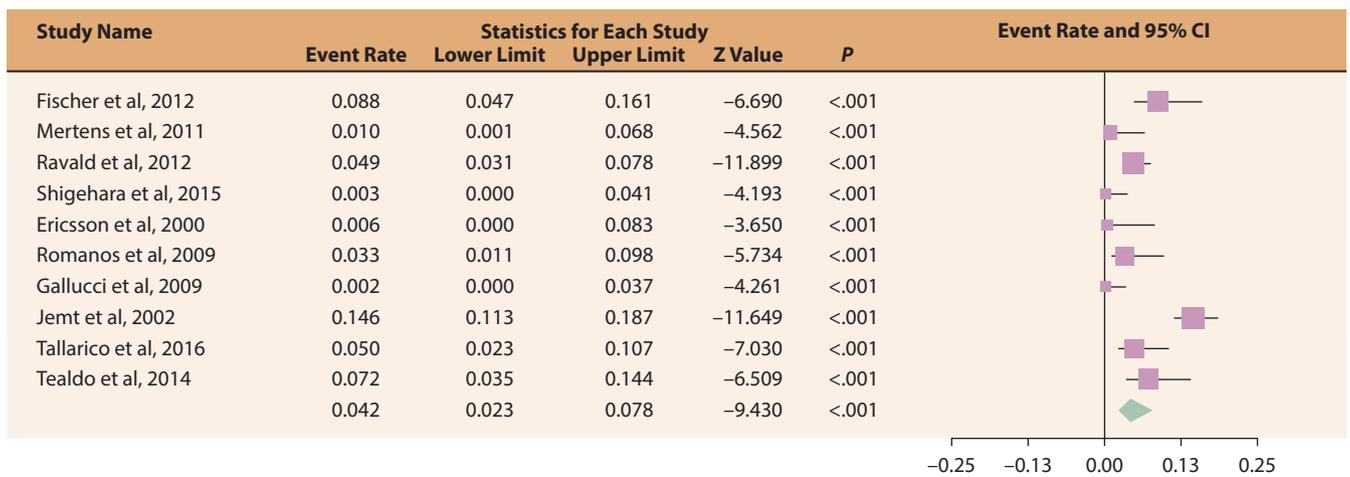−0.25 −0.13 0.00 0.13 0.25

Figure 3. Forest plot for implant survival rate in complete-arch prostheses with more than 4 implants per jaw. Quantitative analysis of pooled weighted event rate: 4.2% (95% CI, 2.3%-7.8%; I^2=81.35%; P<.001). CI, confidence interval.

Study Name	Statistics for Each Study					Event Rate and 95% CI
	Event Rate	Lower Limit	Upper Limit	Z Value	P	
Agliardi et al, 2010	0.003	0.000	0.044	−4.130	<.001	
Cannizzaro et al, 2016	0.025	0.006	0.094	−5.116	<.001	
Francetti et al, 2012	0.010	0.001	0.146	−3.203	<.001	
Tallarico et al, 2016	0.024	0.001	0.287	−2.594	<.001	
Ayna et al, 2017	0.029	0.002	0.336	−2.436	<.001	
Eliasson et al, 2000	0.004	0.000	0.063	−3.864	<.001	
	0.015	0.006	0.037	−8.829	<.001	

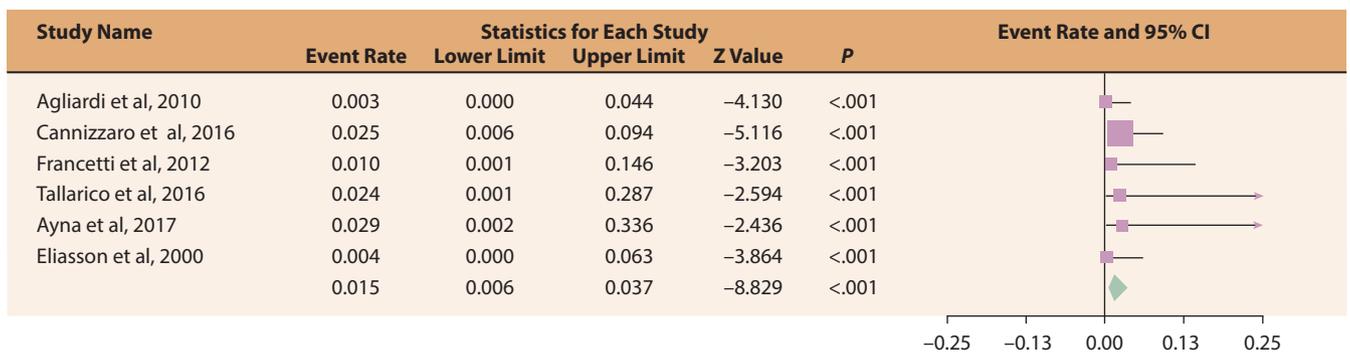−0.25 −0.13 0.00 0.13 0.25

Figure 4. Forest plot for prosthetic survival rate in complete-arch prostheses with fewer than 5 implants per jaw. Pooled weighted event rate: 1.5% (95% CI, 0.6%-3.7%; I^2=0%; P=.677). CI, confidence interval.

Selective reporting and other biases were considered low risk for all selected studies (Table 2).

For nonrandomized studies (prospective), assessment of the risk of bias using the NOS (Table 3) revealed that of the 19 studies, 2 had 5 stars (indicating high risk of bias), whereas 1 had 6 stars, 4 had 7 stars, 3 had 8 stars, and 2 had 9 stars, indicating low risk of bias. A low number of stars were primarily associated with the
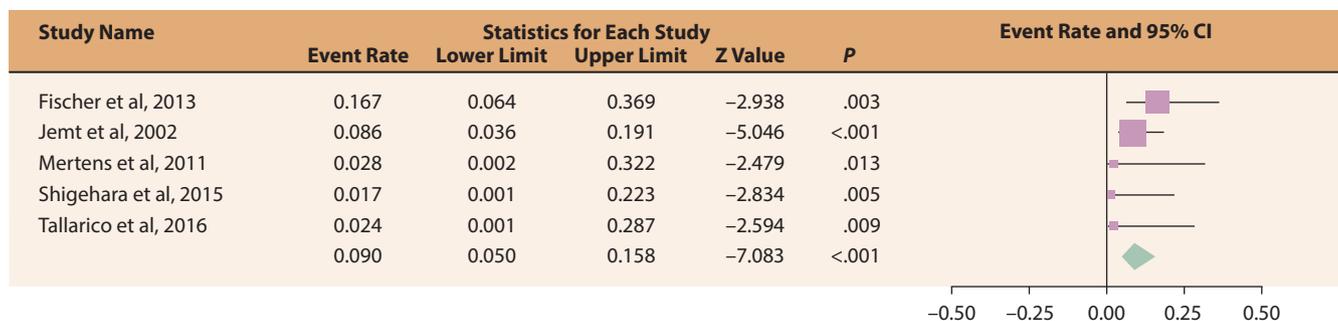
Study Name	Statistics for Each Study					Event Rate and 95% CI
	Event Rate	Lower Limit	Upper Limit	Z Value	P	
Fischer et al, 2013	0.167	0.064	0.369	−2.938	.003	
Jemt et al, 2002	0.086	0.036	0.191	−5.046	<.001	
Mertens et al, 2011	0.028	0.002	0.322	−2.479	.013	
Shigehara et al, 2015	0.017	0.001	0.223	−2.834	.005	
Tallarico et al, 2016	0.024	0.001	0.287	−2.594	.009	
	0.090	0.050	0.158	−7.083	<.001	

−0.50   −0.25   0.00   0.25   0.50

Figure 5. Forest plot for prosthetic survival rate in complete-arch prostheses with more than 4 implants per jaw. Pooled weighted event rate: 9% (95% CI, 5%-15.8%; I^2=17.33%; P=.304). CI, confidence interval.

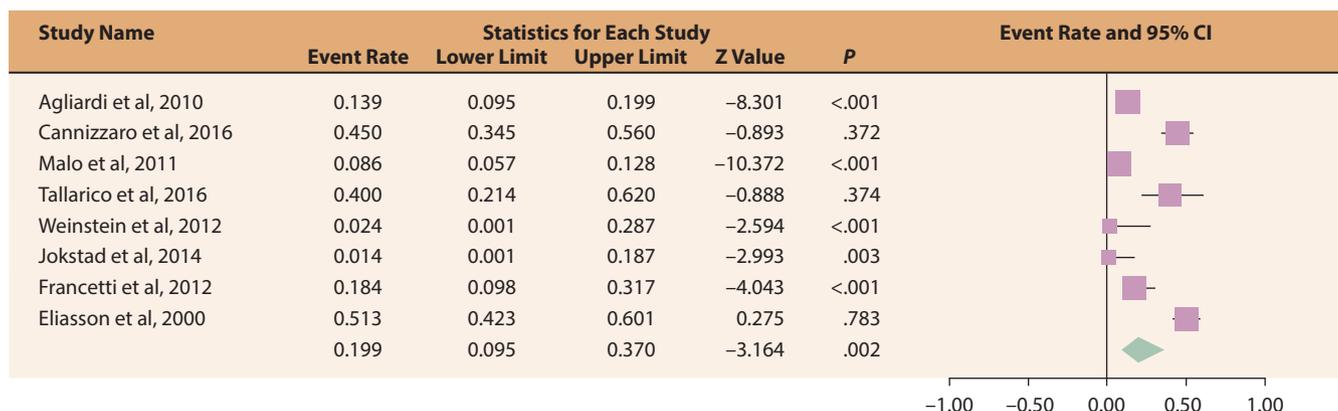| Study Name	Statistics for Each Study					Event Rate and 95% CI
	Event Rate	Lower Limit	Upper Limit	Z Value	P	
Agliardi et al, 2010	0.139	0.095	0.199	−8.301	<.001	
Cannizzaro et al, 2016	0.450	0.345	0.560	−0.893	.372	
Malo et al, 2011	0.086	0.057	0.128	−10.372	<.001	
Tallarico et al, 2016	0.400	0.214	0.620	−0.888	.374	
Weinstein et al, 2012	0.024	0.001	0.287	−2.594	<.001	
Jokstad et al, 2014	0.014	0.001	0.187	−2.993	.003	
Francetti et al, 2012	0.184	0.098	0.317	−4.043	<.001	
Eliasson et al, 2000	0.513	0.423	0.601	0.275	.783	
	0.199	0.095	0.370	−3.164	.002	

−1.00   −0.50   0.00   0.50   1.00

Figure 6. Forest plot for prosthetic complications for complete-arch prostheses with fewer than 5 implants per jaw. Pooled weighted event rate: 19.9% (95% CI, 9.5%-37%; I^2=93.5%; P<.001). CI, confidence interval.

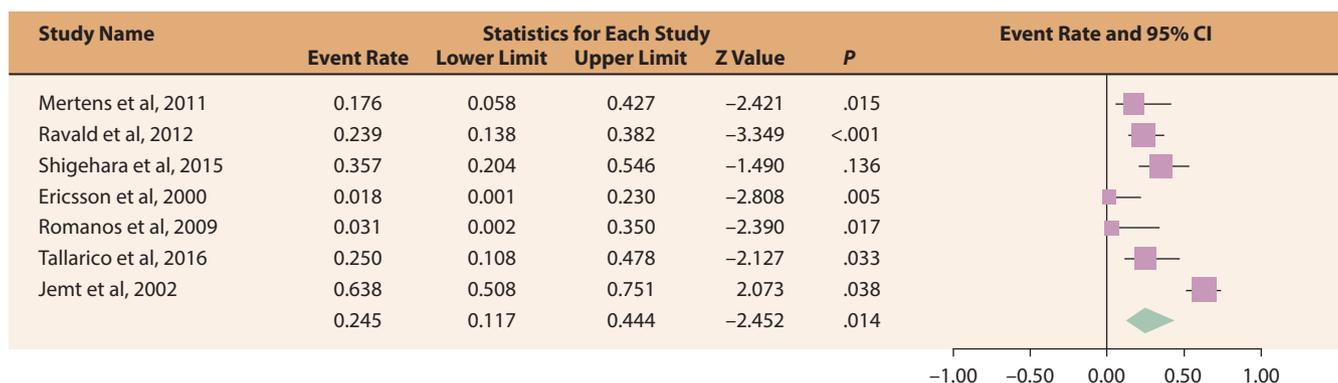| Study Name	Statistics for Each Study					Event Rate and 95% CI
	Event Rate	Lower Limit	Upper Limit	Z Value	P	
Mertens et al, 2011	0.176	0.058	0.427	−2.421	.015	
Ravald et al, 2012	0.239	0.138	0.382	−3.349	<.001	
Shigehara et al, 2015	0.357	0.204	0.546	−1.490	.136	
Ericsson et al, 2000	0.018	0.001	0.230	−2.808	.005	
Romanos et al, 2009	0.031	0.002	0.350	−2.390	.017	
Tallarico et al, 2016	0.250	0.108	0.478	−2.127	.033	
Jemt et al, 2002	0.638	0.508	0.751	2.073	.038	
	0.245	0.117	0.444	−2.452	.014	

−1.00   −0.50   0.00   0.50   1.00

Figure 7. Forest plot for prosthetic complications for complete-arch prostheses with more than 4 implants per jaw. Pooled weighted event rate: 24.5% (95% CI, 11.7%-44.4%; I^2=88.89; P<.001). CI, confidence interval.

absence of a nonexposed cohort, comparability between groups, and the outcome of interest not being present at baseline.

DISCUSSION

The first null hypothesis was accepted. Complete-arch prostheses with fewer than 5 implants per jaw exhibited an event rate of 1.4%, whereas complete-arch prostheses with more than 4 implants per jaw had an event rate of 4.2%. The studies included in this systematic review had a follow-up period of at least 5 years, which is described as long term.[33] The higher failure rates for complete-arch prostheses with more than 4 implants per jaw can be explained by the longer average follow-up period than those with fewer than 5 implants per jaw. Thus, the longer follow-up period may have contributed to greater bone loss and, consequently, a greater risk for implant failure.[34]

Some studies have reported that a reduction in the number of implants in complete-arch prostheses contributes
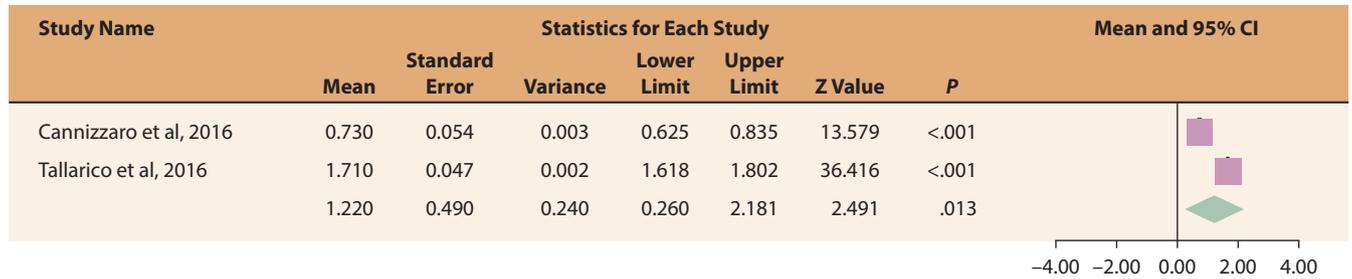
Study Name			Statistics for Each Study					Mean and 95% CI
	Mean	Standard Error	Variance	Lower Limit	Upper Limit	Z Value	P	
Cannizzaro et al, 2016	0.730	0.054	0.003	0.625	0.835	13.579	<.001	
Tallarico et al, 2016	1.710	0.047	0.002	1.618	1.802	36.416	<.001	
	1.220	0.490	0.240	0.260	2.181	2.491	.013	

−4.00 −2.00 0.00 2.00 4.00

Figure 8. Forest plot for mean marginal bone loss for complete-arch prostheses with fewer than 5 implants per jaw. Pooled weighted mean: 1.22 ±0.49 (95% CI, 0.26-2.181; I^2=99.46; P<.001). CI, confidence interval.

Study Name			Statistics for Each Study					Mean and 95% CI
	Mean	Standard Error	Variance	Lower Limit	Upper Limit	Z Value	P	
Fischer et al, 2011	3.470	0.116	0.013	3.243	3.697	29.953	<.001	
Jemt et al, 2002	0.590	0.052	0.003	0.488	0.692	11.363	<.001	
Mertens et al, 2011	0.300	0.072	0.005	0.158	0.442	4.146	<.001	
Tallarico et al, 2015	1.510	0.033	0.001	1.446	1.574	45.948	<.001	
	1.462	0.461	0.213	0.558	2.367	3.168	.002	

−4.00 −2.00 0.00 2.00 4.00
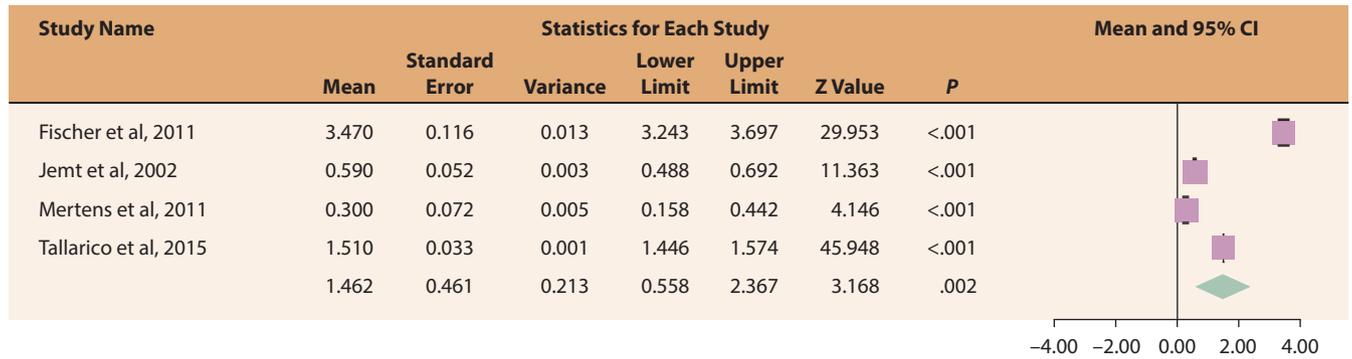
Figure 9. Forest plot for mean marginal bone loss for complete-arch prostheses with more than 4 implants per jaw. Pooled weighted mean: 1.46 ±0.46 (95% CI, 0.558-2.367; I^2=99.6; P<.001). CI, confidence interval.

Table 2. Risk of bias of randomized controlled trials—Cochrane Scale

Domain	Jemt et al 2002	Jokstad et al 2014	Fischer et al 2012 (A)	Fischer et al 2012 (B)	Ravald et al 2013	Tallarico et al 2016
Sequence generation	Low	Low	Low	Low	Low	Low
Allocation concealment	Low	Low	Low	Low	Low	Low
Blinding of participants, personnel, and outcome assessors	High	High	Low	Low	High	High
Incomplete outcome data	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Selective outcome reporting	Low	Low	Low	Low	Low	Low
Other sources of bias	Low	Low	Low	Low	Low	Low

to increased stress on the structures.[13,35] However, distribution–in addition to the number of implants–may affect rehabilitation.[35] The all-on-four technique was developed to overcome anatomic limitations and reduce the cantilever. This technique was evaluated in 3 studies[12,24,30] and can be considered to have achieved good clinical outcomes.[12] Among the selected studies, 2 reported survival rates of 100% over a 5-year follow-up period,[24,30] and 1 study reported an implant survival rate of 93.8% over a 10-year follow-up.[12] The high survival rates for this technique may be attributable to appropriate patient selection[11,12] because implant loss can be higher in patients with local or systemic disease.[12] Moreover, implant survival rates also depend on the amount of residual ridge, independent of the arch.[36,37]

Only 1 study evaluated 2 implants in the mandibular arch and reported high survival rates (98.75%).[8] This result was corroborated in a recent systematic review demonstrating that mandibular complete-arch prostheses with 2 or 4 implants have a high implant survival rate.[10] However, the use of only 2 implants can contribute to more risk of complication due to more biomechanical stress on the prostheses.[36,38] The authors who evaluated this treatment modality did not recommend immediate loading of mandibular cross-arch dental prostheses supported by 2 implants because, to date, it is considered a therapeutic approach without sufficient validation.[8] This must be considered because in complete-arch prostheses, the failure of only 1 implant represents a failure of the entire complete-arch prosthesis.[29] Therefore, the use of at least 5 implants in the mandible and 6 in the maxilla could be indicated for immediate complete-arch prostheses. A study reported no impairment of rehabilitation in situations with at least 5 implants in the mandible and 6 in the maxilla.[29] Implant survival rates

Table 3. Risk of bias—Newcastle-Ottawa scale for prospective studies

| Studies | Selection | | | | Comparability | | Outcome | | | Total |
	Exposed Cohort	Nonexposed Cohort	Ascertainment of Exposure	Outcome of Interest not Present at Start	Main Factor	Additional Factor	Assessment of Outcome	Follow-up Long Enough	Adequacy of Follow-up	
Agliardi et al, 2010	☆	☆	☆	0	☆	☆	☆	☆	0	7
Cannizzaro et al, 2016	☆	☆	☆	☆	☆	☆	☆	☆	☆	9
Fischer et al 2012, A	☆	☆	☆	☆	☆	0	☆	☆	☆	8
Fischer et al 2012, B	☆	☆	☆	☆	☆	0	☆	☆	☆	8
Malo et al, 2011	☆	0	☆	0	0	0	☆	☆	☆	5
Mertens et al, 2011	☆	0	☆	☆	0	☆	☆	☆	☆	7
Ravald et al, 2013	☆	☆	☆	☆	☆	☆	☆	☆	☆	9
Shigehara et al, 2015	☆	☆	☆	☆	☆	0	☆	☆	☆	8
Tallarico et al, 2016	☆	☆	☆	0	☆	☆	☆	☆	☆	8
Tealdo et al, 2014	☆	☆	☆	0	☆	☆	☆	☆	☆	8
Weinstein et al, 2012	☆	0	☆	0	0	0	☆	☆	☆	5
Ericsson et al, 2000	☆	☆	☆	0	☆	0	☆	☆	☆	7
Pozzi et al, 2015	☆	0	☆	0	0	0	☆	☆	☆	5
Romanos et al, 2009	☆	0	☆	0	0	0	☆	☆	☆	5
Jokstad et al, 2014	☆	☆	☆	☆	☆	☆	☆	☆	☆	9

should not be evaluated without assessing correlation with prosthesis success rates.[14,39]

The results of this systematic review also led to the acceptance of the second null hypothesis, that is, prosthetic survival, complication rate, and marginal bone level would not be influenced by the number of implants used in complete-arch prostheses. The mean prosthesis survival rate in complete-arch prostheses with fewer than 5 implants per jaw was 99.5% and 89.62% for complete-arch prostheses with more than 4 implants per jaw. These favorable survival rates after long-term follow-up may be attributable to the choice of durable dental materials and good impression techniques, both of which are needed to achieve satisfactory long-term survival and reduce maintenance costs.[21]

Complete-arch prostheses with fewer than 5 implants per jaw which depend on the distribution of implants can have a longer distal cantilever length (approximately >15 mm in the mandible and <10 mm in the maxilla), which is associated with more complications, especially when the type of antagonist teeth is considered.[40] However, the selected studies did not assess the relationship between the antagonist arch and the complete-arch prosthesis. In addition, a longer distal cantilever could increase the force on the implant closer to the cantilever.[41,42] In the present systematic review, only 2 studies[8,23] reported the fracture of acrylic resin prostheses and the relationship with distal cantilever length for complete-arch prostheses with fewer than 5 implants per jaw.

In complete-arch prostheses with fewer than 5 implants, the complication rate ranged 12.2% to 19.3% for complete-arch prostheses with more than 4 implants. This suggests that the number of implants is independent of the complication rate. The most common complications observed in the selected studies were screw loosening and acrylic resin

fracture. The results of this study are consistent with those of other studies.[43,44] The risk for prosthetic complications increased with long-term follow-up periods.[43] According to Bozini et al,[43] approximately 30% of the complete-arch prostheses had complications of acrylic resin fracture, and 5% had screw loosening after 5 years of follow-up.

These complications may occur because individuals with a complete denture recover their masticatory efficiency and change their diet from soft to harder foods, causing fracture of the acrylic resin.[23] Furthermore, when the masticatory forces are applied to the distal extension of the prostheses, screw loosening/fracture or acrylic resin fracture can occur, perhaps secondary to marginal bone loss.[42,45]

Marginal bone loss around the implants can lead to secondary failure of the implants and, consequently, the need for retreatment.[34] In the selected studies, the mean marginal bone loss was higher for complete-arch prostheses with more than 4 implants per jaw (mean, 1.46 mm) than that for those with fewer than 5 implants per jaw (mean, 1.22 mm). However, this small difference between the mean values may not be clinically significant, which leads us to believe that the number of implants does not influence marginal bone loss in complete-arch prostheses.

As previously reported, the distribution of implants is as important as the number of implants.[35] Biomechanical studies have reported that the increase in stress is related to the increase in cantilever length, which could also contribute to increased bone resorption around the implant.[42] However, almost all of the included studies reported a reduction in the cantilever length with tilting of the distal implants in complete arches with fewer than 5 implants (such as with the all-on-four technique),[6,8,19,23,24,26,29] thereby contributing to the same mean marginal bone loss compared with

that reported in studies with more than 4 implants. Furthermore, almost all the studies reported marginal bone level <1.5 mm. These results agree with those of Albrektsson et al,[46] who reported an acceptable bone loss of 1 mm during the first year of rehabilitation and 0.2 mm annually thereafter.[17]

One limitation of the present systematic review was that most of the selected studies did not directly describe the groups used to evaluate and compare different numbers of implants with the same design (fewer than 5 implants versus more than 4 implants); only 2 studies[6,23] provided this direct comparison. According to the results of these studies, the number of implants did not influence the evaluated outcomes. Nevertheless, more RCTs are needed to evaluate the direct effect of the number of implants on treatment longevity. Although there is no apparent difference in longevity when different numbers of implants are used for complete-arch implant-supported prostheses, the results of this systematic review should be carefully considered.

CONCLUSION

Based on the findings of this systematic review, the following conclusion was drawn:

1. The number of implants used in complete-arch prostheses did not influence implant survival rate, prosthesis survival rate, prosthesis complications, or marginal bone loss, in studies with a follow-up period of between 5 and 15 years.

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Supplementary Table 1. Journals used for search

1. Journal of Prosthetic Dentistry
2. International Journal of Prosthodontics
3. Journal of Prosthodontics
4. Journal of Prosthodontic Research
5. International Journal of Periodontics and Restorative Dentistry
6. Journal of Clinical Periodontology
7. Journal of Dental Research
8. Journal of Oral Implantology
9. Journal of Oral Rehabilitation
10. Clinical Implant Dentistry and Related Research
11. Clinical Oral Implants Research
12. European Journal of Oral Implantology
13. Implant Dentistry
14. International Journal of Oral and Maxillofacial Implants
15. International Journal of Oral and Maxillofacial Surgery
16. Journal of Oral Periodontal Research
17. Journal of Periodontology

Supplementary Table 2. Characteristics of included studies (n=19)

Author, Year	Type of Study	Patients (n)	Sex	Mean Age (Years)	Region of Rehabilitation	Total Number of Implants	Number of Implants per Jaw	Follow-up	Implant Survival Rate, %	Marginal Bone Level, (Mean ±SD)	Prosthetic Survival Rate, %	Complications
										Outcomes		
Agliardi et al, 2010	Prospective single cohort	173	F (80); M (93)	57.3	Maxilla and mandible	692	4	5 y	Maxilla, 98.36; Mandible, 99.73	Maxilla, 0.9 ±0.7 mm; mandible, 1.2 ±0.9 mm	Maxilla, 100; mandible, 100	Fracture of the acrylic prosthesis (n=24)
Ayna et al, 2018	Prospective	16	F (10); M (6)	72.06	Mandible	64	4	7 y	100	32 region: 3.15 ±0.56; 42 region: 3.06 ±0.47; 35 region: 3.68 ±0.57; 45 region: 4.00 ±0.51	100	Tooth detachment; loss of the abutment screw; denture repair in the laboratory (7-y follow-up).
Cannizzaro et al, 2016	Prospective single cohort	80	F (40); M (40)	53.2	Mandible	160	2	5 y	98.75	0.73 ±0.68 mm	97.5	Function and esthetic complaint; framework fracture; loosening prosthetic screw; distal extension framework fracture; detachment of anterior teeth twice; implant stuck at the placement; bone perforation; hemorrhage at implant placement; peri-implantitis; hyperplasia
Eliasson et al, 2000	Prospective	53	F (31); M (22)	61-90	Mandible	476	4	>5 y	98.6	NR	100	Loss of screw torque; framework fracture; fracture of the artificial teeth.
Fischer et al, 2012 and 2013	RCT	24	F (16); M (8)	64	Maxilla	102	5 or 6	10 y	93	3.47 ±1.17	82	Bridge on and off (n=8); recementation or replacement of tooth (n=26); flap operation (n=4); failure and remaking of bridge (n=2); filling of retention hole (n=8); filling of tooth fracture (n=8); installation of a new tooth (n=3)
Francetti et al, 2012	Prospective	47	F (22); M (25)	53	Maxilla and mandible	196	4	6 y	100	Titled: 0.39 ±0.18; Axial: 0.51 ±0.17	100	Fracture of the acrylic (n=5)
Gallucci et al, 2009	Prospective	45	F (26); M (19)	F: 60.2; M: 58.8	Mandible	237	4-6	5 y	100	NR	95.5	Fracture of the acrylic tooth or denture base (n=20); screw loosening (n=2); fracture of the screw (n=5); fracture of the porcelain (n=1); fracture of metal framework (n=2)
Jemt et al, 2002	Prospective	58	F (25); M (33)	G1: 59; G2: 61	Maxilla	349	≥5	5 y	G1: 91.4; G2: 94	0.59 ±0.97	G1: 96.4; G2: 93.3	Fracture of resin teeth or base (n=23); unstable prosthesis (n=1); loss of the screw (n=6); adverse tissue reaction (n=7)

Supplementary Table 2. (*Continued*) Characteristics of included studies (n=19)

Author, Year	Type of Study	Patients (n)	Sex	Mean Age (Years)	Region of Rehabilitation	Total Number of Implants	Number of Implants per Jaw	Follow-up	Implant Survival Rate, %	Marginal Bone Level, (Mean ±SD)	Prosthetic Survival Rate, %	Complications
										Outcomes		
Malo et al, 2011	Prospective	245	F (149); M (96)	59	Mandible	980	4	10 y	93.8	NR	NR	Prosthetic screw loosening (*n*=12); abutment loosening (*n*=2); implant mobility and radiolucent areas (*n*=1); peri-implantitis (*n*=4)
Mertens et al, 2011	Prospective	17	F (12); M (5)	55.6	Maxilla	99	6-8	8 y	99	0.3 ±0.72 mm	82.4	Chipping of acrylic teeth (*n*=3); aging of the acrylic base; discolorations
Ravald et al, 2013	RCT	46	AT: F (13) and M (12); B: F (14) and M (7)	AT: 73.1; B: 75.7	Maxilla and mandible	AT: 170; B: 175	5 or 6	15 y	AT: 95.5; B: 94.7	AT: −0.17 ±1.18; B: −0.43 ±0.81	NR	Fracture of the framework (*n*=1); patients reported severe wear of the acrylic dentition because they have bruxism (*n*=2); chipping of the ceramic veneers (*n*=7); abutment screw fracture (*n*=1)
Shigehara et al, 2015	Prospective	27	F (12); M (15)	61.8	Maxilla and mandible	189	6 or 5	5 y	100	NR	100	Uncomfortable feeling (*n*=2); oppressive headache feeling (*n*=2); prosthesis breakage (*n*=4)
Tallarico et al, 2016	RCT	40	F (19); M (21)	63	Maxilla	200	4 or 6	5 y	G1: 98.75; G2: 95	G1: 1.71 ±0.42 (1.45-1.83); G2: 1.51 ±0.36 (1.38-1.66)	G1: 100; G2: 100	G1: prosthetic screw loosening (*n*=2) and fracture of the veneers (*n*=3); G2: fracture of the veneers (*n*=1) and implant failure (*n*=2)
Tealdo et al, 2014	Prospective	49	T: F (19) and M (15); C: F (6) and M (9)	58.2	Maxilla	260	T: 4-6; C: 6-9	6 y	T: 93.9; C: 95.9	T: 1.62 ±1.23 mm; C: 2.44 ±1.44 mm	T: 82.4; C: 73.3	Fractures of the veneers (*n*=10); loosening of the prosthetic screw (*n*=8)
Weinstein et al, 2010	Prospective	20	F (12); M (8)	60.8	Mandible	80	4	5 y	100	Axial implants: 0.6 ±0.3 mm; titled implants: 0.7 ±0.4 mm	NR	NR
Ericsson et al, 2000	Prospective	16	F (9); M (7)	66.3	Mandible	88	5-6	5 y	100	Early: 0.2 ±0.5 mm; delayed: 0.0 ±0.5 mm	NR	None
Romanos et al, 2009	Prospective	15	F (5); M (10)	54.8	Maxilla	90	6	5 y	96.6	NR	NR	None
Jokstad et al, 2014	RCT	35	F (15); M (20)	62	Mandible	140	4	5 y	100	T: 1.1 ±0.7; C: 1.3 ±0.7	NR	NR

AT, Astra Tech TiOblast (implant surface); B, Branemark turned (implant surface); C, control group; F, female; M, male; RCT, randomized controlled trial; SD, standard deviation; T, test group.