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SYSTEMATIC REVIEW

Influence of different implant-abutment connection designs on the mechanical and biological behavior of single-tooth implants in the maxillary esthetic zone: A systematic review

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ABSTRACT

Statement of problem. A consensus regarding which implant-abutment connection type would perform best in the anterior maxilla is lacking.

Purpose. The purpose of this systematic review was to determine the best implant-abutment connection type for anterior single-tooth implants considering esthetics, success, and survival rates.

Material and methods. An electronic search was conducted in MEDLINE, Scopus, Embase, and the Cochrane Library databases to identify clinical studies on single-tooth implants with external and internal hexagon, and/or Morse taper connections. These studies needed to describe at least one of the following outcomes: esthetic score, survival/success rate, or marginal bone loss. The included studies and reports were assessed for bias using the Cochrane risk of bias tool.

Results. Of the 891 articles identified, 29 were selected and analyzed. The most common technical complications were abutment screw loosening and crown-cement loosening, while dehiscence and recession were the most common biological complications. The most frequent complications were dehiscence for external hexagon, crown-cement loosening for the internal hexagon, and ceramic fracture for the Morse taper. Esthetics were favorable for all connections, but the internal hexagon performed better. However, better results for marginal bone loss, success, and survival were found for the Morse taper. The global annual failure rate was 0.90% and 0.2% for Morse taper, 0.3% for external hexagon, and 2.2% for internal hexagon.

Conclusions. This review suggests that Morse taper performs better for survival, success, and marginal bone loss. Internal hexagon performed better for esthetic parameters. Additional controlled studies are needed to provide stronger evidence because the evidence generated in this study was considered low. (J Prosthet Dent 2019;121:398-403)

Tooth replacement with implants has become part of clinical practice because of its predictable outcomes.[1] Single-tooth implants were first described in 1986,[2] and survival rates varying between 90% and 96.3% after up to 10 years have been reported.[3] Although highly predictable, complications may occur and may sometimes be difficult to overcome.

Biological complications with damage to the peri-implant tissues are typically related to the patient,[4] while technical complications involving damage to the implant are associated with the design of the components and the material used.[5] When the implant is placed in the anterior region of the maxilla, excellent esthetics and the complex anatomy present challenges. Although long-term studies have demonstrated a survival rate of 95.5% for single-tooth implants placed in the anterior maxilla, the occurrence of prosthetic complications remains high.[6]

Knowledge of the mechanical and functional limitations of implant-abutment connection types becomes essential when they are directly related to the success of the procedure.[7] Different types of interface designs have been developed, each of which have its own advantages and disadvantages. The external hexagon (EH) facilitates the insertion of the prosthesis, provides an antirotational mechanism, and allows removal of the prosthesis.

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Clinical Implications

When esthetics is desirable in a prosthetic rehabilitation, an internal hexagon presents the best result. However, survival rates are higher and marginal bone loss lower when the Morse taper is selected.

However, the EH does not prevent the microgap formation leading to complications when subjected to high occlusal load.[8] The internal hexagon (IH) connections increased the contact area between the implant and abutment, allowing load dissipation and providing greater stability. However, only the Morse taper (MT) connection provides intimate contact between the implant and abutment, achieving the best antibacterial seal and best bone stability.[9,10]

Survival and marginal bone loss (MBL) have been used as criteria for implant evaluation. Irrespective of the implant's quality and success, survival is recorded when the implant is in place, where the implant is not associated with pain, mobility, discomfort, or infection, where it is surrounded by stabilized bone, where it can support the prosthesis, and where the esthetics of the prosthesis is satisfactory.[11] MBL is one of the criteria for success and is acceptable if lower than 1.5 mm after 1 year of function and 0.2 mm for the following years.[12] The implant-abutment design is one of the factors that influences MBL.[13] Also, the peri-implant soft tissue, prosthesis, and patient satisfaction may be measures of success.[14]

Nevertheless, a comparison among implant-abutment connection types has not been completely clarified, especially considering the many factors that may affect esthetic outcomes in the maxilla. Thus, the purpose of this study was to systematically review the subject to help dentists in their decision-making process regarding best performance for esthetics, success, and survival.

MATERIAL AND METHODS

This review followed the guidelines of the Cochrane Handbook for Systematic Reviews of Interventions,[15] and the reporting was based on the PRISMA checklist.[16] The protocol of this review was registered with the PROSPERO database (CRD42016019791).

This study focused on answering the following patient, problem, or population; intervention; comparison, control, or comparator; outcome (PICO) question: Which implant-abutment connection type (EH, IH, or MT) performs best regarding the esthetics, success, and survival of single-tooth implants placed in the esthetic zone of the maxilla?

Randomized controlled trials (RCTs), controlled clinical trials, follow-up studies, retrospective studies, and prospective studies were included in the study. Studies should present at least one of the implant-abutment connection designs (EH, IH, or MT) and data regarding single-tooth implants placed in the anterior maxilla; information about survival and/or success rates for the connection types; evaluate esthetics; have at least 1 year of follow-up; and be published in English. In situ and in vitro studies, case series, and case reports; studies with no information about the implant-abutment connection design used; studies in which implants were placed in other areas; and studies with less than 1 year of follow-up were excluded.

Searches were performed without time restrictions in electronic databases (MEDLINE, Embase, Scopus, and the Cochrane Collaboration's Library). When missing, data were requested from the authors by email. The literature search strategy is presented in Supplemental Table 1. Duplicates were removed with a reference software program (EndNote; Clarivate Analytics), and data were collected in a spreadsheet (Excel; Microsoft Corp).

Two researchers (B.M.V., L.P.B.) independently identified articles by first analyzing titles and abstracts for relevance and the presence of the selection criteria. Retrieved records were classified as include, exclude, or uncertain. The full-text articles of included and uncertain records were obtained for further eligibility screening by the same 2 reviewers. Discrepancies in eligibility were resolved through discussion between the 2 reviewers. In the event of disagreement, the opinion of a third investigator (C.D.B.) was obtained. In the case of identification of the same study, the article with the longer follow-up was considered.

A standardized outline was used to extract publication details (author and year of publication); characteristics of the study (study design, sample size, duration of follow-up); characteristics of the implants evaluated (implant-abutment connection type, abutment material, prosthesis retention type); and outcome information (survival and success rates, MBL, esthetic evaluation, and technical and biological complications). The primary outcome was esthetic evaluation, and the secondary outcomes were MBL, success rate, survival rate, and biological parameters. Survival was applied to an implant that was in position, irrespective of its quality. The implant was considered a success when there was absence of pain, mobility, discomfort, and infection, when it was surrounded by stabilized bone, and when it was capable of receiving the prosthesis, with satisfactory esthetics.[11]

The annual failure rate (AFR) of the investigated restorations was calculated according to the formula: $(1-y)^Z = (1-x)$, where y is the mean AFR, and x is the total failure rate at z years. The annual success rate (ASR) was calculated with the same formula, where y is the mean ASR, and x is the total success rate at z years. To evaluate the esthetic outcome in studies that included a subjective assessment by the participants, the results

were grouped as 0 (unsatisfactory) or 1 (satisfactory). Other outcomes were evaluated by qualitative analysis. Reports of the studies were assessed for bias using the Cochrane risk of bias tool considering the judgment of the blinding of participants and personnel, incomplete outcome data, selective reporting, exclusion of risk patients, and presence of a control group.[15]

RESULTS

The literature search yielded 891 titles and abstracts. After duplicates had been removed and titles and abstracts had been analyzed, 151 articles were selected for full-text analysis (Fig. 1). Twenty-nine studies fulfilled the eligibility criteria and were included in the review (Supplemental Tables 2, 3). The data were inappropriate for quantitative synthesis (meta-analysis) because of the heterogeneity of the results, which were expressed in scores, percentages, or even descriptively. However, AFR, ASR, and MBL were calculated.

Of the 1142 implants considered, 13% showed complications. The most common were crown-cement loosening for technical failure and dehiscence for biological failure. Only 1 study evaluated more than 1 connection type.[17] Among the 14 evaluating MT (473 implants), the most common complication was ceramic fracture, while for the 7 studies evaluating EH (268 implants) dehiscence was more common. Nine studies evaluated IH connection (401 implants) and found crown-cement loosening as the most common complication. The technical complications appeared almost twice as often as the biological ones (Table 1).

Concerning the loading protocol, 17 studies used delayed loading, while 15 used immediate loading.[18-26] The more frequent complication was recession or fistula for delayed loading and dehiscence or crown-cement loosening for immediate loading.

Among the 15 studies that used an esthetic evaluation, 4 reported a subjective assessment by the participants, and the results were considered as 0 (unsatisfactory) or 1 (satisfactory).[18,19,27-30] Most participants self-reported the score 1. A visual analog scale was used by 2 studies, with a satisfactory result for EH and IH.[31,32] The most used score, Pink Esthetic Score/White Esthetic Score (PES/WES) was used by 9 studies,[33-41] and the anterior maxilla in general and all the connections presented score 1, with the best performance for IH and the worst for EH. Another study used a papilla index for EH with favorable results.[31]

To measure the survival and success rates, the AFR (25 studies) and the ASR (8 studies) were calculated for each study (Supplemental Table 2). The ASR was 4.8% and the AFR 0.9% for the anterior maxilla in general. Regarding implant-abutment connection type, the AFR was 0.2% for MT, 0.3% for EH, and 2.2% for IH. Because of the low number of studies evaluating each connection for success, this outcome was not measured by connection type. In the studies with 1 year of follow-up, the AFR was 2.2% decreasing to 0.27% for the following years. Twenty-six studies assessed MBL, with an overall mean

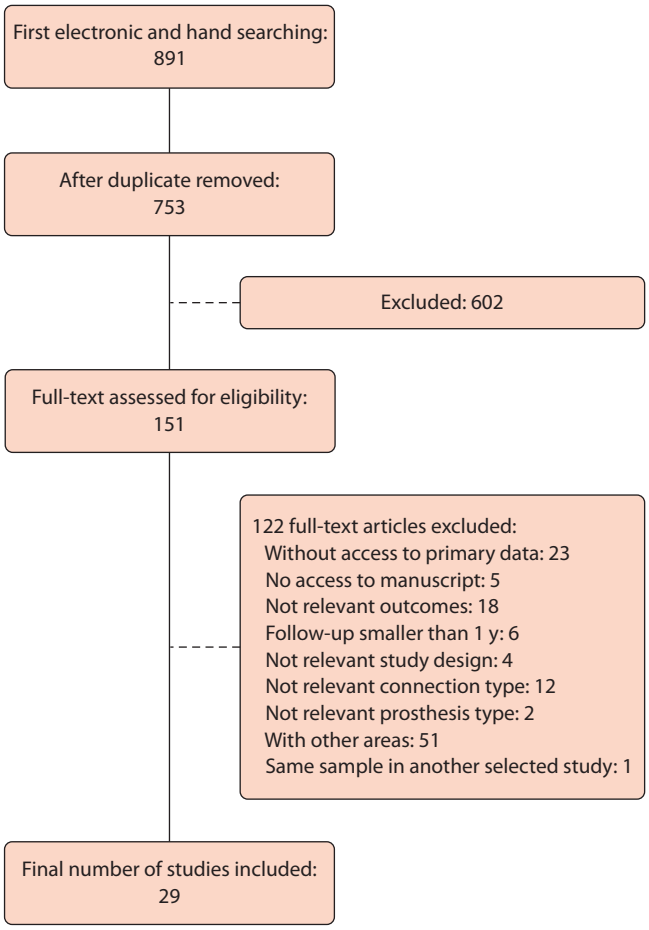

Figure 1. Study design.

Table 1. Complications reported in selected studies

	Number of Implants			
Complication	**Anterior Maxilla**	**EH**	**IH**	**MT**
Biological	82	28	53	1
Dehiscence	36	.	36	.
Recession	32	15	17	.
Fistula	13	13	.	.
Sinus communication	1	.	.	1
Technical	53	9	40	4
Abutment screw loosening	5	4	1	.
Crown-cement loosening	40	.	39	1
Screw loosening	1	.	.	1
Abutment fracture	2	2	.	.
Ceramic fracture	3	1	.	2
Ceramic chipping	2	2	.	.
Unfavorable esthetic	17	.	.	17
Total	152	37	93	22

EH, external hexagon; IH, internal hexagon; MT, Morse taper.

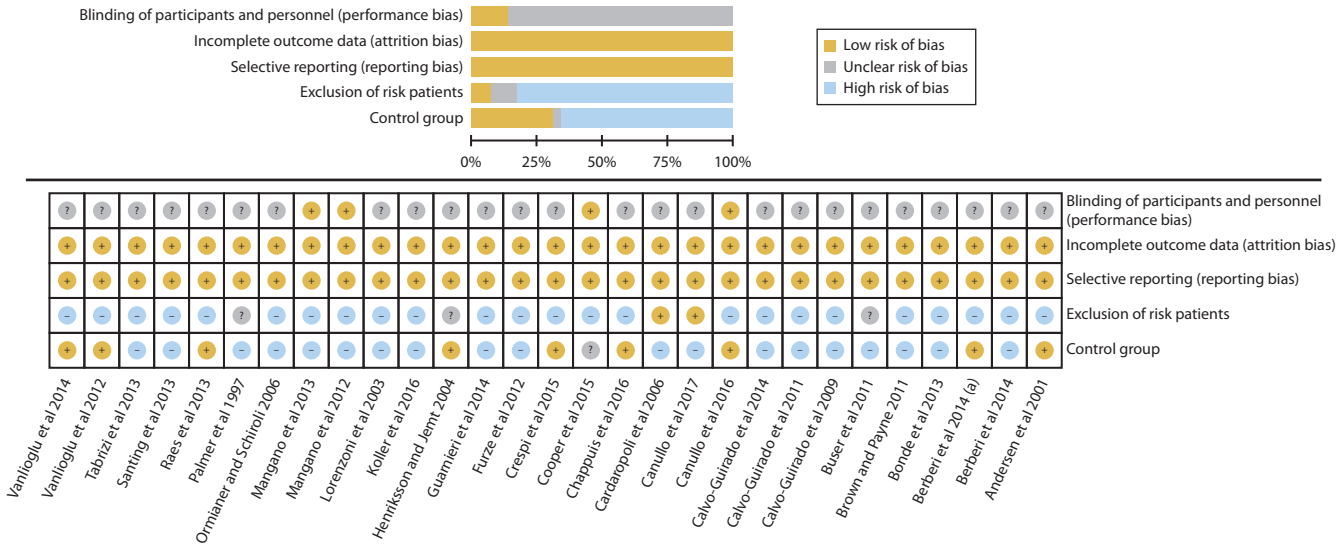

Figure 2. Risk of bias assessment. Review authors' judgment about each risk of bias item presented as percentages across all included studies and for each included study.

of 0.6 mm. Focusing on the connection type, the mean MBL was 0.4% for MT, 0.6% for EH, and 0.7% for IH (Supplemental Table 3).

Regarding the abutment material, the most used material was titanium (11 studies). Zirconia abutments were used in 5 studies, and the other 4 studies used both zirconia and titanium. Gold and alumina were used in 2 studies, and 7 did not report the abutment material. A cement-retained prosthesis was the main option (20 studies), while 3 studies used a screw-retained prosthesis and 1 used both. The retention type was not reported in 5 studies.

The majority of included studies had unclear risk of bias for blinding of participants and personnel. Most studies had low risk of bias for incomplete outcome data and selective reporting. Exclusion of risk patients and presence of a control group were the items with high risk of bias (Fig. 2). Only one RCT was identified in this review.

DISCUSSION

Few studies have assessed the esthetics of implant-retained prostheses objectively and the few that did used a variety of assessments. Nevertheless, in general all the implant-abutment connections were associated with good esthetic results in the anterior area. The PES/WES score was the most used approach and is a suitable evaluation method, validated by a clinical trial.[42] Moreover, it does not depend on survival, and its robust result is important for statistical analysis. The soft and hard tissue parameters are assessed by direct comparison with the natural, contralateral reference tooth, estimating the degree of match or eventual mismatch. The IH interface had the best PES/WES score, although this result came from only 1 study, while all connections presented satisfactory results, which may still be considered weak evidence. These results could be explained by the internal connection that reduces the bacterial count on the interface implant/abutment, decreasing bone loss around the implant and consequently improving the PES/WES score.

In evaluating some parameters for this review, confusion arose between the terms success and survival in implant dentistry. In this review, a study that incorrectly used the terms was corrected so that its results could be used.[19] However, in recent years, the correct use of success and survival criteria has increased. Survival means that the implant is in position, regardless of the quality of the restoration. Success means that the implant results in no pain, mobility, discomfort, or infection, is surrounded by stabilized bone, is capable of receiving the prosthesis, and has satisfactory esthetics.[11]

AFR was the most reported outcome found (86% of the studies). The MT interface had the best survival rate, followed by EH and IH. With respect to ASR, it was not possible to calculate for connection type because of the low number of studies evaluating this outcome. However, the total ASR was 4.8 for the esthetic zone. Rehabilitation with implants in the anterior maxilla is especially challenging because of the esthetic demand of the patients and the difficult pre-existing anatomy,[43] and these may explain the lower success rates in this area. The low AFR is in agreement with the high survival rates for single-tooth implants.[44] As expected, the AFR decreased in the studies with more than 1 year of follow-up; however, some failures in the first year may have been excluded which may have undervalued the AFR.

In general, the most common technical complications were abutment screw loosening and crown-cement

loosening. This finding is consistent with a previous systematic review.[44] In contrast, this same review found a high biological complication rate that was not found in the present study. A possible reason for this discrepancy is that the present study focused only on the anterior area, while Jung et al[44] considered outcome data from both anterior and posterior sites. The most common biological complications were dehiscence and recession. Considering the implant-abutment connection type, the most frequent complication was dehiscence for EH, crown-cement loosening for IH, and ceramic fracture for MT. In all situations evaluated, the MBL presented satisfactory values considering the acceptable value of 1.5 mm established in the literature at the first year.[12] The overall mean for the anterior maxilla was 0.6 mm. Focusing on the connection type, the best performance was for the MT, with a mean of 0.4 mm, followed by EH (0.6 mm), and IH (0.7 mm). The MT results can be explained by the lack of significant micromotion. A previous study[45] has shown the lower MBL in comparison with EH and even bone increase and contact with the abutment surface. Although the manufacturers name abutment material and retention type as the influencing factors of performance, conclusions could not be drawn on this issue.

Negative findings from the systematic review included poor descriptions of the results and a lack of studies with a long-term follow-up. In addition, the response rates from corresponding authors contacted via email was very low. One limitation of the results of the present review is only 1 RCT was included. The included studies were, in general, prospective, follow-up, and retrospective studies, with a high risk of bias for important items such as the exclusion of risk patients and presence of a control group. None of the studies discussed patient risk factors, such as periodontal disease or parafunctional habits, despite these being commonly encountered in patients requiring implant-supported restorations. The blinding of participants and personnel was unclear. An important limitation of this study is that the evidence generated by this review according to the risk of bias analysis was classified as low.

CONCLUSIONS

Based on the findings of this systematic review, the following conclusions were drawn:

1. MT implants performed best in terms of survival, MBL, and success.
2. IHs had the best results in esthetic evaluations, although all connections presented satisfactory values.
3. Controlled studies are needed to provide stronger evidence because that generated in this study was considered low.

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Supplemental Table 1. Search strategies for electronic databases

Database	Search strategy
PubMed	(((((“Dental Implants, Single-Tooth”[Mesh] OR “Dental Implants, Single Tooth” OR “Implant, Single-Tooth Dental” OR “Implant, Single Tooth Dental” OR “Implants, Single-Tooth Dental” OR “Implants, Single Tooth Dental” OR “Single-Tooth Implants” OR “Implant, Single-Tooth” OR “Implants, Single-Tooth” OR “Single Tooth Implants” OR “Single-Tooth Implant” OR “Single-Tooth Dental Implants” OR "Single Tooth Dental Implants" OR “Dental Implant, Single-Tooth” OR “Dental Implant, Single Tooth” OR “Single-Tooth Dental Implant” OR “Single Tooth Dental Implant”))) AND ((Aesthetic* OR esthetic* OR incisor* OR front* OR anterior*))) AND ((“Dental Implant-Abutment Design”[Mesh] OR “Dental Implant Abutment Design” OR “Design, Dental Implant-Abutment” OR “Designs, Dental Implant-Abutment” OR “Implant-Abutment Design, Dental” OR “Implant-Abutment Designs, Dental” OR “Dental Implant-Abutment Designs” OR “Dental Implant Abutment Designs” OR “Dental Implant-Abutment Interface” OR “Dental Implant Abutment Interface” OR “Dental Implant-Abutment Interfaces” OR “Implant-Abutment Interface, Dental” OR “Implant-Abutment Interfaces, Dental” OR “Interface, Dental Implant-Abutment” OR “Interfaces, Dental Implant-Abutment” OR “Dental Implant-Abutment Connection” OR “Connection, Dental Implant-Abutment” OR “Connections, Dental Implant-Abutment” OR “Dental Implant Abutment Connection” OR “Dental Implant-Abutment Connections” OR “Implant-Abutment Connection, Dental” OR “Implant-Abutment Connections, Dental” OR “Morse Taper Dental Implant-Abutment Interface” OR “Morse Taper Dental Implant Abutment Interface” OR “Morse Taper Dental Implant-Abutment Connection” OR “Morse Taper Dental Implant Abutment Connection” OR “Dental Implant Platform Switching” OR “Platform Switching, Dental Implant” OR external* OR internal*))) AND ((“Prospective Studies”[Mesh] OR “Prospective Study” OR “Studies, Prospective” OR “Study, Prospective” OR “Retrospective Studies”[Mesh] OR “Studies, Retrospective” OR “Study, Retrospective” OR “Retrospective Study” OR “Clinical Trial”[Publication Type] OR “Intervention Study” OR “Controlled Clinical Trial”[Publication Type] OR “Randomized Controlled Trial”[Publication Type] OR “Follow-Up Studies”[Mesh] OR “Follow Up Studies” OR “Follow-Up Study” OR “Studies, Follow-Up” OR “Study, Follow-Up” OR “Followup Studies” OR “Followup Study” OR “Studies, Followup” OR “Study, Followup”))
Scopus	(ALL ("Dental Implants, Single-Tooth" OR "Dental Implants, Single Tooth" OR "Implant, Single-Tooth Dental" OR "Implant, Single Tooth Dental" OR "Implants, Single-Tooth Dental" OR "Implants, Single Tooth Dental" OR "Single-Tooth Implants" OR "Implant, Single-Tooth" OR "Implants, Single-Tooth" OR "Single Tooth Implants" OR "Single-Tooth Implant" OR "Single-Tooth Dental Implants" OR "Single Tooth Dental Implants" OR "Dental Implant, Single-Tooth" OR "Dental Implant, Single Tooth" OR "Single-Tooth Dental Implant" OR "Single Tooth Dental Implant") AND ALL (aesthetic* OR esthetic* OR incisor* OR front* OR anterior*) AND ALL ("Dental Implant-Abutment Design" OR "Dental Implant Abutment Design" OR "Design, Dental Implant-Abutment" OR "Designs, Dental Implant-Abutment" OR "Implant-Abutment Design, Dental" OR "Implant-Abutment Designs, Dental" OR "Dental Implant-Abutment Designs" OR "Dental Implant Abutment Designs" OR "Dental Implant-Abutment Interface" OR "Dental Implant Abutment Interface" OR "Dental Implant-Abutment Interfaces" OR "Implant-Abutment Interface, Dental" OR "Implant-Abutment Interfaces, Dental" OR "Interface, Dental Implant-Abutment" OR "Interfaces, Dental Implant-Abutment" OR "Dental Implant-Abutment Connection" OR "Connection, Dental Implant-Abutment" OR "Connections, Dental Implant-Abutment" OR "Dental Implant Abutment Connection" OR "Dental Implant-Abutment Connections" OR "Implant-Abutment Connection, Dental" OR "Implant-Abutment Connections, Dental" OR "Morse Taper Dental Implant-Abutment Interface" OR "Morse Taper Dental Implant Abutment Interface" OR "Morse Taper Dental Implant-Abutment Connection" OR "Morse Taper Dental Implant Abutment Connection" OR "Dental Implant Platform Switching" OR "Platform Switching, Dental Implant" OR external* OR internal*) AND ALL ("Prospective Studies" OR "Prospective Study" OR "Studies, Prospective" OR "Study, Prospective" OR "Retrospective Studies" OR "Studies, Retrospective" OR "Study, Retrospective" OR "Retrospective Study" OR "Clinical Trial" OR "Intervention Study" OR "Controlled Clinical Trial" OR "Randomized Controlled Trial" OR "Follow-Up Studies" OR "Follow Up Studies" OR "Follow-Up Study" OR "Studies, Follow-Up" OR "Study, Follow-Up" OR "Followup Studies" OR "Followup Study" OR "Studies, Followup" OR "Study, Followup"))
Embase	‘dental implants single tooth’/exp OR ‘dental implants single tooth’ AND (‘aesthetic*’ OR ‘esthetic*’ OR ‘incisor*’ OR ‘front*’ OR ‘anterior*’) AND (‘dental implant-abutment design’/exp OR ‘external*’ OR ‘internal*’) AND (‘clinical article’/de OR ‘clinical trial’/de OR ‘cohort analysis’/de OR ‘comparative study’/de OR ‘controlled clinical trial’/de OR ‘controlled study’/de OR ‘human’/de OR ‘prospective study’/de OR ‘randomized controlled trial’/de OR ‘retrospective study’/de)
Cochrane Library	‘("Dental Implants, Single-Tooth" OR "Dental Implants, Single Tooth" OR "Implant, Single-Tooth Dental" OR "Implant, Single Tooth Dental" OR "Implants, Single-Tooth Dental" OR "Implants, Single Tooth Dental" OR "Single-Tooth Implants" OR "Implant, Single-Tooth" OR "Implants, Single-Tooth" OR "Single Tooth Implants" OR "Single-Tooth Implant" OR "Single-Tooth Dental Implants" OR "Single Tooth Dental Implants" OR "Dental Implant, Single-Tooth" OR "Dental Implant, Single Tooth" OR "Single-Tooth Dental Implant" OR "Single Tooth Dental Implant") and ("Dental Implant-Abutment Design" OR "Dental Implant Abutment Design" OR "Design, Dental Implant-Abutment" OR "Designs, Dental Implant-Abutment" OR "Implant-Abutment Design, Dental" OR "Implant-Abutment Designs, Dental" OR "Dental Implant-Abutment Designs" OR "Dental Implant Abutment Designs" OR "Dental Implant-Abutment Interface" OR "Dental Implant Abutment Interface" OR "Dental Implant-Abutment Interfaces" OR "Implant-Abutment Interface, Dental" OR "Implant-Abutment Interfaces, Dental" OR "Interface, Dental Implant-Abutment" OR "Interfaces, Dental Implant-Abutment" OR "Dental Implant-Abutment Connection" OR "Connection, Dental Implant-Abutment" OR "Connections, Dental Implant-Abutment" OR "Dental Implant Abutment Connection" OR "Dental Implant-Abutment Connections" OR "Implant-Abutment Connection, Dental" OR "Implant-Abutment Connections, Dental" OR "Morse Taper Dental Implant-Abutment Interface" OR "Morse Taper Dental Implant Abutment Interface" OR "Morse Taper Dental Implant-Abutment Connection" OR "Morse Taper Dental Implant Abutment Connection" OR "Dental Implant Platform Switching" OR "Platform Switching, Dental Implant" OR external* OR internal*) and (Aesthetic* OR esthetic* OR incisor* OR front* OR anterior*)’

Supplemental Table 2. Annual success rate (ASR) and annual failure rate (AFR) for selected studies

Year	Author	Study Type	Number of Implants	Loading Protocol	Mean Follow-Up (y)	Connection Type	Abutment Material	Prosthesis Retention	Success Rate	ASR	Survival Rate	AFR
1995	Haas et al[46]	Retrospective	76	D	6	EH	Ti	.	.	.	96.3%	0.44
1996	Malevez et al[47]	Retrospective	84	D	5	EH	Ti	.	.	.	97.6%	0.48
1997	Palmer et al[48]	Prospective	12	D	2	MT	.	CR	.	.	100%	0
2001	Andersen et al[27]	Prospective	55	D	3	EH	Zr/Au/none	CR	.	.	97%	1.23
2003	Lorenzoni et al[49]	Prospective	12	I	1	IH	.	.	.	.	100%	0
2004	Henriksson and Jemt[50]	Prospective	18	D	1	EH	Ti/Zr	CR	100%	100%	100%	0
2006	Ormianer and Schiroli[28]	Prospective	22	D/I	1.5	EH	.	CR		.	100%	0
2009	Calvo-Guirado et al[51]	Prospective	61	I	1	IH	Ti	CR	.	.	96.7%	1.64
2011	Brown and Payne[31]	Prospective	28	I	1	EH	Zr	SR	100%	100%	100%	0
2011	Buser et al[34]	Prospective	20	D	3	MT	Ti	SR	100%	100%	100%	0
2011	Calvo-Guirado et al[52]	Prospective	83	I	5	IH	Ti	CR	70%	21.34	100%	0
2012	Furze et al[36]	Prospective	10	D	1	MT	Zr	CR	100%	100%	100%	0
2012	Mangano et al[39]	Retrospective	26	I	2	MT	.	CR	100%	100%	100%	0
2012	Vanlioglu et al[53]	Prospective	23	D	5	MT	Ti/Zr	CR	.	.	100%	0
2013	Mangano et al[40]	Retrospective	40	D/I	2.7	MT	.	CR	100%	100%	100%	0
2013	Raes et al[41]	Prospective	48	D/I	1	MT	Ti	CR		.	98%	2.08
2013	Tabrizi et al[25]	Prospective	33	D	3	MT	.	.	.	.	100%	0
2014	Berberi et al[54]	Prospective	20	I	3	MT	.	CR	.	.	100%	0
2014	Calvo-Guirado et al[56]	Prospective	83	I	10	IH	Ti	CR	70%	11.31	100%	0
2014	Guarnieri et al[38]	Retrospective multicenter	46	I	2	IH	Ti	.	.	.	95.6%	2.20
2014	Vanlioglu et al[57]	Prospective	30	D	3*	MT	Ti/Zr	CR		.	100%	0
2015	Cooper et al[17]	Prospective multicenter	48 44	I	1	MT IH	Zr	CR	.	.	100% 86.4%	0 13.64
2015	Crespi et al[58]	Prospective	94	I	3	EH	.	.	.	.	100%	0
2016	Canullo et al[32]	RCT	30	D	5	IH	Ti	CR	.	.	100%	0
2017	Canullo et al[59]	Prospective	20	D	1.5	IH	Zr	CR	.	.	100%	0

CR, cement-retained; EH, external hexagon; I, immediate; IH, internal hexagon; M, mediate; MT, Morse taper; RCT, randomized controlled trial; SD, standard deviation; SR, screw-retained; Ti, titanium; Zr, zirconia. *Estimated because study did not report mean values.

Supplemental Table 3. Marginal bone loss (MBL) of selected studies

	Author	Study Type	Number of Implants	Loading Protocol	Mean Follow-Up (y)	Connection Type	Abutment Material	Prosthesis Retention	MBL	
									Mean (mm)	SD
1997	Palmer et al[48]	Prospective	12	D	2	MT	.	CR	0.36	0.13
2001	Andersen et al[27]	Prospective	55	D	3	EH	Zr/Au/none	CR	1.46	0.06
2003	Lorenzoni et al[49]	Prospective	12	I	1	IH	.	.	0.75	0.50
2004	Henriksson and Jemt[50]	Prospective	18	D	1	EH	Ti/Zr	CR	0.30	0.63
2006	Cardaropoli et al[60]	Prospective	11	D	1	EH	Al	CR	1.80	0.70
2009	Calvo-Guirado et al[51]	Prospective	61	I	1	IH	Ti	CR	0.09	0.01
2011	Brown and Payne[31]	Prospective	28	I	1	EH	Zr	SR	-0.98	2.67
2011	Buser et al[34]	Prospective	20	D	3	MT	Ti	SR	0.18	0.23
2011	Calvo-Guirado et al[52]	Prospective	83	I	5	IH	Ti	CR	0.97	0.39
2012	Mangano et al[39]	Retrospective	26	I	2	MT	.	CR	0.44	0.14
2012	Vanlioglu et al[53]	Prospective	23	D	5	MT	Ti/Zr	CR	0.21	.
2013	Mangano et al[40]	Retrospective	40	D/I	2.7	MT	.	CR	0.50	0.07
2013	Raes et al[41]	Prospective	48	D/I	1	MT	Ti	CR	0.38	0.62
2013	Santing et al[62]	Prospective cohort	60	D	1.5	MT	Ti/Zr	27 CR/33 SR	0.10	0.27
2013	Tabrizi et al[25]	Prospective	33	D	3	MT	.	.	0.75	0.14
2014	Berberi et al[54]	Prospective	20	I	3	MT	.	CR	0.27	0.17
2014	Berberi et al[55]	Prospective	42	I	5	MT	Ti/Zr	CR	0.20	0.01
2014	Calvo-Guirado et al[56]	Prospective	83	I	10	IH	Ti	CR	1.01	0.22
2014	Guarnieri et al[38]	Retrospective multicenter	46	I	2	IH	Ti	.	0.58	0.01
2014	Vanlioglu et al[57]	Prospective	30	D	3*	MT	Ti/Zr	CR	0.12	0.22
2015	Cooper et al[17]	Prospective multicenter	48 44	I	1	MT IH	Zr	CR	0.22 1.32	0.28 1.01
2015	Crespi et al[58]	Prospective	94	I	3	EH	.	.	0.81	0.40
2016	Canullo et al[32]	RCT	30	D	5	IH	Ti	CR	0.43	0.29
2016	Chappuis et al[35]	Prospective	61	D	5	MT	.	SR	1.31	.
2016	Koller et al[63]	Retrospective	16	D	5.7	EH	.	.	0.28	.
2017	Canullo et al[59]	Prospective	20	D	1.5	IH	Zr	CR	0.09	0.08

CR, cement-retained; EH, external hexagon; I, immediate; IH, internal hexagon; M, mediate; MT, Morse taper; RCT, randomized controlled trial; SD, standard deviation; SR, screw-retained; Ti, titanium; Zr, zirconia. *Estimated because study did not report mean values.

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