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REVIEW

Influence of implant location on the clinical outcomes of implant abutments: a systematic review and meta-analysis

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Purpose: To compare the failure events and incidence of complications of different abutment materials in anterior and posterior regions. Failure was defined as complete loss of the abutment requiring replacement by a new abutment.

Materials and methods: Electronic searches using PubMed/Medline and Google Scholar complemented with manual searches were performed with specific search terms. Searches were restricted to publications in English between January 2006 and March 2016.

Results: A total of 863 and 1,264 implants were inserted in the anterior and posterior regions, respectively, in a total of 1,529 patients. No titanium abutments failed in anterior or posterior regions. On the other hand, 1.6% of zirconia abutments failed in the anterior region and 1.5% failed in the posterior region. Technical complications occurred mostly in the posterior region and mostly involved zirconia abutment. Meta-analysis was possible only for zirconia-abutment failure, due to considerable heterogeneity of studies and outcome variables. No significant difference in failure rate was found between anterior and posterior zirconia abutments (risk ratio 1.53, 95% CI 0.49–4.77; P=0.47).

Conclusion: This systematic review and meta-analysis showed similar outcomes of different abutment materials when used in anterior and posterior regions in terms of failure events and biological and aesthetic complications. The only significant finding was the increased incidence of technical complications in the posterior region, mostly involving zirconia abutments. Abutment-screw loosening was the most common technical complication.

Keywords: implant abutment, zirconia, titanium, implant location, systematic review

Introduction

Implant-supported restorations are considered a viable and predictable treatment option for replacing a missing tooth.[1,2] Important parameters controlling the success of dental implants include proper case selection, surgical technique, and choice of implant-abutment material and design.[3]

Continuous research has led to the evolution of a variety of implant-abutment materials suitable for different clinical situations, in order to achieve ultimate mechanical, biological, and aesthetic outcomes. Implant-abutment materials that are currently used can be divided into two main categories: metal abutments and ceramic abutments. Metal-implant abutments include UCLA abutments, cast metal abutments, and titanium abutments, while ceramic abutments include alumina abutments and zirconia abutments. The clinical outcomes of different implant abutments are influenced by several factors; among these are the method of manufacture, implant–abutment connection, and implant location.[4]

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The location of the implant in the jaw has a significant influence on the magnitude of load generated by masticatory activity, with the highest biting force occurring at the first molar and the lowest biting force occurring at the incisors. The average values of occlusal forces reported in the anterior region range from 60 N to 270 N,[5] while in the premolar and molar regions the mean maximum masticatory forces are 179–294 N,[6] with much greater loads expected on restorations in patients with functional disorder, such as clenching or bruxism, with forces of 216–890 N.[7]

The implant location affects the magnitude of masticatory force that the implant abutment is subjected to, affecting the success rate and complications of the implant abutment. Therefore, the clinician's choice of implant-abutment material is influenced by the implant location in the jaw.

Several systematic reviews have reported on the success rate and incidence of technical, biological, and aesthetic complications of implant abutments without any comparison between anterior and posterior regions where all the abutments were pooled together.[8,9] Other systematic reviews have evaluated the outcomes of implant-abutment material in only the anterior region[10] or the posterior region.[11] Therefore, at present there are still limited data reflecting the differences between implant-abutment outcomes in anterior and posterior regions. As such, the aim of this study was to investigate the effect of implant location (anterior and posterior) on failure rates and technical, biological, and aesthetic complications of different implant-abutment materials (metal and ceramic). Failure was defined as complete loss of the abutment, requiring replacement by a new abutment.

Materials and methods

Focus question

The PICO (population, intervention, comparison, and outcome) question was stated thus: Does the location of implant restorations (anterior or posterior) have an effect on different implant-abutment materials in terms of survival, mechanical performance, and biological clinical outcomes?

- population: patients treated with dental implant restorations
- intervention: different implant-abutment material
- comparison: anterior and posterior locations
- outcome: survival, mechanical, biological, and aesthetic clinical outcomes.

Literature search

A Medline (PubMed) and Google Scholar search was performed for clinical studies published in dental journals from January 2006 up to and including March 2016. The search was limited to English-language publications. The electronic search was complemented by manual searching of the bibliographies of the most recent systematic reviews and of all full articles selected to maximize the likelihood of capturing all relevant publications. Key terms included in the search were implant abutment material, zirconia abutments, titanium abutments, gold abutments, UCLA abutments, CadCam abutments, customized abutments, pre-fabricated abutments, alumina abutments, ceramic abutments, and aesthetic abutments.

Study selection

All publications found were entered into reference-manager software (EndNote, Thomson Reuters Research Soft) to sort selected studies and to discard duplicate references. The criteria for study inclusion were articles in English, articles published in the last 10 years (2006–2016), human clinical studies, at least five patients included in each study, and mean follow-up of at least 1 year. The criteria for study exclusion were articles not pertaining to the inclusion criteria, articles from which data on selected outcome variables could not be directly extracted or calculated, articles pertaining only to one-piece implants, articles with provisional or interim abutments only, animal studies, in vitro experiments, technique, review, or discussion articles, and human clinical studies with fewer than five patients.

All obtained titles identified from the broad electronic and manual search were screened by two independent reviewers to eliminate articles that clearly failed to meet the inclusion and exclusion criteria. Disagreements were resolved by discussion. This was followed by obtaining and screening abstracts of all titles agreed upon by both investigators. Based on the selection of abstracts, articles were obtained in full text. If title and abstract did not provide sufficient information regarding the inclusion criteria, the full report was obtained as well. Again, any disagreement was resolved by discussion. Finally, the selection of full-text articles based on inclusion/exclusion criteria was made. For this purpose, the Materials and methods, Results, and Discussion sections of these studies were screened. Any questions that came up during the screening were discussed between the two reviewers to aim for consensus.

Quality assessment

The quality of eligible studies was assessed independently by two authors. Randomized controlled trials (RCTs) were assessed for bias according to the Cochrane Collaboration

tool. This tool uses six domains (random-sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, and selective reporting) to investigate selection, performance, detection, attrition, and reporting biases.[12]

The quality of nonrandomized clinical studies was assessed using the Newcastle–Ottawa scale. This scale includes nine domains using a star system based on three aspects: selection of the study groups (up to 4 points), comparability of the groups (up to 2 points), and exposure or outcome (up to 3 points).[13] Due to the variability in the quality of the observational studies found in our initial literature search, we considered studies that met five or more of the Newcastle–Ottawa scale score criteria as good quality and included them in our study.

For other types of studies, the quality-assessment tool used was based on an earlier tool developed by den Hartog et al focusing on the criteria: Are the characteristics of the study group clearly described?; Is there a high risk of selection bias?; Are the inclusion and exclusion criteria clearly described?; Is the intervention clearly described?; Are all patients treated according to the same intervention?; Are the outcomes clearly described?; Are adequate methods used to assess the outcome?; Is blinding used to assess the outcome?; Is there a sufficient follow-up?; Can selective loss to follow-up sufficiently be excluded?; Are the most important confounders or prognostic factors identified, and are these taken into consideration with respect to the study design and analysis?[14] It was decided that studies scoring five or more pluses were considered acceptable.

Data extraction

A data-extraction sheet was used by two reviewers to extract the relevant data from the included papers. Information on several parameters was recorded: author(s), study design, year of publication, mean follow-up time, abutment manufacturer, number of patients, number of abutments, implant location (anterior or posterior), abutment material, abutment-failure events, implant failures, and incidence of biologic, technical, and aesthetic complications of abutments. Disagreement regarding data extraction was resolved by consensus. Based on the included studies, the number of events of complications or failures was calculated. Where the publication did not provide sufficient information, the corresponding authors were contacted via email.

The anterior region was defined as the area from canine to canine, and the posterior region was defined as the area distal to the canines. Failure was defined as complete loss of the abutment requiring replacement by a new abutment. Technical complications included abutment-screw fracture and abutment-screw loosening. Prosthetic complications included misfit at the implant–abutment junction (gap), fracture of the implant prosthesis, chipping of the veneering ceramic, and loosening of the implant prosthesis. Biological complications included recession, peri-implant bone loss, peri-implant pockets >3 mm, peri-implant mucosal defects, fistulas, and suppuration on probing.

Statistical analysis

Meta-analysis was performed using the statistical software package RevMan (version 5.3; Nordic Cochrane Centre, Copenhagen, Denmark) to collect the data, calculate the overall estimated effects, and produce the forest plots. RRs for abutment failure with 95% CIs were calculated. The pooled effect was considered significant if $P<0.05$. Discrepancies between studies in estimating the effect of treatment were assessed using Cochran's Q test for heterogeneity and associated significant heterogeneity was indicated by $P<0.1$. The I^2 statistic was used to describe variations across studies due to heterogeneity, and with I^2 values more than 50%, considerable heterogeneity among studies could be present.

Results

Study selection

The initial database search yielded 1,902 studies after duplicate references had been discarded (Figure 1): 222 potentially relevant titles were selected by two reviewers for abstract evaluation, of which 37 studies were considered for full-text analysis; 14 studies were added after manual searching of the bibliographies of the most recent systematic reviews and of all full articles selected, resulting in a total of 51 articles; 32 studies were finally selected for systematic review and qualitative analysis after screening on the basis of the inclusion and exclusion criteria. The excluded studies and reasons for their exclusion are listed in Table 1. Of the 32 studies, five were eligible for inclusion into a meta-analysis. The 32 studies that met the inclusion criteria are presented in Table 2. A total of seven studies were RCTs, 21 were prospective studies, and the remaining four were retrospective studies.

Quality assessment

Summaries of the methodological-quality assessment of included studies using the Cochrane risk-of-bias tool and Newcastle–Ottawa Scale are provided in Tables 3 and 4, respectively. For the RCTs, information indicating a low risk of bias was found in two studies. One study revealed unclear

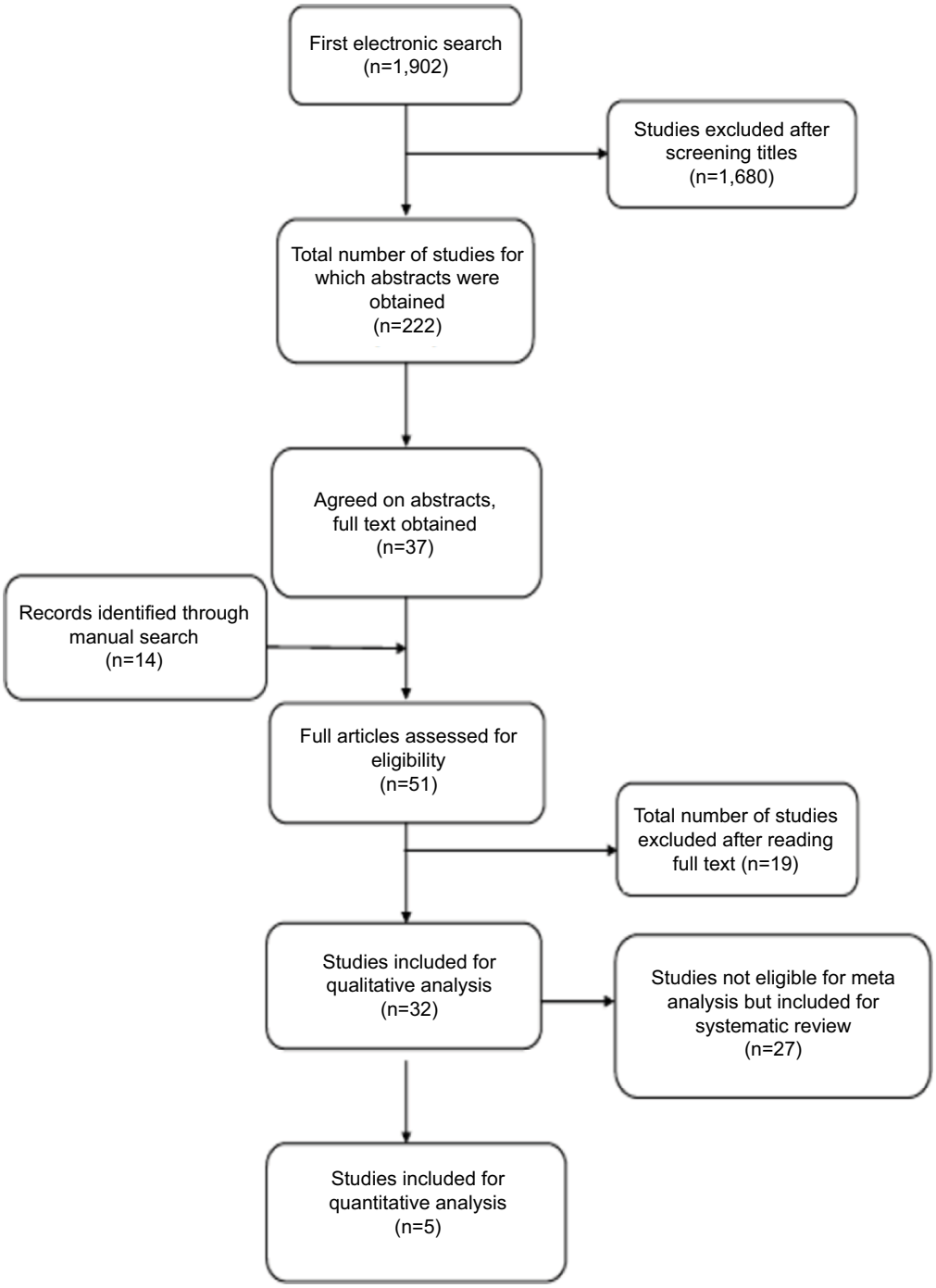

Figure 1 Search strategy flowchart.

risk of bias in one key domain. Another study showed high risk of bias in two key domains. For one study, high risk of bias was found in three key domains. Another study showed high risk of bias in three key domains, as well as two unclear risks of bias in two key domains. A further study revealed two key domains with high risk of bias and two key domains with unclear risk of bias. According to 2011 definitions,[12] the overall ranking revealed only two studies with a low risk of bias. All of the studies revealed a tendency of a high risk of bias, resulting in an overall unclear and high risk of bias across studies.

On the other hand, the scores of the 12 nonrandomized studies eligible for the Newcastle–Ottawa scale ranged 5–8, and the mean score was 6.9. For the other 13 studies assessed by den Hartog et al quality-assessment tool,[14] all those included had a score of 5 or more.

Table 1 Excluded articles and reasons for exclusion

Study	Reason for exclusion
Bonde et al[15]	Did not allow data extraction
Bressan et al[16]	No follow-up
Büchi et al[17]	No follow-up
Camargos et al[18]	Did not allow data extraction
Cooper et al[19]	Did not allow data extraction
Cosgarea et al[20]	No follow-up
Deporter et al[21]	Did not allow data extraction
Ferrari et al[22]	Did not allow data extraction
Happe et al[23]	No follow-up
Kreissl et al[25]	Did not allow data extraction
Jung and Yoon[24]	Did not allow data extraction
Payer et al[26]	Single-piece implant
Pettersson and Sennerby[27]	Did not allow data extraction
Redemagni et al[28]	Did not allow data extraction
Rompen et al[29]	Did not allow data extraction
van Brakel et al[30]	No follow-up
van Brakel et al[31]	3-month follow-up
Vanlıoğlu et al[32]	Did not allow data extraction
Visser et al[33]	Did not allow data extraction

Included studies

The patients in the included studies were treated in university (24 studies), private practice (five studies), and multicenter (one study) settings, while in two studies the setting was not reported. A total of 2,127 implants were placed in 1,529 patients aged 17–77 years, with a mean age of 42.1 years. The majority of studies (17) reported on anterior and posterior abutment, while eight reported on anterior abutment only and seven described posterior abutment only; 19 studies evaluated implant systems with internal implant–abutment connections, ten evaluated implant systems with external implant–abutment connection, and three reported on both internal and external implant–abutment connections. Almost all studies reported use of abutments to support single-crown restorations (29 studies), one study reported use of abutments to support fixed partial dentures, and two studies reported use of both. The majority of the studies (24) reported use of

Table 2 Characteristics of included studies

Study	Type	Setting	Patients, n	Mean age, years	Mean follow-up, years
de Albornoz et al[34]	RCT	University	26	51.7	1
Bae et al[35]	Prospective	University	19	47	1
Cabello et al[36]	Prospective	Private	14	52	1
Canullo and Götz[37]	Prospective	NR	5	49.1	1.5
Canullo[38]	Prospective	Private	25	52.28	3.3
Cionca et al[39]	Prospective	University	32	51.9	1.6
Cooper et al[40]	Prospective	University	41	30.6	3
Cosyn et al[41]	Prospective	University	25	54	3
den Hartog et al[42]	RCT	University	62	39.3	1.5
Ekfeldt et al[43]	Retrospective	Private	130	23	NR
Furze et al[44]	Prospective	Private	10	45.1	1
Galluci et al[45]	RCT	University	20	NR	2
Gotfredsen[46]	Prospective	University	20	33	10
Guljé et al[47]	Prospective	Multicenter	21	57	1
Hosseini et al[48]	RCT	University	36	28.1	1
Hosseini et al[49]	Prospective	University	59	27.9	3
Jemt[50]	Retrospective	University	35	33.5	10
Kim et al[51]	Prospective	University	213	56.5	3.6
Lee and Hasegawa[52]	Prospective	NR	9	42	1
Lops et al[53]	Prospective	University	81	54	5
Lops et al[54]	Prospective	University	72	46	2
MacDonald et al[55]	Prospective	University	20	43.5	NR
Nejatidanesh et al[56]	Retrospective	University	122	50	4.9
Nothdurft and Pospiech[57]	Prospective	University	24	NR	1
Passos et al[58]	Retrospective	University	141	NR	NR
Payer et al[59]	RCT	University	30	NR	2
Pozzi et al[60]	Prospective	University	27	54.18	3.6
Vanlıoglu et al[61]	Prospective	University	12	33.2	5
Vigolo et al[62]	RCT	University	20	NR	4
Vigolo and Givani[63]	Prospective	Private	144	37	5
Zembic et al[64]	RCT	University	18	41.6	5.6
Zembic et al[65]	Prospective	University	16	46	11.3

Abbreviations: RCT, randomized controlled trial; NR, not reported.

Table 3 Risk of bias for randomized controlled trials

Study	Random-sequence generation	Allocation concealment	Blinding (participants and personnel)	Blinding (outcome assessment)	Incomplete outcome data addressed	Selective reporting	Other bias
De Albornoz et al[34]	Low	Low	Low	Low	Low	Unclear	No
den Hartog et al[42]	Low	Low	Low	Low	Low	Low	No
Galluci et al[45]	Low	Low	Low	Low	Low	Low	No
Hosseini et al[48]	High	Low	Low	Low	High	Low	No
Payer et al[59]	Low	Low	High	High	High	Low	No
Vigolo et al[62]	Low	Unclear	High	High	Low	Unclear	No
Zembic et al[64]	Low	Unclear	Unclear	High	High	High	No

Table 4 Quality of included studies using Newcastle–Ottawa scale

Study	Selection****	Comparability**	Outcome***	Score
Canullo[38]	****	*	*	6
Gotfredsen[46]	****	*	**	7
Hosseini et al[49]	****	*	***	8
Jemt[50]	****	*	***	8
Kim et al[51]	**	*	**	5
Lops et al[53]	****	*	***	8
Lops et al[54]	****	*	**	7
Nejatidanesh et al[56]	***	*	***	7
Passos et al[58]	**	*	***	6
Pozzi et al[60]	**	**	***	7
Vanlıoglu et al[61]	****	*	**	7
Vigolo and Givani[63]	****	*	**	7

Note: Each * refers to the number of points. Selection of the study groups (up to 4 points), comparability of the groups (up to 2 points), and exposure or outcome (up to 3 points)..

cement-retained restorations. Screw-retained restorations were reported exclusively in eight studies, and six studies reported the use of both cement- and screw-retained restorations. For definitive crown material fabricated over the abutments, 16 studies reported on the use of all-ceramic crown, seven on metal ceramic crowns, eight on both all-ceramic and metal ceramic crowns, and one did not mention the type of crown used (Table 5).

The 32 studies included a total number of 2,127 implants placed in 1,529 patients, with follow-up of 1–12 (mean 3.3) years. A total of 863 implants were placed in the anterior region and 1,264 implants in the posterior region. Altogether, 1,242 zirconia abutments, 646 titanium abutments, and 239 UCLA abutments were evaluated at follow-up in the included studies. Of the total number of zirconia abutments, 623 zirconia abutments were used in the anterior region and 619 in the posterior region. Titanium abutments were divided into 214 abutments in the anterior region and 432 in the posterior region. There were 26 UCLA abutments in the anterior region and 213 in the posterior region.

Implant abutments in the anterior region

A total number of 863 abutments were placed in the anterior region, of which 623 were zirconia abutment, 214 titanium abutments, and 26 UCLA abutments. Abutment failure occurred in ten abutments, all of which were zirconia. The failure manifested as abutment fracture. No abutment failure was reported in titanium or UCLA abutments.

One implant restored with a titanium abutment was lost at the 1-month follow-up due to mobility. Only one implant supporting a titanium abutment was lost after loading in the anterior region. Nine technical complications were reported: six related to zirconia abutments and three related to titanium abutments. All the nine technical complications were abutment-screw loosening. A total of 34 prosthetic complications were reported: 19 related to zirconia abutments, 14 related to titanium abutments, and 1 related to a UCLA abutment. Prosthetic complications were minor chipping of porcelain (17), loss of crown retention (13), and major complications leading to crown remake (four), such as major chipping of porcelain and unacceptable marginal adaptation. There were 16 biological complications reported: nine related to zirconia abutments, five to titanium abutments, and two to UCLA abutments. Biological complications were recession (eight), buccal fistulas (six), peri-implant bone loss >2 mm (one), and peri-implant mucosal defect (one). There were no aesthetic complications reported, although two studies reported better aesthetic outcomes for zirconia abutments.[34,49]

Table 5 Abutment material and prosthetic characteristics

Study	Type of implant restoration	Type of abutment connection	Type of abutment material	Abutment manufacturer	Prosthetic restoration material	Nature of prosthetic restoration
de Albornoz et al[34]	Single crown	Internal	Prefabricated Zr and Ti abutments	Ti/SPI Easy-Zr/Spy Art	AC	Cement retained
Bae et al[35]	Single crown and FPDs	External	Prefabricated alumina-toughened Zr abutment	ZirAce, Acucera	AC	Cement retained
Cabello et al[36]	Single crown	Internal	UCLA and prefabricated Zr and custom-made Zr	Straumann	MC, AC	Screw retained (12) and cement retained (2)
Canullo and Götz[37]	Single crown	Internal	Prefabricated Ti	Sweden and Martina	MC	Cement retained
Canullo[38]	Single crown	Internal	CadCam Zr on a prefabricated Ti base	ProUnic abutment, implanted with Zirkonzahn	AC	Cement retained
Cionca et al[39]	Single crown	Internal	Prefabricated Zr	Zeramex T implant system; Dental Point	AC	Cement retained
Cooper et al[40]	Single crown	Internal	Prefabricated Ti	Astra abutment ST titanium	NR	Cement retained
Cosyn et al[41]	Single crown	Internal	Prefabricated Ti	Aesthetic abutment, Nobel Biocare	MC	Cement retained
den Hartog et al[42]	Single crown	Internal	Individually fabricated Zr	Procera, Nobel Biocare	AC	Cement and screw retained
Ekfeldt et al[43]	Single crown	Internal and External	CadCam Zr	Procera, Nobel Biocare	AC	One-piece screw and cement retained
Furze et al[44]	Single crown	Internal	CadCam Zr	Straumann	AC	Cement retained
Galluci et al[45]	Single crown	Internal	Prefabricated Ti coupled with In-Ceram alumina or cast-gold alloy	SynOcta 1.5 screw-retained abutment, Straumann	MC, AC	Two-piece screw retained
Gotfredsen[46]	Single crown	Internal	Prefabricated and custom-made Ti	Astra abutment ST titanium, Astra preparable abutments	MC	Cement retained
Guljé et al[47]	Single crown	External	Custom-made titanium abutments	Atlantis, Dentsply	AC	Cement retained
Hosseini et al[48]	Single crown	Internal	Prefabricated Zr and Ti and gold abutments	ZirDesign (Astra Tech), Ti Design (Astra Tech), Cast-To (Astra Tech)	MC,AC	Cement retained
Hosseini et al[49]	Single crown	Internal	UCLA-prefabricated Zr-prefabricated Ti	Astra Tech	MC, AC	Cement retained
Jemt[50]	Single crown	External	Prefabricated titanium	TiAdapt and CeraOne, Nobel Biocare	MC	One-piece screw retained and externally cemented crowns with single-abutment screw
Kim et al[51]	Single crown and FPDs	External	Prefabricated alumina-toughened Zr abutment	ZirAce, Acucera	MC, AC	One-piece screw and cement retained
Lee and Hasegawa[52]	Single crown	Internal	Prefabricated Zr with a Ti interface ring	Zimmer contour all ceramic abutment	AC	Cement retained
Lops et al[53]	Single crown	Internal	Prefabricated Zr and Ti abutments	Ti/profile bi abutment, Astra Tech Zr/ceramic abutment ST ZirDesign abutment, Astra Tech	MC, AC	Cement retained
Lops et al[54]	Single crown	External	Prefabricated Zr and Ti, CadCam Zr and Ti	ZirDesign (Astra Tech), TiDesign (Astra Tech), Zr Atlantis, Ti Atlantis	MC, AC	Cement retained

(*Continued*)

Table 5 (*Continued*)

Study	Type of implant restoration	Type of abutment connection	Type of abutment material	Abutment manufacturer	Prosthetic restoration material	Nature of prosthetic restoration
MacDonald et al[55]	Single crown	External	Prefabricated Ti	Not reported	MC	Screw retained
Nejatidanesh et al[56]	Single crown	Internal	Prefabricated Ti	SynOcta, Straumann	AC	Cement retained
Nothdurft and Pospiech[57]	Single crown	Internal	Prefabricated Zr	Cercon abutment, Dentsply Friadent	AC	Cement retained
Passos et al[58]	Single crown	Internal and External	Prefabricated and customized Zr	3i, Astra Tech, Nobel Biocare, Straumann	AC	Cement retained
Payer et al[59]	Single crown	Internal	Prefabricated Zr and Ti abutments	Ziteron Zr abutment, Ziteron Ti abutment	AC	Cement retained
Pozzi et al[60]	FPD	Internal and External	CadCam Zr and Ti	Procera, Nobel Biocare	AC	Cement retained
Vanlıoglu et al[61]	Single crowns	Internal	Prefabricated Ti and custom-made Zr MAD/MAM (Zirkonzhan, Steger)	Not reported	AC	Cement retained
Vigolo et al[62]	Single crown	External	Titanium and gold UCLA	Ti, Procera, Nobel Biocare, gold, SGUCA1C, 3i, Implant Innovations	MC	Cement retained
Vigolo and Givani[63]	Single crown	External	Custom-made gold UCLA	SWGA51C, SGUCA1C, 3i, Implant Innovations	MC	Cement retained
Zembic et al[64]	Single crown	External	CadCam Ti and CadCam Zr	Procera, Nobel Biocare	MC, AC	Cement and two screws retained
Zembic et al[65]	Single crown	External	Customized experimental Zr abutments	Wohlwend	AC	Cement retained

Abbreviations: MC, metal ceramic; AC, all ceramic; FPDs, fixed partial dentures.

In general, studies showed minimal differences in aesthetic outcomes and patient satisfaction when comparing ceramic and metal abutments (Table 6).

Implant abutments in the posterior region

Altogether, 1,264 abutments were placed in the posterior region: 619 zirconia, 432 titanium, and 213 UCLA. Failure occurred in nine of the zirconia abutments, manifesting as abutment fracture. No abutment failures were reported in titanium or UCLA abutments (Tables 6 and 7). A total of 14 implants were lost due to loss of osseointegration: ten were supporting zirconia abutments and four supporting titanium abutments. A total of 27 technical complications were reported, the majority of which occurred in zirconia abutments (25 of 27), while two occurred in titanium abutments. All technical complications were abutment-screw loosening, except one, a screw fracture that occurred in an external-connection zirconia abutment. A total of 32 prosthetic complications were reported: eleven related to zirconia-supported crowns and 21 to metal-supported crowns. The majority of prosthetic complications were minor chipping of porcelain (29); the other complication was loss of retention, one of which needed to be remade. There were eleven biological complications: four related to zirconia abutments and seven to metal abutments. Six of the complications were suppuration on probing and pocket depth >5 mm, four were buccal marginal fistulas, and one was implant mucositis (Table 6).

Meta-analysis

Due to heterogeneity of study designs and reported data, only within-study comparison of failure events of anterior and posterior zirconia-implant abutments was possible, and this was feasible in only five studies involving 660 implants (one RCT, three prospective, one retrospective), which is illustrated as a forest plot in Figure 2. Based on the fixed-effect model, no significant difference in failure rates were found between anterior and posterior zirconia abutments (RR 1.53, 95% CI 0.49–4.77; P=0.47). No within-study (χ^2=2.09, P=0.72) or between-study (I^2= 0) heterogeneity was observed.

Publication bias

Visual examination of the funnel plot indicated low-level publication bias evident from the symmetrical distribution for all studies (Figure 3).

Discussion

Systematic reviews are often useful in the evaluation of different materials, since they extract the best evidence from the scientific literature; therefore, this systematic review and meta-analysis was conducted to compare the clinical outcome of different abutment materials on abutment-failure rate and technical, prosthetic, biological, and aesthetic outcomes in anterior and posterior regions. Due to heterogeneity of the included studies, variation of data included, and outcome results, a meta-analysis was feasible only for zirconia-abutment failure in anterior and posterior regions. All the reported abutment failures manifested as fractures. The results of the meta-analysis showed that implant-abutment failure did not seem to be affected by position in the jaw. Zirconia abutments exhibited similar fracture rates in anterior and posterior regions. On the other hand, no titanium abutments fractured. Usually, fractures of metal abutments are scarce. This is in accordance with another systematic review that indicated a fracture rate of 0.07% at 5 years.[8] The majority of data available endorsing zirconia abutment loading refer to stimulated treatments of anterior teeth.[66–69] These in vitro studies suggested that zirconia abutments were suitable to withstand occlusal loading for anterior sites in normal human subjects with fractures at loads above 400 N.[70] On the other hand, in vitro studies involving ceramic-implant abutments with a focus on stimulated treatments of posterior teeth were not found in the published literature.

A previous systematic review showed that failures in the anterior region were restricted to ceramic abutments,[10] but this is in contrast to other systematic reviews reporting no differences in the survival and failure rates of ceramic and metal abutments.[8,9,11] Therefore, superior clinical behavior for zirconia might be expected, and it might even serve as an alternative to metal in various indications.

Our study showed significant differences in implant-failure rates in anterior and posterior regions (0.1% anterior, 1.1% posterior), all of which were lost after loading. In the posterior region, 1.6% of implants supporting zirconia abutments and 0.9% of implants supporting titanium abutments failed. Failure reasons ranged from loss of osseointegration, marginal bone loss ≥2 mm, and aseptic loosening. Long-term implant-survival studies have even indicated that the posterior maxilla presents the lowest survival rate.[71,72] One of the studies identified in this systematic review described the use of two-piece zirconia abutments, which contributed to five of the 14 implants lost in the posterior region.[39]

Technical complications were detected primarily in posterior regions, reflecting the high functional loading in this region. Complications were mostly observed in zirconia abutments. Abutment-screw loosening was the most common technical complication, accounting for all but one (abutment-screw fracture) of the total complications. This is in accordance with previous systematic reviews.[8–10] The incidence of screw loosening was minimal across the included studies, except for one,[51] which accounted for 23 of the total screw-loosening events. In that study, alumina-toughened zirconia abutments were used.

Prosthetic complications showed no significant differences in anterior and posterior regions, regardless of abutment material used. The most common complications were minor chipping of porcelain and loss of crown retention, probably due to provisional cementation. Biological complications reported in the anterior region were buccal fistulas and gingival recessions, while in the posterior region only buccal fistulas were reported. A reason for this may be the increased risk of recession of thin gingiva in the anterior region compared to thicker gingiva in the posterior region.[8] Biological outcomes did not reveal any differences between different abutment materials. This is in accordance with a systematic review[8] and an animal study,[73] which exhibited similar soft-tissue integration of different abutment materials. Only one of the included studies reported on probing depth ≥5 mm and/or suppuration affecting three implants supporting zirconia abutments in the posterior region.[48] No aesthetic complications were reported in any of the included studies.

There was diversity in methods of assessment and measurements of aesthetic outcomes. Overall, no significant differences were found between zirconia and titanium abutments. The results of our study are in accordance with another systematic review,[10] but in contrast to two other systematic reviews,[8,74] which demonstrated superiority of ceramic abutments in terms of aesthetic outcome.

It is widely accepted that RCTs provide "gold standard" evidence of the effectiveness of therapies. However, probably due to costs associated with this type of research and due to ethical reasons, there is a scarcity of RCTs in implant research. Nonetheless, relevant information is not provided exclusively by RCTs. Cohort studies, case series, and clinical trials can still offer valuable longitudinal information. As such, those types of studies were considered for evaluation too.

A total of 13 studies included for this review could be classified as case series, and consequently were of a lower level of evidence. Although these studies were acceptable methodologically within their framework and well documented, results of these studies require cautious

Table 6 Comparison of clinical outcomes in anterior and posterior regions

Study	Anterior			
	Technical complications	**Prosthetic complications**	**Biological complications**	**Aesthetic complications**
de Albornoz et al[34]	None	None	None	None
Bae et al[35]	None	None	None	NR
Cabello et al[36]	None	1 loss of retention of crown (abutment material not reported)	None	None
Canullo and Götz[37]	NR	NR	None	NR
Canullo[38]	None	NA	None	NR
Cionca et al[39]	None	NA	None	None
Cooper et al[40]	None	3 minor chipping of porcelain (Zr), loss of retention of 2 crowns (Zr)	Tenderness of buccal mucosa and peri-implant mucosal defect (1 Zr)	NR
Cosyn et al[41]	1 implant lost due to mobility (Ti)	Loss of retention of 1 MC crown (Ti)	Mid-facial recession of mucosa (1 Ti)	None
den Hartog et al[42]	None	None	None	None
Ekfeldt et al[43]	1 abutment screw loosening (Zr)	3 minor chipping of porcelain (Zr)	None	None
Furze et al[44]	None	None	None	None
Galluci et al[45]	None	2 minor chipping of porcelain (2 Ti)	None	None
Gotfredsen[46]	2 abutment-screw loosening (Ti)	2 crowns remade (Ti), 1 due to abutment loosening and 1 due to major ceramic fracture	1 buccal fistula (Ti)	NR
Guljé et al[47]	—	—	—	
Hosseini et al[48]	—	—	—	—
Hosseini et al[49]	None	1 major chipping of porcelain (remade) (Zr), loss of retention of 1 MC crown (Ti), 1 unacceptable marginal adaptation (remade), 1 UCLA	5 buccal fistulas (3 Zr + 2 UCLA)	None
Jemt[50]	NA	None	1 buccal fistula (Ti) 2 gingival recession (Ti)	NR
Kim et al[51]	1 abutment-screw loosening (Zr)	NR	None	NR
Lee and Hasegawa[52]	None	None	None	None
Lops et al[53]	—	—	—	—
Lops et al[54]	1 abutment-screw loosening (Zr)	None	None	NR
MacDonald et al[55]	1 abutment-screw loosening (Ti)	None	None	NR
Nejatidanesh et al[56]	None	7 minor chipping of porcelain (Ti)	NA	None
Nothdurft and Pospiech[57]	—	—	—	—

Posterior				Other
Technical complications	**Prosthetic complications**	**Biological complications**	**Aesthetic complications**	**Notes**
None	None	None	None	
None	None	None	NR	
—	—	—	—	
—	—	—	—	
None	NA	None	NR	1 minor chipping of porcelain (Zr), site not reported
5 implants lost due to aseptic loosening (Zr)	NA	None	None	1 minor chipping of porcelain (Zr), site not reported
—	—	—	—	
—	—	—	—	
None	None	None	None	
None	None	None	None	
None	None	None	None	
—	—	—	—	
NA	NA	None	NR	2 minor porcelain fracture (Ti), position not reported 2 crown loosening (Ti), position not reported 1 implant ≥2 mm bone loss (Ti), position not reported
None	None	None	None	
None	1 minor chipping of porcelain (abutment material not reported) Loss of retention of 1 MC crown (remade) (abutment material not reported)	1 buccal fistula (Zr) 1 suppuration on probing (Zr) 2 pocket depth ≥5 mm (Zr) 3 suppuration on probing and pocket depth ≥5 mm (abutment material not reported)	None	
None	Loss of retention of 2 MC crowns (Ti)	None	None	
NA	None	3 buccal fistulas (Ti)	NR	5 screw loosening (Ti), location not reported
23 abutment-screw loosening (Zr), 1 abutment-screw fracture (Zr)	NR	None	NR	
—	—	—	—	
2 screw loosening (1 Zr, 1 Ti)	7 minor chipping of porcelain (4 Zr, 3 Ti)	Mucositis of implant supporting metal crown (Ti)	NR	
1 abutment-screw loosening (Ti)	None	None	NR	
1 implant lost due to marginal bone loss ≤2 mm (Zr)	None	None	NR	1 abutment-screw loosening (Ti), location not reported
1 implant lost due to loss of osseointegration (Ti)	12 minor chipping of porcelain (Ti)	NA	None	14 implants had pocket depth ≥4 mm (Ti) location not reported
None	4 minor chipping of porcelain (Zr)	None	NR	

(*Continued*)

Table 6 (*Continued*)

Study	Anterior			
	Technical complications	**Prosthetic complications**	**Biological complications**	**Aesthetic complications**
Passos et al[58]	1 abutment-screw loosening (Zr)	7 crown decementation (Zr)	5 gingival recession ≥2 (Zr)	NR
Payer et al[59]	None	None	None	None
Pozzi et al[60]	—	—	—	—
Vanlıoglu et al[61]	1 abutment-screw loosening (abutment material not reported)	None	None	None
Vigolo et al[62]	—	—	—	—
Vigolo and Givani[63]	—	—	—	—
Zembic et al[64]	None	1 minor chipping of porcelain (Ti)	None	None
Zembic et al[65]	2 screw loosening (Zr)	3 minor chipping of porcelain (Zr)	None	NR
Total	1 implant lost (Ti)/6 abutment loosening (Zr)/3 abutment loosening (Ti)	12 loss of crown retention/19 minor chipping/two major ceramic fracture/ one unacceptable margin	7 fistulas (3 Zr, 2 Ti, 2 UCLA)/8 recession (5 Zr, 3 Ti)	

Abbreviations: NA, not available; NR, not reported.

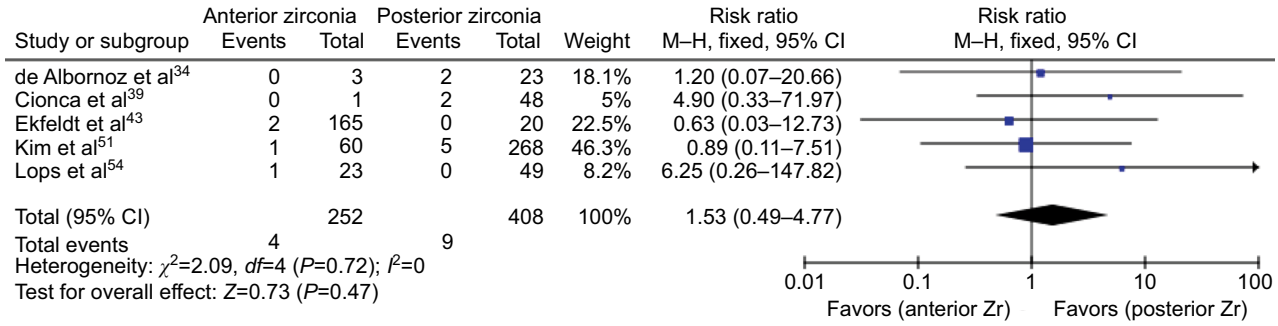

Figure 2 Forest plot of comparison.
Notes: Anterior zirconia versus posterior zirconia. Outcome: abutment failure.
Abbreviation: M–H, Mantel–Haenszel.

interpretation. Selection and measurement bias will always be present in case series, in addition to potential risk of incorporation bias, to benefit the final outcome of the intervention. Other than the low number of RCTs, one of the major shortcomings of the reviewed literature was the potential language bias in our study, as we considered only literature written in English.

A further limitation of the study was the lack of data regarding the exact material composition of titanium and zirconia abutments used in the included studies, which could have been helpful to verify if there were a correlation between the abutment failures manifested and the actual material composition of the zirconia abutment. However, this information was lacking in the reviewed literature, due to the fact that most manufacturers do not usually disclose such information.

Due to the diversity of parameters, lack of standardized methods, and the heterogeneity of the included studies, the results of our study require cautious interpretation. High-level evidence-based comparative studies are needed to demonstrate outcomes of abutment materials in the anterior region compared to the posterior region. The next step for

Posterior				Other
Technical complications	**Prosthetic complications**	**Biological complications**	**Aesthetic complications**	**Notes**
—	—	—	—	
1 implant lost 8 months after restoration (Zr)	None	None	None	
3 implants lost in the same patient after loading, but before final restoration (1 Zr,2 Ti)	3 minor chipping of porcelain (Zr)	None	NR	
—	—	—	—	
None	None	None	NR	
None	None	None	NR	
3 implant failures due to loss of osseointegration (2 Zr, 1Ti)	2 minor chipping of porcelain (Ti)	None	None	
None	None	None	NR	
10 implants lost (Zr)/4 implants lost (Ti)/24 abutment loosening (Zr)/1 screw fracture (Zr)/2 abutment loosening (Ti)	3 loss of crown retention/29 minor chipping	4 fistula (1 Zr, 3 Ti), suppuration on probing and pocket depth ≥5 mm		

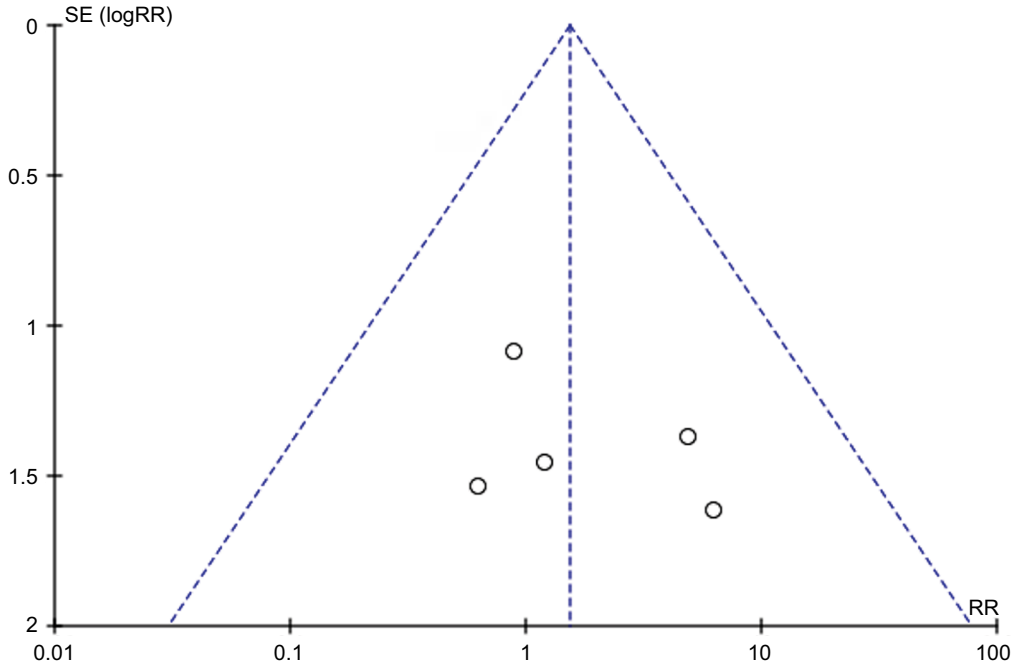

Figure 3 Funnel plot of comparison.
Notes: Anterior versus posterior zirconia. Outcome: abutment failure.
Abbreviations: SE, standard error; RR, risk ratio.

Table 7 Comparison of abutment failure events in anterior and posterior regions

Study	Total abutments	Anterior					Posterior				
		Zr abutments	Ti abutments	UCLA abutments	Failed Zr abutments	Failed Ti abutments	Zr abutments	Ti abutments	UCLA abutments	Failed Zr abutments	Failed Ti abutments
de Albornoz et al[34]	26	3	0	0	0	0	9	14	0	2	0
Bae et al[35]	37	2	0	0	0	0	35	0	0	0	0
Cabello et al[36]	14	4	0	10	0	0	–	–	–	–	–
Canullo and Götz[37]	5	0	5	0	0	0	–	–	–	–	–
Canullo[38]	30	16	0	0	0	0	14	0	0	0	0
Cionca et al[39]	49	1	0	0	0	0	48	0	0	2	0
Cooper et al[40]	43	43	0	0	0	0	–	–	–	–	–
Cosyn et al[41]	25	0	25	0	0	0	–	–	–	–	–
den Hartog et al[42]	62	57	0	0	0	0	5	0	0	0	0
Ekfeldt et al[43]	185	165	0	0	2	0	20	0	0	0	0
Furze et al[44]	10	9	0	0	0	0	1	0	0	0	0
Galluci et al[45]	20	0	20	0	0	0	–	–	–	–	–
Gotfredsen[46]	20	0	18	0	0	0	0	2	0	0	0
Guljé et al[47]	31	–	–	–	–	–	0	31	0	0	0
Hosseini et al[48]	75	–	–	–	–	–	38	35	2	0	0
Hosseini et al[49]	98	41	11	16	0	0	11	10	9	0	0
Jemt[50]	41	0	37	0	0	0	0	4	0	0	0
Kim et al[51]	328	60	0	0	1	0	268	0	0	5	0
Lee and Hasegawa[52]	9	9	0	0	0	0	–	–	–	–	–
Lops et al[53]	81	–	–	–	–	–	37	44	0	0	0
Lops et al[54]	72	15	8	0	1	0	18	31	0	0	0
MacDonald et al[55]	20	0	7	0	0	0	0	13	0	0	0
Nejatidanesh et al[56]	232	0	67	0	0	0	0	165	0	0	0
Nothdurft and Pospiech[57]	40	–	–	–	–	–	40	0	0	0	0
Passos et al[58]	158	158	0	0	6	0	–	–	–	–	–
Payer et al[59]	31	3	2	0	0	0	13	13	0	0	0
Pozzi et al[60]	81	–	–	–	–	–	39	42	0	0	0
Vanlıoglu et al[61]	23	11	12	0	0	0	–	–	–	–	–
Vigolo et al[62]	40	–	–	–	–	–	0	20	20	0	0
Vigolo and Givani[63]	182	–	–	–	–	–	0	0	182	0	0
Zembic et al[64]	28	2	2	0	0	0	16	8	0	0	0
Zembic et al[65]	31	24	0	0	0	0	7	0	0	0	0
Total	2,127	623	214	26	10	0	619	432	213	9	0

future clinical trials should be to compare directly the performance of an implant-abutment material in the anterior and posterior regions.

Conclusion

There were no reported failures of titanium or UCLA abutments. For failures of zirconia abutments, a meta-analysis showed no significant differences in zirconia-abutment failure between anterior and posterior regions. However, technical complications were more commonly reported in posterior locations and commonly reported in zirconia abutments. Abutment-screw loosening was the most common technical complication, while prosthetic, biological, and aesthetic complications showed insignificant differences irrespective to the abutment material used.

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Disclosure

The authors report no conflicts of interest in this work.

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