

SYSTEMATIC REVIEW

Ceramic versus metal-ceramic implant-supported prostheses: A systematic review and meta-analysis



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Dental implant rehabilitation provides a favorable treatment option with long-term predictability.^{1,2} The success of rehabilitation treatment is related not only to the osseointegration and the functional load-bearing capacity of the implant but also to factors related to the prosthesis, such as its interrelationship with soft and hard tissues.³

Implant-supported single crowns or fixed partial dentures (FPDs) have shown high survival rates over long follow-up periods.¹ However, care should be taken in considering the complication rate (technical/mechanical and biological), which may interfere with rehabilitation treatment success.^{2,4,5} Two different restorative materials can be used for rehabilitation in implant-supported prostheses: metal-ceramic or ceramic.⁶

ABSTRACT

Statement of problem. There is insufficient evidence to recommend the restorative material for implant-supported prostheses.

Purpose. The purpose of this systematic review and meta-analysis was to evaluate studies that compared ceramic and metal-ceramic restorations for implant-supported prostheses (within the same study to avoid indirect comparison) in terms of the mechanical and biological complication rates, prosthesis survival rate, and marginal bone loss.

Material and methods. Two independent reviewers performed a comprehensive search in databases (PubMed/MEDLINE, Web of Science, and Cochrane Library) for articles indexed until March 31, 2018. The search was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and methods were registered in the International Prospective Register of Systematic Reviews (PROSPERO). The focused question was "Do ceramic restorations have mechanical/biological complication rates, prosthesis survival rates, and marginal bone loss similar to those of metal-ceramic restorations?"

Results. The search identified 949 references. The interinvestigator agreement using kappa values was 0.87 for PubMed/MEDLINE, 0.93 for Scopus, and 1.0 for the Cochrane Library. After analysis, 12 studies were selected for qualitative and quantitative analysis. The mechanical complication rate did not differ between ceramic and metal-ceramic restorations ($P=.89$), independent of the type of prostheses (single crown: $P=.63$; fixed partial denture: $P=.65$). The biological complication rate was also not significantly different between ceramic and metal-ceramic restorations ($P=.21$). The prosthesis survival rate showed no significant differences between the 2 types of restorations ($P=.56$). Marginal bone loss was also similar for both types of restorations ($P=.12$).

Conclusions. This systematic review indicated that ceramic and metal-ceramic implant-supported prostheses have similar mechanical and biological complication rates, prosthesis survival rates, and marginal bone loss. Thus, both treatments are appropriate options for long-term rehabilitation treatment. (*J Prosthet Dent* 2019;121:879-86)

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Clinical Implications

The choice of material for restorations (ceramic or metal-ceramic) could be based on clinician or patient preference as the clinical outcomes for each restoration type are similar.

The use of metal-ceramic prostheses supported by metal abutments (titanium or gold) is an established treatment approach with a low complication rate and high prosthesis survival rate.^{1,7,8} However, this rehabilitation approach presents some disadvantages, including high cost and time because of the manual method of fabrication and limited esthetics.^{1,9}

Ceramic materials (abutments and restorative crowns) have been used as an alternative to metal-ceramic implant-supported prostheses.^{10,11} They are produced from high-strength zirconia ceramics with a digital workflow by using computer-aided design and computer-aided manufacturing (CAD-CAM).¹²⁻¹⁶ Advantages of ceramic implant-supported prostheses beyond esthetics include the reduced possibility of gingival discoloration, greater translucency of the material,¹ lower bacterial adhesion than to metals,¹⁷ and faster processing time with CAD-CAM.¹¹ However, ceramics are brittle materials with low resistance to tensile stress.^{1,18}

Recent systematic reviews have evaluated the influence of abutment material.¹ However, a consensus regarding the choice between ceramic and metal-ceramic restorations for implant-supported restorations is lacking. Therefore, this systematic review and meta-analysis aimed to evaluate the effects of different materials in implant-supported prostheses in terms of mechanical and/or biological complication rates, prosthesis survival rates, and marginal bone loss. The null hypotheses tested were that no differences would be found between metal-ceramic and ceramic restorations in terms of mechanical and/or biological complication rates; and that no differences would be found between the 2 types of restorations in terms of prosthesis survival rates and marginal bone loss.

MATERIAL AND METHODS

This systematic review and meta-analysis was structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist, in accordance with different published models.¹⁹⁻²² The study was registered on the International Prospective Register of Systematic Reviews (PROSPERO-CRD42017078397).

This review included randomized controlled trials (RCTs), prospective studies, and papers that compared metal-ceramic and ceramic restorations in the same study (direct comparison) and follow-up periods with a

minimum of 1 year. The exclusion criteria were in vitro studies, animal studies, computer simulations, case series and reports, studies that evaluated only 1 type of material without a direct comparison, and literature reviews. No restriction of language was applied. A specific question was formulated based on the population, intervention, control, and outcome (PICO) criteria: "Do ceramic restorations have mechanical/biological complication rates, prosthesis survival rates, and marginal bone loss similar to those of metal-ceramic restorations?" From these criteria, the population was composed of patients rehabilitated with implant-supported prostheses, and ceramic restorations (intervention) were compared with metal-ceramic restorations. The primary outcomes were the mechanical and/or biological complication rates, and the secondary outcomes were the prosthesis survival rate and marginal bone loss.

Two independent authors (C.A.A.L., J.M.L.G.) conducted an electronic search of PubMed/MEDLINE, Scopus, and the Cochrane Library for indexed articles until March 31, 2018 using the search terms: "(((dental implant [MeSH Terms] OR framework implant [All Fields])) AND (all-ceramic [All Fields] OR ceramic [MeSH Terms] OR metal free [All Fields] OR monolithic [All Fields] OR zirconia [MeSH Terms] OR lithium disilicate [All Fields] OR feldspathic [MeSH Terms] OR alumina [MeSH Terms] OR zirconia-ceramic [All Fields] OR resin nanoceramic [All Fields])) AND (metal-ceramic [MeSH Terms] OR porcelain-fused-to-metal [MeSH Terms])".

Also, a manual research was performed for articles published in the following journals: *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *International Journal of Oral and Maxillofacial Implants*, *International Journal of Prosthodontics*, *Journal of Dentistry*, *Journal of Dental Research*, *Journal of Oral Rehabilitation*, *Journal of Prosthodontics*, *Journal of Prosthodontic Research*, and the *Journal of Prosthetic Dentistry*. The authors also conducted a search of nonpeer-reviewed literature at <http://www.opengrey.eu/>. The studies were initially selected by screening the title and abstract of the articles according to the eligibility criteria. A third author (E.P.P.) analyzed all differences in choices between the investigators, and a consensus was reached through discussion.

One of the authors (C.A.A.L.) collected relevant information from the articles, and a second author (F.R.V.) checked all the collected information. One investigator (C.A.A.L.) assessed the quality and risk of bias of the studies included in this systematic review using the Cochrane Risk of Bias Tool for RCT studies. The risk of bias for non-RCT (prospective) studies was evaluated using the Newcastle-Ottawa scale.²³

The meta-analysis was based on the inverse variance and Mantel-Haenzel methods. Mechanical and

biological complication rates and prosthesis survival rates were the dichotomous outcomes evaluated using the risk ratio (RR). Marginal bone loss was considered the continuous outcome and evaluated using mean difference (MD) values. A subanalysis was performed for mechanical complications in terms of the type of prosthesis (single crowns and FPDs). Subanalyses for the other analyses could not be performed because of the absence of data of included studies on FPDs. In analysis with significant heterogeneity ($P < .10$), a random-effects model was used to assess the significance of the treatment effects. Where no statistically significant heterogeneity was found, analysis was performed using a fixed effects model.²⁴ The RR and MD values were considered significant when $P < .05$. Software (Reviewer Manager 5; Cochrane Group) was used for meta-analysis. Additional analysis was performed using the kappa statistic to calculate the interreader agreement.

RESULTS

A search of the databases retrieved 949 references: 581 from PubMed/MEDLINE, 285 from Web of Science, and 83 from the Cochrane Library. After removing duplicates, 623 studies remained. Twenty-nine studies were eligible for analysis after review. On reading the full texts, 17 studies were excluded (Supplemental Table 1). Thus, 12 studies—8 RCTs^{14-16,25-29} and 4 prospective^{3,6,30,31}—were included in this systematic review (Fig. 1). All studies compared ceramic and metal-ceramic restorations within the same study. Detailed data of the 12 included studies (2 studies^{27,28} reported the same patients but with different outcomes) are listed in Supplemental Table 2. Assessment of interinvestigator agreement using kappa values for the selected articles yielded values of 0.87 for PubMed/MEDLINE, 0.93 for Scopus, and 1.0 for Cochrane Library, indicating a high level of agreement.³²

The total number of participants in the included studies were 438 (range: 20 to 98) with a mean age of 42.9 years. A total of the number of ceramic restorations in included studies were 308 (range: 7 to 52), whereas metal-ceramic restorations were 343 (range: 13 to 48). Internal connection was the most commonly used connection type with different implant systems (Straumann AG; Dentsply Sirona; Warantec; Zimmer; Nobel Biocare). Single crowns were the most frequently used (only 3 studies evaluated FPDs),^{15,16,26} while cemented prostheses were chosen in most of the selected studies. Most studies evaluated the posterior area in the maxilla and mandible.

Different abutment materials were reported in the selected studies. One study did not report the abutment used.³⁰ Five studies reported the use of zirconia abutments,^{3,14,26,29,31} 5 reported titanium or gold abutments,^{15,16,25,27,28} and 1 study reported aluminum oxide

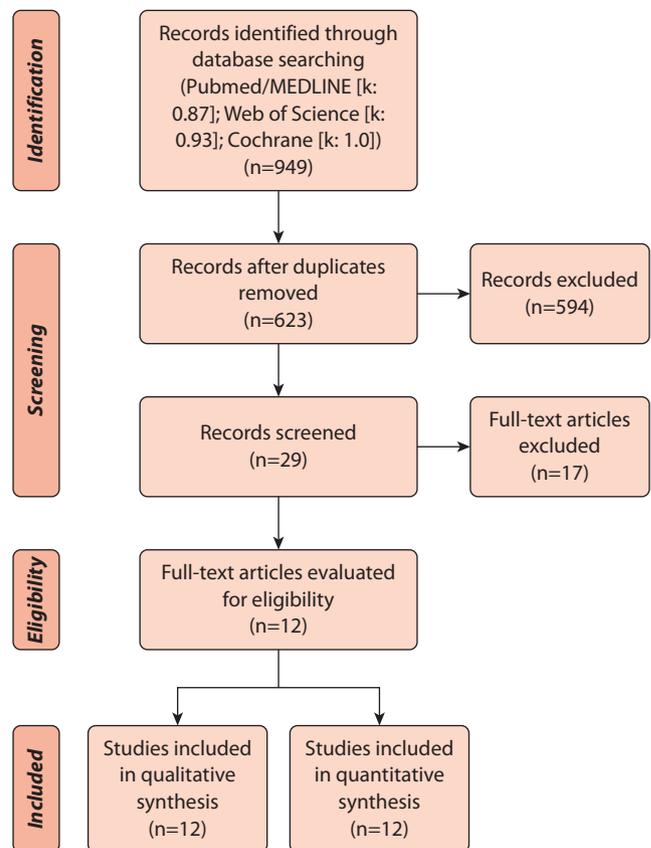


Figure 1. Flowchart of search strategy.

base or alumina⁶ for ceramic prostheses. For metal-ceramic prostheses, only titanium or gold abutments were used.^{3,6,14-16,25-29,31}

All selected studies evaluated the mechanical complication rates. Minor chipping and ceramic fracture were the most frequently reported mechanical complications, whereas fistulas and suppuration were the most common biological complications reported. Quantitative analysis showed no significant differences between ceramic and metal-ceramic restorations in terms of mechanical complications ($P = .89$; RR: 0.95; 95% confidence interval [CI]: 0.45 to 1.98; heterogeneity: $P = .02$; I^2 : 53%) (Fig. 2). A subanalysis was performed with studies that had classified the implants by the type of prosthesis (single crowns and FPDs). The results of the subanalysis showed no significant differences between ceramic and metal-ceramic restorations in terms of single crowns ($P = .63$; RR: 0.77; 95% CI: 0.26 to 2.24; heterogeneity: $P = .007$; I^2 : 64%) (Fig. 3A) and FPDs ($P = .65$; RR: 1.19; 95% CI: 0.56 to 2.56; heterogeneity: $P = .61$; I^2 : 0%) (Fig. 3B).

Three studies did not report the biological complications.^{15,16,25} The biological complication rates also showed no significant differences between ceramic and metal-ceramic restorations ($P = .21$; RR: 1.48; 95% CI: 0.80 to 2.73; heterogeneity: $P = .40$; I^2 : 2%) (Fig. 4).

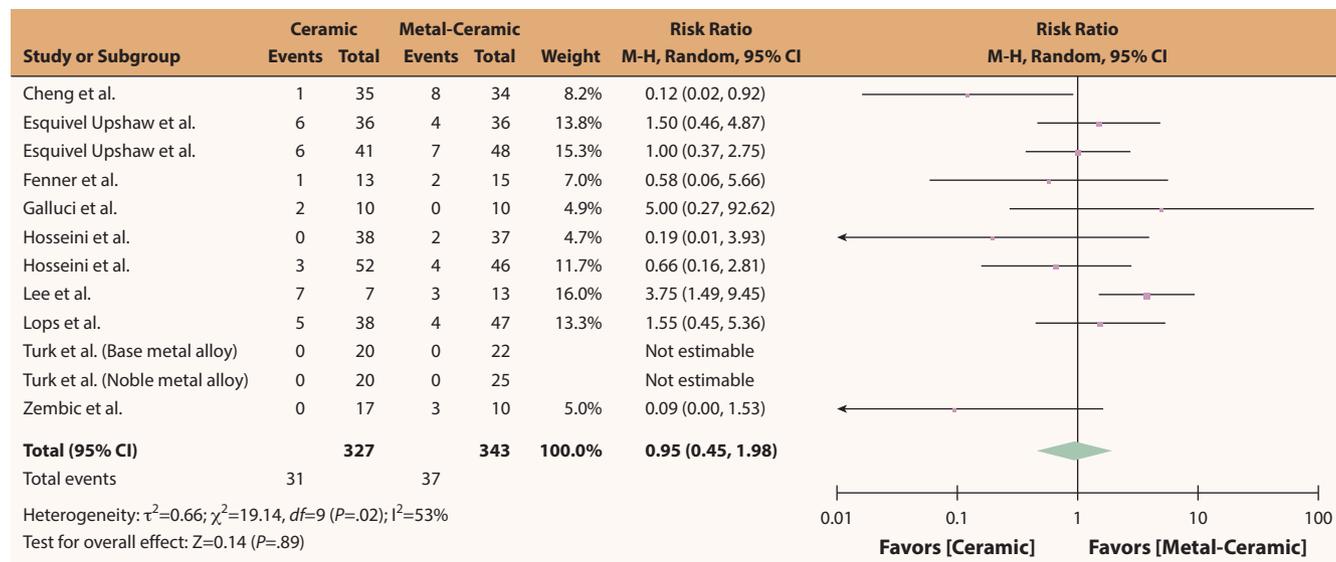
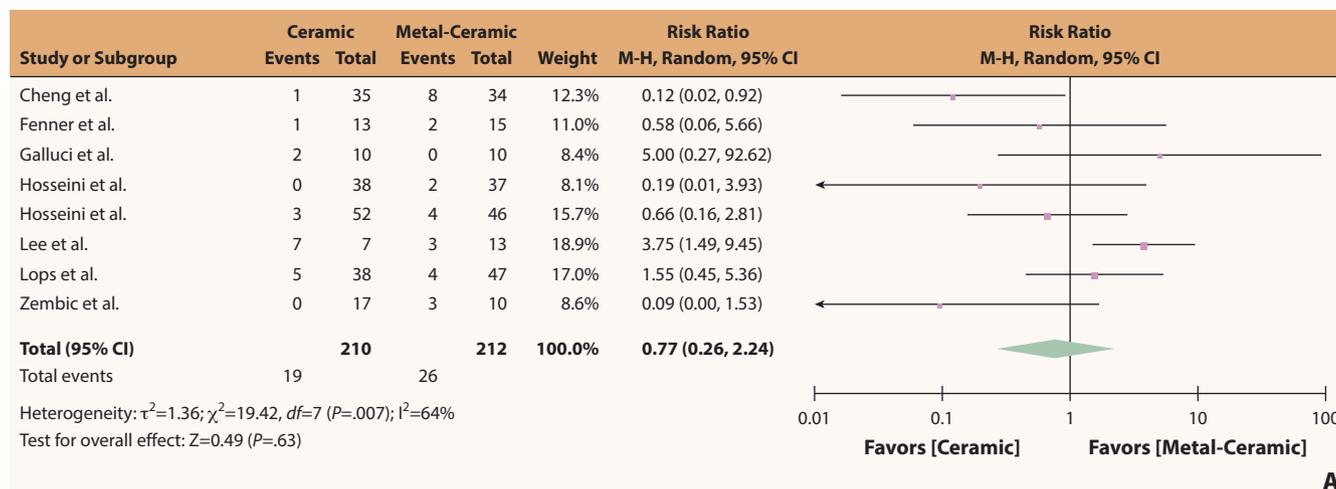
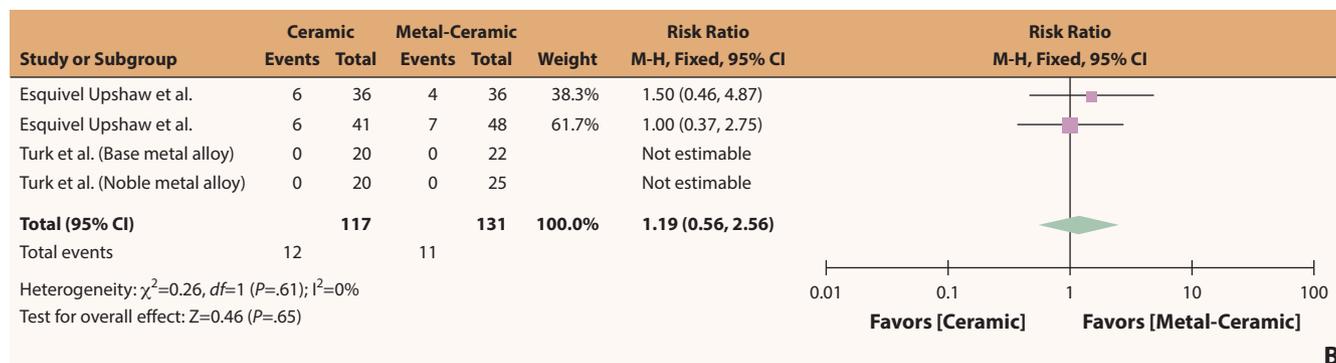


Figure 2. Forest plot of comparison of studies evaluating mechanical complications. CI, confidence interval; M-H, Mantel-Haenzel.



A



B

Figure 3. Forest plot of comparison of studies evaluating mechanical complications (A, single crowns. B, fixed partial denture). CI, confidence interval; M-H, Mantel-Haenzel.

Prosthesis survival was assessed in most studies, except one that did not report these data.¹⁵ The assessed studies reported failures in 8 of 582 implants placed

(1.37%); these included 5 ceramic restorations (1.83%) and 3 metal-ceramic restorations (0.97%) (Supplemental Table 3). Six studies reported 100% prosthesis survival for

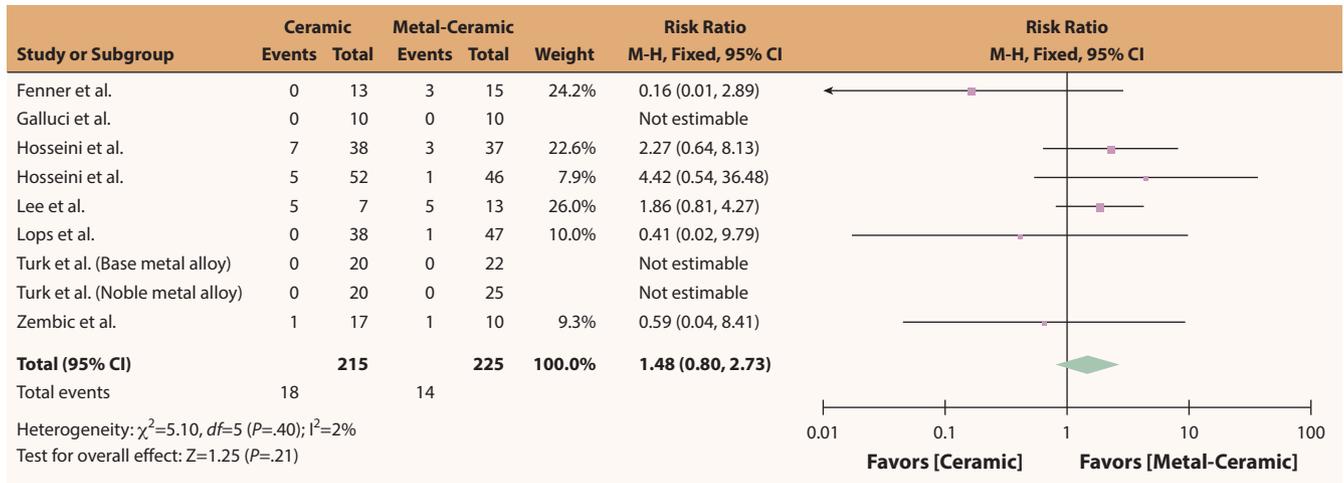


Figure 4. Forest plot of comparison of studies evaluating biological complications. CI, confidence interval; M-H, Mantel-Haenzel.

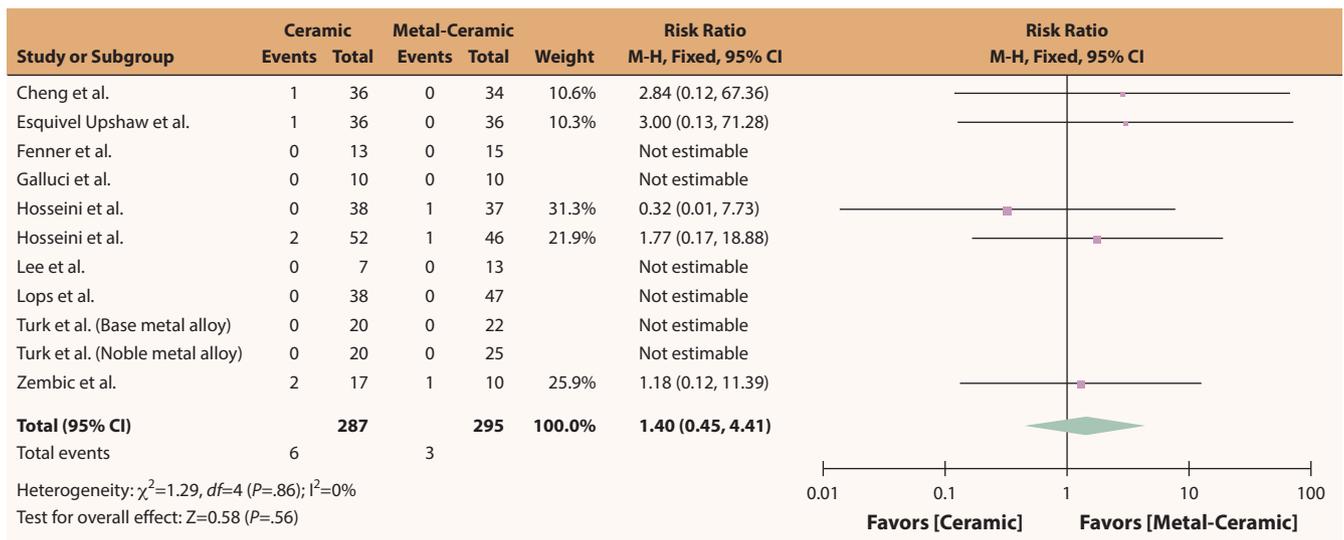


Figure 5. Forest plot of comparison of studies evaluating prostheses survival rate. CI, confidence interval; M-H, Mantel-Haenzel.

both restoration type.^{3,6,26-28,30} Quantitative analysis showed no significant differences in prosthesis survival between the evaluated restorations ($P=.56$; RR: 1.40; 95% CI: 0.45 to 4.41; heterogeneity: $P=.86$; I^2 : 0%) (Fig. 5).

Marginal bone loss was evaluated in 8 studies.^{3,6,14,26,27,29-31} Ceramic restorations showed similar marginal bone loss to metal-ceramic restorations ($P=.12$; MD: -0.05; 95% CI: -0.11 to 0.01; heterogeneity: $P=.26$; I^2 : 20%) (Fig. 6).

All RCT studies showed low risk of bias to random sequence generation. The allocation concealment was considered low for most of the studies, except for 1 study which was considered unclear.¹⁴ One study reported no blinding of participants²⁶ and 3 studies were considered unclear.^{14,25,29} Regarding blinding of outcome assessment, 3 studies²⁷⁻²⁹ were graded with low risk, while 4 studies were unclear^{14-16,25} and 1 study

showed high risk of bias.²⁶ Incomplete outcome data showed low risk for most of the studies, except for 1 study that was graded as unclear risk.²⁶ Selective reporting and other biases were considered low risk for all the selected studies (Fig. 7). The non-RCTs studies were evaluated based on Newcastle-Ottawa Scale. Two studies scored 9 stars^{3,6} and 2 studies scored 8 stars,^{30,31} indicating a low risk of bias for non-RCT studies (Supplemental Table 4).

DISCUSSION

The choice of restorative material is occasionally based on clinical experience and/or patient acceptability with the proposed treatment. For many years, the use of metal-ceramic restorations was considered the gold standard for rehabilitation of teeth and implants.¹ However, with

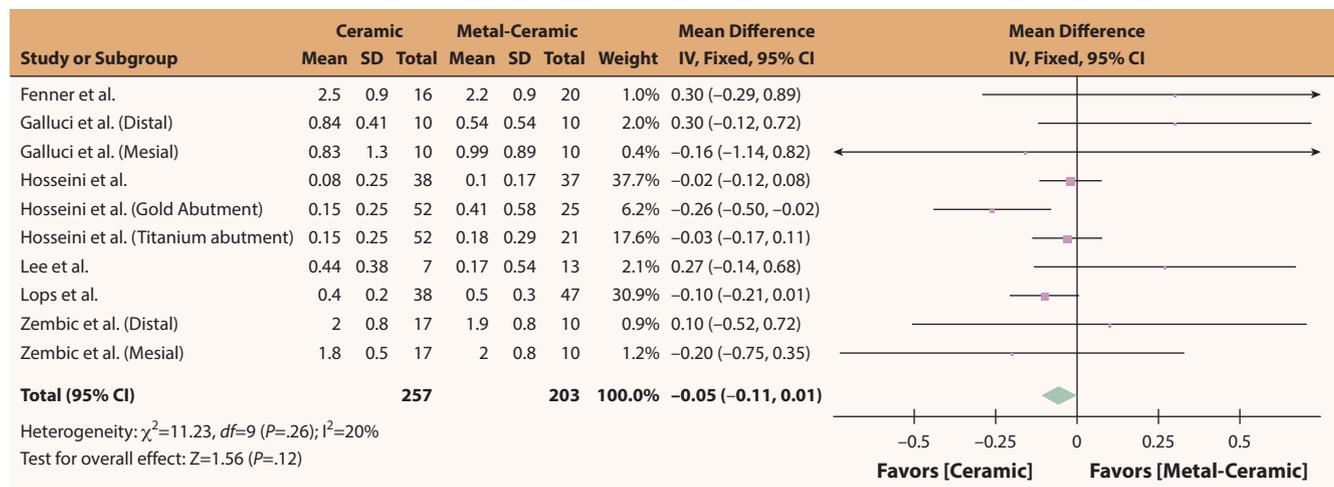


Figure 6. Forest plot of comparison of studies evaluating marginal bone loss. CI, confidence interval; IV, inverse variance; SD, standard deviation.

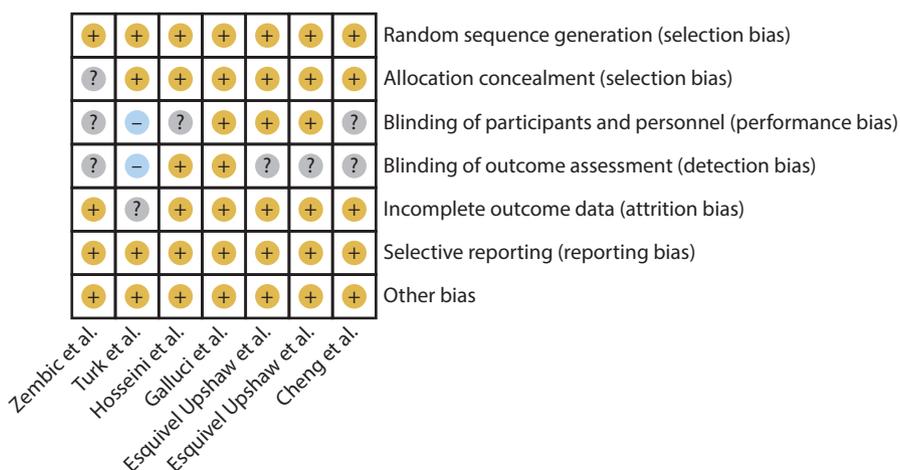


Figure 7. Assessment of risk of bias of included studies using Cochrane Risk of Bias tools.

the development of high-strength ceramic materials, ceramic restorations are considered viable alternatives for patients with high esthetic demands. Thus, the choice of restoration material should be based on evidence to improve the longevity of treatment.

The first null hypothesis tested was accepted because meta-analysis reported no differences between restorations of different materials in terms of mechanical and biological complication rates. These results may have been influenced by the use of zirconia abutments and restorations for almost all the ceramic restorations in the included studies. Zirconia has the highest flexural strength and fracture toughness in comparison with other ceramics.^{3,18} These properties could have contributed to the low mechanical complication rate for ceramic restorations (10.27%), which was similar to that for metal-ceramic restorations (9.03%). Of the included studies, only one did not report mechanical

complications.²⁶ This is probably related to the low follow-up period in that study (1 year).

Although there has been much concern regarding the performance of ceramic and metal abutments used for implant-supported prostheses, none of the selected studies reported mechanical complications related to the abutment, regardless of the restoration materials evaluated. Minor chipping in restoration materials was among the most frequently reported mechanical complications. These complications were mainly reported in the posterior region^{15,16,30,31} or in FPDs.^{15,16} The chipping rate for ceramic prostheses (9.25%) was higher than that for metal-ceramic prostheses (7.41%), although the values were not significantly different.

Chipping was considered one of the most common problems for ceramic zirconia-based prostheses.¹⁴ Several factors may influence chipping in ceramic restorations. Anusavice¹⁰ has reported that the specific

etiology of chipping is unknown. The presence of chipping fracture is not, by itself, considered a failure. In some situations, this complication can be resolved by finishing and polishing the restorations. However, replacement may be needed.¹⁰

Different causes of chipping can be considered, for example, the adhesion interface. The bonding interface between zirconia copings and the veneering ceramic is still considered a challenging factor.³⁰ The generation of residual stress caused by the slow cooling of the zirconia also can affect the veneer ceramic coating, increasing the possibility of chipping fractures.¹⁶ In addition, the quality, design, and thickness of the veneer ceramic should be adequate to prevent possible fractures of the ceramic materials.¹⁶

Monolithic zirconia restorations have been advocated to prevent the fracture of the veneering ceramic. In the selected studies, only 1 reported the comparison of metal-ceramic with modified monolithic (veneering porcelain limited to the buccal surface for improvement of the esthetic) single crown.²⁵ The authors reported significantly more technical complications for metal-ceramic compared with monolithic single crowns.²⁵ However, further clinical research is needed because of the scarcity of studies comparing monolithic with veneered restorations.

Some systematic reviews have reported that screw loosening is the most prevalent mechanical complication.^{1,5} However, only 1 of the included studies³ reported this complication. This could be because most of the included studies used cemented single crowns, and screw loosening is observed more frequently in screw-retained prostheses.¹⁹ Furthermore, Hosseini et al³¹ have reported that the results could be explained by the use of a torque wrench to tighten all abutment screws. Three of the included studies had a follow-up period of 1 year, and this may have contributed to the lack of screw loosening.

Some studies have reported higher complications rates for FPDs.^{4,5} However, in this study, no difference was observed between ceramic and metal-ceramic restorations, regardless of the type of prosthesis. This result should be interpreted with caution because only 3 studies compared the influence of different restoration materials for FPDs with short follow-up periods (1 to 3 years). Therefore, further randomized clinical trials are recommended to compare the influence of materials in FPDs.

Fistulas, suppuration, pain, and sensitivity were the most reported biological complications in the included studies.²⁹⁻³¹ Mucositis and peri-implantitis were reported in only 2 studies.^{3,14} The quantitative data showed no difference between ceramic and metal-ceramic restorations. Zirconia is considered a good material with lower bacterial adhesion than titanium.^{14,17} However, no differences were observed for biological complications among restorations of different materials.

Two included studies reported a high incidence of fistulas and suppuration with ceramic prostheses.^{29,31} According to the authors, this may not be directly related to the material, but to the fact that ceramic restorations had a greater marginal misfit than metal-ceramic restorations that may increase bacterial accumulation and eventually lead to fistulas.^{29,31} The authors stated that the greater marginal misfit in ceramic prostheses is related to the manufacturing procedures for the presintered zirconia copings, which could influence the marginal adaptation values. However, this fact is not related only to marginal misfit because the authors reported that buccal apical fistulas were caused by necrosis of adjacent teeth or exfoliation of bone substitutes.³¹

The second null hypothesis was also accepted because no differences were observed between ceramic and metal-ceramic restorations in terms of prosthesis survival rates and marginal bone loss. Restorations with both materials showed high prosthesis survival rates (98.17% for ceramic restorations and 98.63% for metal-ceramic restorations). Different factors contributed to prosthesis failures, such as implant loss due to peri-implantitis, and/or excess cement,¹⁴ inadequate marginal adaptation,³¹ lack of retention,²⁹ or major fractures that compromised prosthesis maintenance.^{16,31} However, as mentioned previously, 3 of the included studies had follow-up periods of 1 year, and this may be considered a limitation for this outcome as a delimited period for prosthesis survival rate should be much longer than 1 year. In addition, marginal bone loss can be considered one of the factors that influence the implant loss. According to this study, the material used for the restorations (ceramic and/or metal-ceramic) did not influence this parameter.

The current systematic review included only those articles that compared ceramic and metal-ceramic restorations within the same study to avoid any indirect comparisons. This is considered important to reduce bias. However, none of the selected articles reported a split-mouth design to evaluate these criteria in the same patients and different ceramic veneering materials were evaluated by the authors. This is a limitation of the included studies. Furthermore, 3 studies had follow-up periods of 1 year, which can be considered inadequate to verify the rate of complications and prosthesis survival. Thus, further RCTs with longer follow-up periods are recommended to reassess the impact of new data.

CONCLUSIONS

Within the limitations of the current systematic review and meta-analysis, the following conclusions were drawn:

1. Ceramic implant-supported prostheses have similar mechanical and biological complication rates,

prosthesis survival rates, and marginal bone loss as metal-ceramic restorations.

2. Both treatments are viable for long-term restoration.

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Supplemental Table 1. Reasons for excluded studies

Author, Year	Reason for Exclusion
Jiehua et al, 2017	Follow-up lower than 1 year
Baldini et al, 2016	Only abutment comparison
Wang et al, 2016	Retrospective study
Ferrari et al, 2016	Only abutment comparison
Peng et al, 2013	Without outcomes evaluated
Biscaro et al, 2012	Without outcomes evaluated
Mal et al, 2012	Retrospective study
Rammelsberg et al, 2012	Tooth-implant supported
Schwarz et al, 2011	Retrospective study
Bergenblock et al, 2010	Did not report outcome for groups evaluated
Zembic et al, 2009	Lower follow-up article
Sailer et al, 2009	Lower follow-up article
Mangano et al, 2008	Did not report outcome for groups evaluated
Jung et al, 2008	Without outcomes evaluated
Andersson et al, 2003	Only abutment comparison
Andersson et al, 2001	Did not report outcome for groups evaluated
Scholander 1999	Retrospective study

Supplemental Table 2. Characteristic of included studies (n=12)

Author, Year	Design	Patient, Prosthesis, n	Mean Age, y	Implant System	Abutment Material, n	Region/Arch	Prosthesis/Retention System
Cheng et al, 2018 ²⁵	RCT	38; C ^a : 36; MC: 34	47.9	Internal Connection/Soft Tissue Level (Straumann)	AC and MC: prefabricated titanium abutments (synOcta cementable abutment) or MC: customized implant abutments (synOcta gold abutment; Straumann); AC: titanium inserts (variobase abutment; Straumann).	Posterior/Mand and Max	SC/SR and CR
Fenner et al, 2015 ⁶	P	28; C: 13; MC: 15	48	Internal Connection/ (Straumann)	AC: aluminum oxide–based/alumina (synOcta In-Ceram blank); MC: titanium abutments (synOcta cementable)	Anterior and Posterior/Mand and Max	SC/SR and CR
Esquivel-Upshaw et al, 2014 ¹⁵	RCT	68; C: 41; MC: 48	NR	Internal Connection/ Osseospeed, Astra Tech/ (Dentsply Sirona)	AC and MC: gold-shaded, custom-milled, titanium abutments (Atlantis, Astra Tech)	Posterior/Mand and Max	FPD/CR
Lee et al, 2014 ³⁰	P	8; C: 7; MC: 13	46	Internal Connection/ (Inplant, Warantec)	NR	Posterior/Mand and Max	SC/CR
Lops et al, 2013 ³	P	85; C: 38; MC: 47	54	Internal Connection/ Osseospeed, Astra Tech/ (Dentsply Sirona)	AC: Zr Std Abutment (Ceramic Abutment ST ZirDesign abutment); MC: Ti Std abutment (Profile Biabutment)	Posterior/Mand and Max	SC/CR
Turk et al, 2013 ²⁶	RCT	23; C: 20; MC (base alloy): 22; MC (gold alloy): 25	52.4	Friadent-Xive (Dentsply Sirona) and Zimmer TSV (Zimmer)	AC: zirconium oxide–based ceramics (ZirkonZahn GmbH); MC: base metal alloy (Remanium CS); MC: noble metal alloy (DeguDent GmbH)	Posterior/Mand and Max	FPD/NR
Hosseini et al, 2013 ³¹	P	59; C: 52; MC: 46	27.9	Internal Connection/Astra Tech/(Dentsply Sirona)	AC: zirconia; MC: titanium; MC: gold alloy	Anterior and posterior/Max	SC/CR
Esquivel-Upshaw et al, 2013 ¹⁶	RCT	55; C: 36; MC: 36	NR	Internal Connection/ Osseospeed, Astra Tech/ (Dentsply Sirona)	AC and MC: Gold-shaded, custom-milled, titanium abutments (Atlantis, Astra Tech)	Posterior/Mand and Max	FPD/CR
Zembic et al, 2013 ¹⁴	RCT	18; C: 17; MC: 10	41.3	External; Connection/ Branemark RP (Nobel Biocare).	AC: customized zirconia abutments (Procera, Nobel Biocare); MC: customized titanium abutments (Procera, Nobel Biocare)	Anterior and Posterior/Mand e Max	SC/CR or SR
Galluci et al, 2011 ^{27,28c}	RCT	20; C: 10; MC: 10	40.6	Internal Connection/ (Straumann)	AC: synOcta abutment (Straumann); MC: synOcta abutment (Straumann)	Anterior and Posterior/Max	SC/SR
Hosseini et al, 2011 ²⁹	RCT	36; C: 38; MC: 37	28.1	Astra Tech/(Dentsply Sirona)	AC: ZirDesign (Astra Tech); MC: TiDesign (Astra Tech)	Posterior/Max and Mand	SC/CR

C, ceramic; CR, cement-retained; FPD, fixed partial denture; Mand, mandible; Max, maxilla; MBL, marginal bone loss; MC, metal-ceramic; NR, not reported; P, prospective; PI, peri-implantitis; PPD, probing pocket depth; RCT, randomized clinical trial; SC, single crown; SR, screw-retained; VAS, visual analog scale. ^aAuthors reported use of modified monolithic zirconia. ^bAuthors reported these data in terms of survival rate of implants. ^cAuthors evaluated same patients with different outcomes.

Supplemental Table 2. (Continued) Characteristic of included studies (n=12)

Prosthesis Materials, n	Complications, n		Prosthesis Survival, n	Other Outcomes	Follow-up	
	Mechanical	Biological				
AC: zirconia/veneering ceramic; MC: metal (Argedent 500; Argen) and veneering ceramic	C: 1 screw loosening; MC: 5 screw loosening; 2 debonding; 1 minor chipping	NR	C: 97.2% ^b ; implant lost; MC: 100%	NR	1 year	
AC: Alumina/Procera; Nobel Biocare; MC: NR	C: 1 major chipping; MC: 2 minor chipping	MC: 3 insufficient color match	C: 100%; MC: 100%	PPD (mm) MBL (mm)	C: 3.87 (0.76); MC: 4.16 (1.19) C: 2.5 (0.9); MC: 2.2 (0.9)	At least 5 years
AC: YTZP (IPS e.max ZirCAD Ivoclar) + Fluorapatite GCV (IPS ZirPress InLine Ivoclar); MC: Pd -Au-Ag alloy + Leucite (IPS InLine POM, Ivoclar)	C: 6 ceramic fracture; MC: 7 ceramic fracture	NR	NR	NR		3 years
AC: Zirconia-ceramics (NR); MC: NR	C: 6 ceramic chipping; 1 screw hole fracture; MC: 3 ceramic chipping	C: 2 blending; 3 sensitivity; MC: 2 metal exposure; 1 gingival redness; 2 sensitivity	C: 100%; MC: 100%	MBL (mm) PPD (mm)	C: 0.44 (0.38); MC: 0.17 (0.54) C: 4.00 (1.41); MC: 3.84 (1.28)	4 years
AC: Zirconia (Lava 3M Espe); MC: NR	C: 4 minor chipping; 1 unscrewing screw; MC: 3 minor chipping; 1 unscrewing screw	MC: 1 mucositis	C: 100%; MC: 100%	PPD (mm) MBL (mm)	C: 2.6 (0.5); MC: 2.7 (0.4) C: 0.4 (0.2); MC: 0.5 (0.3)	5 years
NR	C: 0 complications; MC (base alloy): 0 complications; MC (gold alloy): 0 complications	C: 0 com; MC (base alloy): 0 com; MC (gold alloy): 0 com	C: 100%; MC: 100%	MBL (mm)	C: 0.687 (NR); MC (base alloy): 1.079 (NR); MC (gold alloy): 0.688 (NR)	1 year
AC: Procera Zirconia (Nobel) and IPS Empress (Ivoclar) + IPS Empress 2 (Ivoclar); MC: Procera Zirconia (Nobel) and ORION WX+ IPS Empress 2	C: 1 minor chipping; 1 ceramic fracture; 1 inadequate marginal adaptation; MC: 3 debonding; 1 inadequate marginal adaptation	C: 5 fistulas; MC (gold abutment): 1 suppuration/bleeding	C: 96.2%; MC: 97.8%	MBL (mm)	C: 0.15 (0.25); MC (titanium abutment): 0.18 (0.29); MC (gold abutment): 0.41 (0.58)	3 years
AC: YTZP (IPS e.max ZirCAD, Ivoclar) + Fluorapatite GCV (IPS InLine e.max ZirPress, Ivoclar); MC: Pd -Au-Ag alloy + Leucite-reinforced glass (IPS InLine POM, Ivoclar)	C: 1 ceramic fracture; 5 minor chipping; MC: 4 chipping	NR	C: 97.2%; MC: 100%	NR		2 years
AC: alumina/zirconia; MC: NR	C: 0 complications; MC: 3 minor chipping	C: 1 PI; MC: 1 PI	C: 88.9% ^b ; MC: 90% ^b ; implant lost	PPD (mm) MBL; mesial; MBL; distal	C: 3.3 (0.6); MC: 3.6 (1.1) C: 1.8 (0.5); MC: 2.0 (0.8); AC: 2.0 (0.8); MC: 1.9 (0.8)	5 years
AC: synOcta-In-Ceram Blank (Straumann) MC: synOcta-gold coping (Straumann)	C: 2 minor chipping; MC: 0 complications	C: 0; MC: 0	C: 100%; MC: 100%	MBL; mesial; MBL; distal VAS	C: 0.83 (1.30); MC: 0.99 (0.89); C: -0.84 (0.41); MC: -0.54 (0.54) C: 91.78 (10.04); MC: 91.81 (5.94)	1 year
AC: KaVo (Kavo) and Procera Zirconia (Nobel Biocare)/HeraCeram Zirkonia (Kulzer GmbH) and IPS.Empress (Ivoclar Vivadent AG); MC: HeraNordic (Kulzer GmbH) and ORION WX (Elephant Dental BV)/HeraCeram (Kulzer GmbH) and IPS d.SIGN (Ivoclar Vivadent AG)	C: 0 complications; MC: 1 minor chipping; 1 loss of retention	C: 1 fistula, swelling; 3 suppuration on probing; 2 PPD ≥ 5 mm; 1 pain; MC: 3 suppuration and PPD ≥ 5 mm	C: 100%; MC: 97.4%	MBL (mm)	C: 0.08 (0.25); MC: 0.10 (0.17)	1 year

Supplemental Table 3. Assessment quality of non-RCT included studies based on Newcastle-Ottawa Scale

Studies	Selection			Outcome of Interest Not Present at Start	Comparability		Outcome			Total
	Exposed Cohort	Nonexposed Cohort	Ascertainment of Exposure		Main Factor	Additional Factor	Assessment of Outcome	Follow-up Long Enough*	Adequacy of Follow-up of Cohorts	
Fenner et al ⁶	☆	☆	☆	☆	☆	☆	☆	☆	☆	9
Lee et al ²⁴	☆	☆	☆	☆	☆	☆	☆	0	☆	8
Lops et al ³	☆	☆	☆	☆	☆	☆	☆	☆	☆	9
Hosseini et al ²⁵	☆	☆	☆	☆	☆	☆	☆	0	☆	8

RCT, randomized clinical trial. *Five years considered as adequate follow-up period for outcomes.

Supplemental Table 4. Survival analysis indicating survival rate of ceramic and metal-ceramic restorations of included studies

Follow-up Intervals of Study (mo)	Ceramic			
	Restorations Evaluated in Each Interval	No. of Failures in Each Interval	Survival Rate Within Each Interval (%)	Cumulative Survival Rate (%)*
0-12	267	1	99.63	99.6
12-36	163	3	98.16	98.50
36-60	75	2	97.33	97.75
60-108	13	0	100	97.75
Follow-up Intervals of Study (mo)	Metal-Ceramic			
	Restorations Evaluated in Each Interval	No. of Failures in Each Interval	Survival Rate Within Each Interval (%)	Cumulative Survival Rate (%)*
0-12	296	1	99.66	99.66
12-36	168	1	99.40	99.32
36-60	86	1	98.84	98.99
60-108	15	0	100	98.99

*Considering total failures in comparison with all restorations.