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Review Article

Zirconia-ceramic versus metal-ceramic implant-supported multiunit fixed dental prostheses: A systematic review and meta-analysis

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ABSTRACT

Implant-supported prostheses could serve as a reliable restorative option for partial edentulism. Various restorative materials have been utilized in fabricating these prostheses, impacting both esthetics and peri-implant health. The present systematic review aimed to assess the survival rate and mechanical complications of zirconia ceramic compared to metal-ceramic implant-supported multiunit fixed dental prostheses (FDPs). We conducted searches in online databases such as MEDLINE (PubMed), Scopus, and Cochrane up until December 2022. A risk-of-bias assessment was done for all the included studies. Data extraction was performed based on the following parameters: author, year, study design, number of implants, abutment material, age range, observation period, incidence of mechanical complications, and survival rate. This systematic review included six studies (four randomized controlled trials and two retrospective studies). The meta-analysis significantly favored metal-ceramic restorations regarding mechanical complications with a risk ratio (RR) value of 1.64 and $P = 0.001$. Meta-analysis showed no difference in metal-ceramic FDPs in prostheses survival rate ($P = 0.63$; RR: 1.27, 95% confidence interval: 0.52–3.37; heterogeneity: $P = 0.65$; $I^{2:}$ 0%). While metal-ceramic multiunit implant-supported prostheses exhibited fewer mechanical complications compared to zirconia-ceramic prostheses, there was no significant difference in terms of prosthesis survival rate between the two. Hence, both treatments appear to be viable options for long-term implant-supported prostheses.

Key Words: Mechanical complication, metal ceramic, prosthesis survival, zirconia ceramic

INTRODUCTION

Enhancement in knowledge about oral hygiene measures and regular visits to dental practitioners have decreased tooth loss, and there is a notable shift toward more partially edentulous patients than completely edentulous patients.[1] Implant-supported restoration provides a predictable restorative option for partial edentulism.[2] The long-term success of restorative treatment depends not only on the osseointegration of the implant but also on the prosthetic factors that may affect peri-implant health and esthetics.[3] Consequently, to facilitate the decision-making process regarding the choice of prosthesis type, clinicians seek evidence-based clinical

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data that provide insights into the survival rates and complication rates associated with each restoration type.[4]

Many restorative materials are being introduced for implant-supported prostheses. Among these materials, metal ceramic has long been considered the gold standard due to its exceptional strength and mechanical stability.[5] However, prolonged use shows mucosal discoloration and occasional allergic reactions, making it a less favorable choice for restoration than all-ceramic restorations.[6] All-ceramic restorations provide superior esthetics in comparison to metal-ceramic restorations. It also requires much less tooth reduction and can be fabricated more rapidly with digital workflow.[7]

In the past, all-ceramic restoration was primarily indicated for the anterior region and single-unit crowns, owing to its limited strength and mechanical instability. Recent advancements, including the development of various all-ceramic materials such as lithium disilicate, leucite-reinforced glass ceramic, alumina, and zirconia, alongside notable improvements in computer-aided design and computer-aided manufacturing (CAD-CAM) technology, have rendered it suitable for use in the posterior areas and for multiunit fixed dental prostheses (FDPs).[8]

In the pursuit of the ideal esthetic restorative material, numerous all-ceramic restorations were introduced. Still, due to zirconia's excellent mechanical and biocompatible properties, it has been extensively used for single- and multiple-unit FDPs. Initially, zirconia was employed as a core material, however, due to its increased opacity was veneered with feldspathic or leucite-reinforced feldspathic porcelain. Nonetheless, the core–veneer interface presented as one of the weakest aspects of these restorations; hence, ceramic chipping or cracking is possible due to an incompatible coefficient of thermal expansion (CTE) between core and ceramic materials or inadequate adhesion of the veneering material to the core.[9] To address these concerns, innovative ceramics, like monolithic zirconia crowns, have emerged to minimize the risk of such catastrophic failures.[10]

Zirconia ceramic is a polycrystalline material characterized by an arrangement of metal–oxygen ionic bonds without a glassy phase, rendering it structurally robust.[11] It is a polymorphic material as it exists in three forms: monoclinic, tetragonal, and cubic. The tetragonal phase is mechanically most stable. Notably, zirconium oxide elicits a minimal tissue reaction and demonstrates less inflammatory infiltrate and bacterial adhesion, thereby establishing its superior biocompatibility in comparison to other restorative materials.[9]

Chipping, a common mechanical complication affecting approximately 10%–15% of ceramic restorations, often arises due to the mismatch of CTE between the zirconia ceramic core and the veneered ceramic layer.[12] Clinically, chipping is classified into three grades based on the type of repair required: Grade I (slight chipping treated by surface polishing), Grade II (moderate chipping treated with composite resin), and Grade III (severe chipping exposing the zirconia core that requires replacement of prosthesis).[5,13] Zirconia restorations are typically fabricated using the CAD-CAM technique, employing either hard machining, which involves milling the fully sintered zirconia block, or soft machining, where presintered blocks are milled, typically trimmed 25% larger.[14]

In a previous systematic review, Lemos *et al*.[15] conducted a comparison between ceramic and metal-ceramic implant-supported prostheses, encompassing both single- and multi-unit prostheses. The study concluded that both types exhibited similar rates of mechanical and biological complications, as well as comparable prosthesis survival rates. In the present systematic review, our aim was to assess the survival rate and mechanical complications associated with zirconia ceramic, in comparison to metal-ceramic implant-supported multiunit FDPs.

MATERIALS AND METHODS

The systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The study was registered with the International Prospective Register of Systematic Reviews database having registration number CRD42021278891. Inclusion criteria comprised studies that directly compared metal-ceramic and zirconia-ceramic implant-supported multiunit FDPs within the same study, with a minimum period of 1-year follow-up. The review included randomized controlled trials (RCTs) and retrospective studies. Excluded studies encompassed *in vitro* and animal studies, those assessing only one

type of material without direct comparison, case series, case reports, studies with fewer than 10 patients, and studies focusing solely on implant-supported single crowns.

A review question was designed on the criteria of population, intervention, comparison, and outcome: "In partially edentulous patients undergoing rehabilitation with implant-supported multiunit FDPs, do zirconia-ceramic FDPs demonstrate the comparable rates of mechanical complications and prosthesis survival compared to metal-ceramic FDPs?" The population (P) consisted of partially edentulous patients rehabilitated with implant-supported multiunit FDPs, and intervention (I) was zirconia-ceramic FDPs, comparison (C) with metal-ceramic FDPs. The outcomes (O) were the mechanical complication and prosthesis survival rates.

Criteria for study selection

Two independent reviewers (GS and NT) searched in online databases, including MEDLINE (PubMed), Scopus, and Cochrane, up until December 2022, using a set of predefined keywords such as "dental implant," "zirconia," "zirconia-ceramic," "metal-ceramic," "survival," and "complication." Any disagreement between the reviewers was resolved by a third reviewer (SP). Furthermore, a meticulous hand search was performed in prominent dental journals such as *The Journal of Prosthetic Dentistry*, *The Journal of Indian Prosthodontic Society*, *The International Journal of Prosthodontics*, *The Journal of Prosthodontics*, and Clinical Oral Implant Research, to ensure no relevant articles were overlooked. In addition, the search was supplemented by screening the references of the included studies for any additional pertinent literature.

Search strategy

(((dental implant[Title/Abstract]) OR (implant[Title/Abstract])) AND ((((zirconia[Title/Abstract]) OR (all ceramic[Title/Abstract])) OR (metal free ceramic[Title/Abstract])) OR (zirconia-ceramic[Title/Abstract]))) AND ((metal-ceramic[Title/Abstract]) OR (porcelain-fused-to-metal[Title/Abstract])).

Risk-of-bias assessment

Risk-of-bias assessment was done using the Cochrane risk-of-bias tool for RCTs [Figures 1 and 2], and the Risk of Bias in Nonrandomized Studies-of Interventions (ROBINS-I) tool was used for retrospective studies. The bias analysis is depicted in Table 1.

RESULTS

Initially, 818 studies were identified from different electronic databases PubMed – 141, Scopus – 579, and Cochrane – 98. Duplicate studies were removed. Five hundred and eighty-six studies were excluded after screening the titles and abstracts. Both investigators further evaluated 25 full texts. After going through the full text, only six studies (four RCTs[17-20] and two retrospective studies[12,16]) fulfilled the inclusion criteria and were included in this systematic review [Figure 3].

Data extraction

The reviewers (GS and NT) independently extracted data from the selected articles using data extraction tables, with a thorough cross-verification of all parameters. Data extraction was done under the following parameters: author, year, country, study design, number of patients, number of implants, age range, and observation period. Regarding prostheses, the included parameters are their type, the number of FDPs, the incidence of mechanical complications, and the number of withdrawals [Table 2]. Additional details on the implant system, abutment material, number of implant abutments, region (arch prosthesis), and restoration material are provided in Table 3.

Risk-of-bias assessment

All RCTs showed a low risk of bias for random sequence generation and allocation concealment. Three studies[17-19] demonstrated a high risk of bias for participants blinding, although one study[20] showed a low risk of bias. Regarding blinding of outcome assessment, all the included RCTs were unclear. All the studies demonstrated a low risk of bias for attrition and reporting bias [Figures 1 and 2]. The ROBINS-I tool used for retrospective studies showed a low-to-moderate risk of bias [Table 1].

The included studies comprised 593 patients with an age range of 21–81 years. The total number of FDPs in the included studies was 725 among those four-unit FDPs (n = 18), three-unit FDPs (n = 704), and two-unit FDPs (n = 3), with a maximum follow-up of 6.5 years. The total number of zirconia-ceramic restorations was 341, whereas the total number of metal-ceramic restorations was 384 in the posterior quadrant of the maxilla and mandible. Four studies[16,17,19,20] mentioned ceramic core was fabricated from yttrium-stabilized zirconia. None of the studies reported the use of monolithic zirconia crowns. Two

Table 1: Risk of bias for retrospective studies using risk of bias in nonrandomized studies of interventions tool

Criteria	Shi *et al.*[16]	Nejatidanesh *et al.*[12]	Assessment
Bias due to confounding	Unclear	Unclear	Moderate
Bias in the selection of participants in the study	No	No	Low
Bias in the classification of interventions	No	No	Low
Bias due to deviations from intended interventions	Unclear	Unclear	Moderate
Bias due to missing data	No	No	Low
Bias in the measurement of outcomes	No	No	Low
Bias in the selection of the reported result	No	No	Low

Table 2: Characteristics of included studies

Author/year	Country	Study type	Number of patients/number of FDPs	Age range (years)	Observation period (year)	Mechanical complication		Survival rate	
						Zirconia	MC	Zirconia	MC
Esquivel-Upshaw *et al.*, 2014[17]	USA	RCT	55/72	52–75	2	6/36	4/36	1/36	0/36
Türk *et al.*, 2013[18]	Turkey	RCT	23/42	27–68	1	0/20	0/22	NR	NR
Esquivel-Upshaw *et al.*, 2014[19]	USA	RCT	68/89	21–75	3	6/41	7/48	NR	NR
Shi *et al.*, 2017[16]	China	Retrospective	237/279	34–81	8	45/127	30/152	6/127	7/152
Esquivel-Upshaw *et al.*, 2020[20]	USA	RCT	96/129	21–75	5	16/65	11/64	NR	NR
Nejatidanesh *et al.*, 2020[12]	Iran	Retrospective	114/114	32–77	5	9/52	5/62	1/52	1/62

RCT: Randomized controlled trials; NR: Not reported; FPDs: Fixed dental prostheses

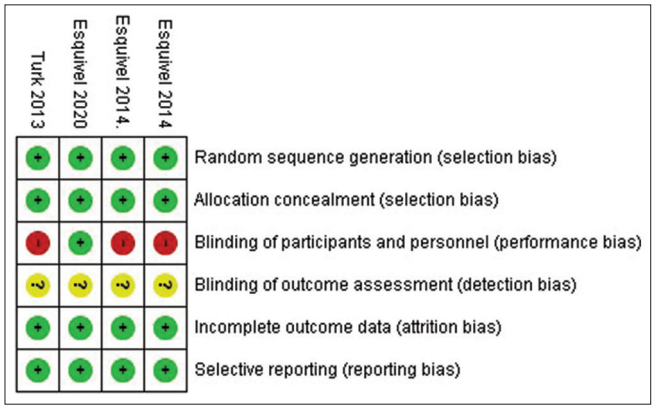

Figure 1: Risk-of-bias assessment of included studies using the Cochrane collaboration tool for risk of bias.

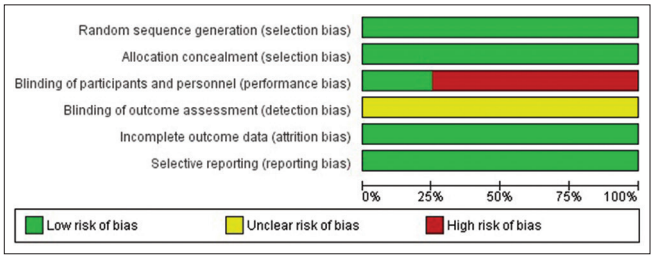

Figure 2: Risk-of-bias graph.

studies reported on the dropouts, which were 13 and 10 patients, respectively,[12,16] as they had not been reported in the follow-up period. Three studies in this review were conducted in the USA[17,19,20] and one each in China,[16] Iran,[12] and Turkey.[18]

The meta-analysis employed the inverse variance and Mantel–Haenszel methods to evaluate the dichotomous outcomes of mechanical complication and prosthesis survival rates, utilizing the risk ratio (RR) as the primary statistical measure. The six included studies assessed the mechanical complication, primarily ceramic fracture, or minor chipping. Statistical heterogeneity among studies was assessed using the I^2 statistics, where values of I^2 below 25% indicated low heterogeneity, 50% suggested moderate heterogeneity, and values exceeding 75% denoted a high level of heterogeneity. The meta-analysis results indicated a significant preference for metal ceramic over zirconia ceramic in terms of mechanical complications, with a RR value of 1.64 (P = 0.001; RR: 1.64; 95% confidence interval [CI]: 1.21–2.21) and no observed heterogeneity (P = 0.82; I^2 = 0%) [Figure 4].

Prosthesis survival was evaluated in three studies.[12,16,17] Out of 465 restorations placed, 15 failures were reported, of which eight were in zirconia-ceramic restorations and seven were in metal-ceramic restorations. Meta-analysis presented no significant difference in prosthesis survival rate between the evaluated FDPs (P = 0.63; RR: 1.27, 95% CI: 0.49–3.32; heterogeneity: P =0.65; I^2 = 0%) [Figure 5].

DISCUSSION

The present systematic review and meta-analysis compared the metal-ceramic and zirconia-ceramic

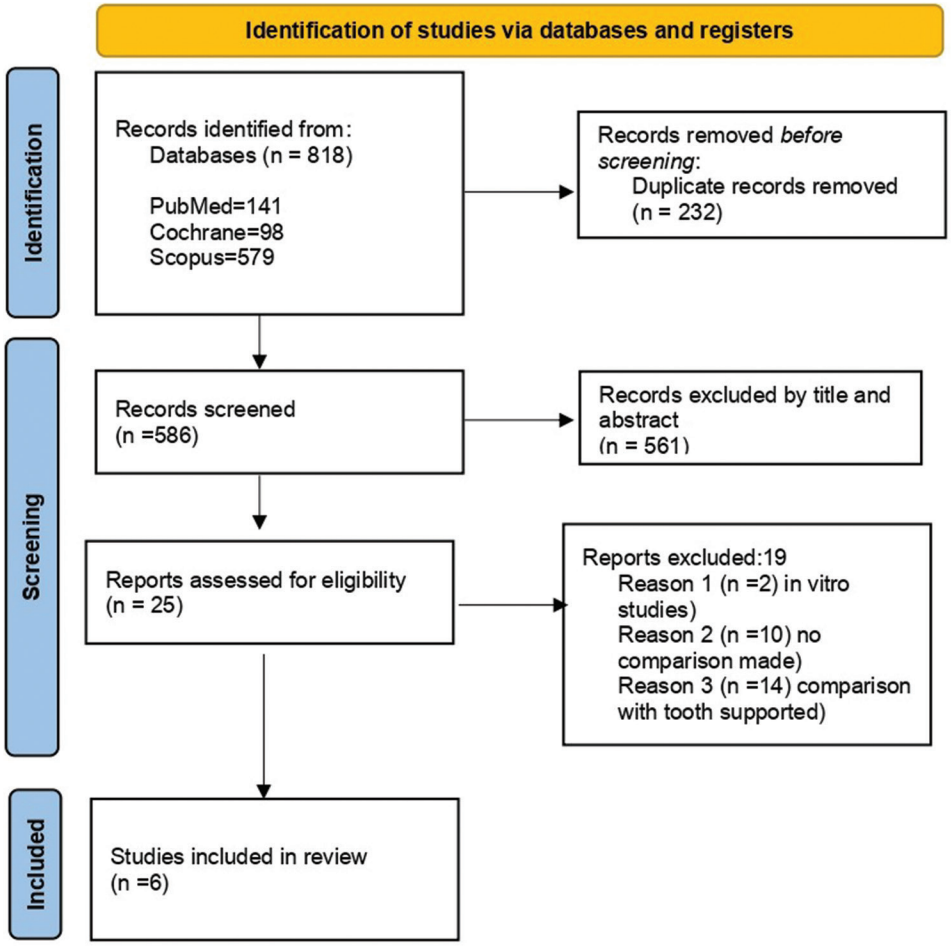

Figure 3: The PRISMA flowchart for literature search.

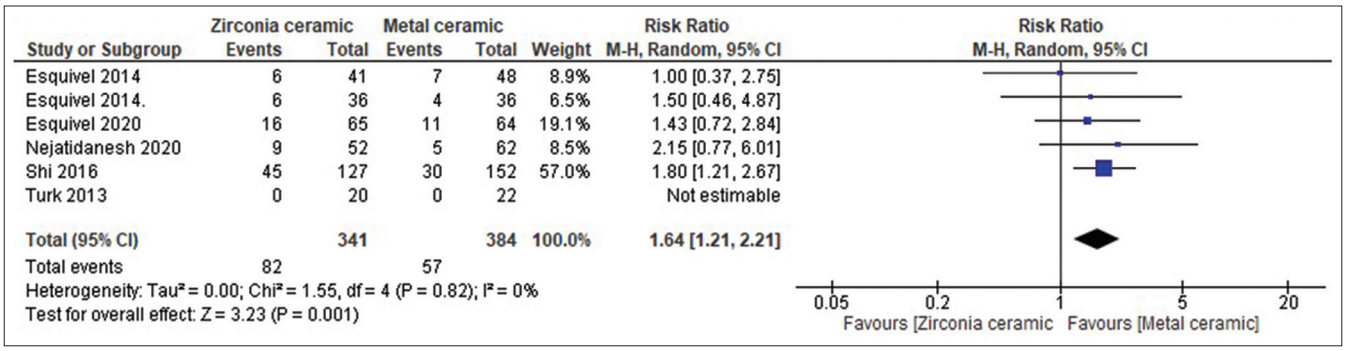

Figure 4: Forest plot of the comparison of studies evaluating mechanical complications. CI: Confidence interval.

implant-supported multiunit FDPs regarding mechanical complications and survival rate. The study sought to aid clinicians in selecting the most suitable restorative material, considering reduced mechanical complications and a high survival rate. To minimize bias, only studies directly comparing multiunit FDPs were included. The meta-analysis results notably favored metal-ceramic restorations over zirconia ceramic, with the inadequate thickness of both the core and veneer ceramics identified as a key factor contributing to chipping in zirconia-ceramic restorations.[17] Notably, an increase in veneer thickness does not necessarily improve fracture resistance and can compromise the substructure by reducing core thickness. Grade I chipping (minor chipping) was significantly more prevalent in the ceramic group, potentially attributed to the bonding interface between zirconia copings and veneering ceramic.

Table 3: Implant and prosthetic specifications of included studies

Author/year	Implant system	Abutment material	Number of implant abutments	Arch	Restoration material	
					AC	MC
Esquivel-Upshaw *et al.*, 2014[17]	OsseoSpeed, Astra Tech/ Dentsply	Customized titanium abutments (Atlantis, Astra Tech)	114	Posterior arch	YTZP (IPS e.max ZirCAD Ivoclar) + fluorapatite GCV (IPS ZirPress InLine Ivoclar)	Pd-Au-Ag alloy + leucite (IPS InLine PoM, Ivoclar)
Türk *et al.*, 2013[18]	Dentsply Friadent-Xive and Zimmer Tapered Screw-Vent	AC: Zirconia ceramics MC: Base metal alloy	67	Maxilla - 43 Mandible - 24	NR	NR
Esquivel-Upshaw *et al.*, 2014[19]	OsseoSpeed, Astra Tech/ Dentsply	Custom-milled titanium (Atlantis, Astra Tech)	72	Posterior arch	YTZP (IPS e.max ZirCAD Ivoclar) + fluorapatite GCV (IPS ZirPress InLine Ivoclar)	Pd-Au-Ag alloy + leucite (IPS InLine PoM, Ivoclar)
Shi *et al.*, 2017[16]	NR	Titanium	616	AC Maxilla - 56 Mandible - 71 MC Maxilla - 85 Mandible - 67	YTZP framework (3M ESPE) and veneered with ceramic VITA VM9)	High-noble alloy and veneered with porcelain (Ivoclar-Vivadent)
Esquivel-Upshaw *et al.*, 2020[20]	OsseoSpeed, Astra Tech, Dentsply Sirona Implants	Milled titanium abutments (Atlantis, Astra Tech)	129	Posterior arch	YTZP fluorapatite glass ceramic, IPS e.max ZirCAD and ZirPress, core	Noble Pd- Au-Ag alloy (Capricorn, Ivoclar, Vivadent/press-on leucite-reinforced glass ceramic veneer IPS InLine PoM, Ivoclar Vivadent)
Nejatidanesh *et al.*, 2020[12]	Straumann Dental Implant System	Cemented type abutment regular or wide neck synOcta abutments, Straumann	244	Maxilla - 107 Mandible - 137	Zirconia (Ceramill ZI)	Base metal alloy casting (Bellavest SH, Bego)

NR: Not reported; YTZP: Yttria-stabilized zirconia pressable; AC: All ceramic; MC: Metal ceramic; IPS: Ivoclar Vivadent's Precision System; CAD: Computer Aided Designing; GCV: Glass Ceramic Veneer; PoM: Press-on-Metal ; SH: Shock heat

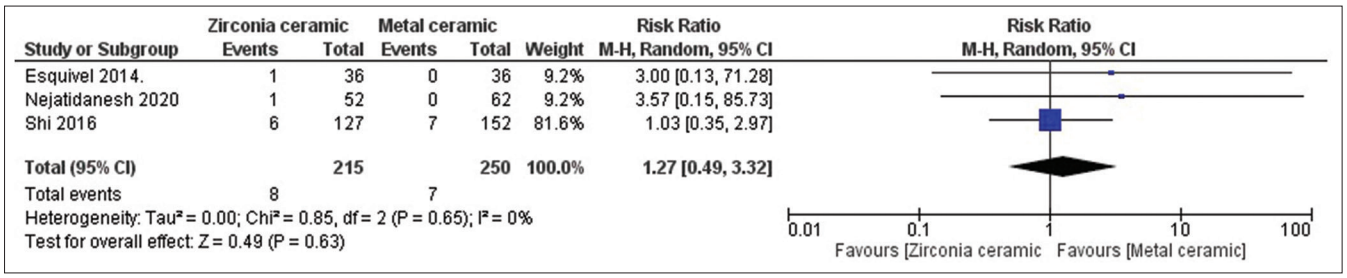

Figure 5: Forest plot of the comparison of studies evaluating prostheses survival rate. CI: Confidence interval.

Consequently, zirconia restorations necessitate more meticulous polishing and maintenance compared to their metal-ceramic counterparts.

In a previous systematic review,[21] where a direct comparison was not made within the same study, the reported survival rate for implant-supported FDPs was 95% after 5 years and 86.7% after 10 years of function. In our study, the survival rate for implant-supported FDPs was notably higher at 96.77%. Notably, the previous study recorded a higher incidence of mechanical complications, amounting to 38.7% for implant-supported FDPs, compared to the 19.17% observed in our study. These findings highlight the enhanced longevity of restorations, which can be attributed to the recent advancements in CAD/CAM technology and ceramic materials.[22,23] Schönberger *et al*. demonstrated the improved precision of fit for frameworks milled from semi-sintered regular zirconia and high-translucent zirconia blanks using two different CAD/CAM systems (Cercon/Ceramill).[23]

The meta-analysis findings indicated no significant difference in the survival rates between metal-ceramic

and zirconia-ceramic restorations. Various factors were identified as contributors to prosthesis failures, encompassing loss of implant due to peri-implantitis, issues related to cement excess, inadequate marginal adaptation, compromised retention, and substantial fractures affecting prosthesis maintenance.[17] Notably, the orientation of the loading force on the prosthesis, particularly lateral and oblique forces, generates tensile stresses that can weaken the substructure and result in chipping.[20] The design quality of the prosthesis also plays a crucial role in determining the risk of fracture, considering the absence of a periodontal ligament to absorb shock. When zirconia is used as a core material, the maximum intercuspation factor emerges as a critical determinant of restoration survival. Employing a pressed form for veneer application has shown promise in reducing chipping, as it minimizes porosity and provides a compact structure within the prosthesis.

Considering the limitation of the study, one of the included studies[18] had a follow-up period of only 1 year, although a more extended period is necessary for assessing the prosthesis survival rate. In addition, marginal bone loss was identified as a significant factor influencing implant survival, with the zirconia-ceramic group demonstrating less marginal bone loss when compared to the base metal alloy.[18] The data suggested that while metal-ceramic restorations exhibited fewer mechanical complications than zirconia ceramic, the performance of the material was also influenced by various parameters, including the connector's height and radius of curvature.[19]

CONCLUSION

While metal-ceramic multiunit implant-supported prostheses exhibited fewer mechanical complications than their zirconia-ceramic counterparts, no significant difference was observed in terms of the prosthesis survival rate between the two. Consequently, both treatments prove to be viable options for long-term implant-supported prostheses. It is important to note that the material of the coping alone cannot be held solely responsible for ceramic fractures. Various factors contributing to chipping include the adhesion interface, implant angulation, and the presence of high occlusal points. In addition, the design, quality, and veneer ceramic thickness also play a crucial role in determining the susceptibility to restoration chipping. The presence of marginal gaps can potentially harm the soft tissues surrounding the implant. Notably, zirconia-based FDPs demonstrated significantly improved marginal fit, highlighting their potential superiority in this aspect.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Jayaraman S. Intervention for replacing missing teeth: Partially absent dentition-evidence summary of Cochrane review. J Indian Prosthodont Soc 2015;15:65-9.
2. Papaspyridakos P, Chen CJ, Singh M, Weber HP, Gallucci GO. Success criteria in implant dentistry: A systematic review. J Dent Res 2012;91:242-8.
3. Lops D, Bressan E, Chiapasco M, Rossi A, Romeo E. Zirconia and titanium implant abutments for single-tooth implant prostheses after 5 years of function in posterior regions. Int J Oral Maxillofac Implants 2013;28:281-7.
4. Sailer I, Strasding M, Valente NA, Zwahlen M, Liu S, Pjetursson BE. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses. Clin Oral Implants Res 2018;29 Suppl 16:184-98.
5. Heintze SD, Rousson V. Survival of zirconia- and metal-supported fixed dental prostheses: A systematic review. Int J Prosthodont 2010;23:493-502.
6. Sailer I, Philipp A, Zembic A, Pjetursson BE, Hämmerle CH, Zwahlen M. A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions. Clin Oral Implants Res 2009;20 Suppl 4:4-31.
7. Joda T, Brägger U. Time-efficiency analysis comparing digital and conventional workflows for implant crowns: A prospective clinical crossover trial. Int J Oral Maxillofac Implants 2015;30:1047-53.
8. Guess PC, Att W, Strub JR. Zirconia in fixed implant prosthodontics. Clin Implant Dent Relat Res 2012;14:633-45.
9. Manicone PF, Rossi Iommetti P, Raffaelli L. An overview of zirconia ceramics: Basic properties and clinical applications. J Dent 2007;35:819-26.
10. Denry I, Kelly JR. State of the art of zirconia for dental applications. Dent Mater 2008;24:299-307.
11. Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. Biomaterials 1999;20:1-25.
12. Nejatidanesh F, Abbasi M, Savabi G, Bonakdarchian M, Atash R, Savabi O. Five year clinical outcomes of metal ceramic and zirconia-based implant-supported dental prostheses: A retrospective study. J Dent 2020;100:103420.
13. Solá-Ruiz MF, Leon-Martine R, Labaig-Rueda C, Selva-Otalaorrouchi E, Agustín-Panadero R. Clinical outcomes of

veneered zirconia anterior partial fixed dental prostheses: A 12-year prospective clinical trial. J Prosthet Dent 2022;127:846-51.
14. Tabesh M, Nejatidanesh F, Savabi G, Davoudi A, Savabi O, Mirmohammadi H. Marginal adaptation of zirconia complete-coverage fixed dental restorations made from digital scans or conventional impressions: A systematic review and meta-analysis. J Prosthet Dent 2021;125:603-10.
15. Lemos CA, Verri FR, Gomes JM, de Souza Batista VE, Cruz RS, Oliveira HF, *et al*. Ceramic versus metal-ceramic implant-supported prostheses: A systematic review and meta-analysis. J Prosthet Dent 2019;121:879-86.e4.
16. Shi JY, Zhang XM, Qiao SC, Qian SJ, Mo JJ, Lai HC. Hardware complications and failure of three-unit zirconia-based and porcelain-fused-metal implant-supported fixed dental prostheses: A retrospective cohort study with up to 8 years. Clin Oral Implants Res 2017;28:571-5.
17. Esquivel-Upshaw JF, Clark AE, Shuster JJ, Anusavice KJ. Randomized clinical trial of implant-supported ceramic-ceramic and metal-ceramic fixed dental prostheses: Preliminary results. J Prosthodont 2014;23:73-82.
18. Türk AG, Ulusoy M, Toksavul S, Güneri P, Koca H. Marginal bone loss of two implant systems with three different superstructure materials: A randomised clinical trial. J Oral Rehabil 2013;40:457-63.
19. Esquivel-Upshaw JF, Mehler A, Clark AE, Neal D, Anusavice KJ. Fracture analysis of randomized implant-supported fixed dental prostheses. J Dent 2014;42:1335-42.
20. Esquivel-Upshaw JF, Mecholsky JJ Jr., Clark AE, Jenkins R, Hsu SM, Neal D, *et al*. Factors influencing the survival of implant-supported ceramic-ceramic prostheses: A randomized, controlled clinical trial. J Dent 2020;103S: 100017.
21. Pjetursson BE, Tan K, Lang NP, Brägger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. Clin Oral Implants Res 2004;15:625-42.
22. Nejatidanesh F, Shakibamehr AH, Savabi O. Comparison of marginal and internal adaptation of CAD/CAM and conventional cement retained implant-supported single crowns. Implant Dent 2016;25:103-8.
23. Schönberger J, Erdelt KJ, Bäumer D, Beuer F. Marginal and internal fit of posterior three-unit fixed zirconia dental prostheses fabricated with two different CAD/CAM systems and materials. Clin Oral Investig 2017;21:2629-35.