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LONG-TERM SURVIVAL AND PERFORMANCE OF ZIRCONIA-BASED FIXED DENTAL PROSTHESES: A NARRATIVE REVIEW OF CLINICAL STUDIES

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ABSTRACT

Background

Zirconia based fixed dental prostheses (FDPs) are widely used because of their favorable mechanical properties, biocompatibility, and improved optical characteristics. However, uncertainty remains regarding their long term clinical performance, particu-

larly with respect to technical complications, differences between monolithic and veneered zirconia, and the influence of restoration design and clinical protocols.

Aim

To critically evaluate the long term survival and clinical performance of zirconia based FDPs, with particular emphasis on technical and biological complications and the influence of zirconia type, restoration design, surface conditioning, and cementation protocols.

Materials and Methods

This narrative review was conducted in accordance with the SANRA recommendations. PubMed, Web of Science, and Scopus were searched for publications from January 2017 to July 2026 using combinations of terms related to zirconia, fixed dental prostheses, monolithic and veneered zirconia, clinical performance, survival, and complications. Prospective and retrospective clinical studies, systematic reviews, meta analyses, and other relevant publications were considered. Clinical studies were required to include at least 10 cases, have a minimum follow up of 3 years, and report clearly defined clinical outcomes. In vitro studies and publications lacking clear outcome measures were excluded. Additional relevant sources were identified through manual screening of reference lists. Twenty four publications reporting clinical survival, complications, and characteristics of zirconia restorations were selected for structured comparative analysis.

Results

Short and medium term outcomes were generally favorable, with survival rates commonly exceeding 90% at approximately 5 years. Long term outcomes were more heterogeneous, with substantially greater variation in survival rates across studies with follow up periods of 10 years or longer. Technical complications, particularly veneering ceramic chipping, loss of retention, and framework fracture, were important determinants of clinical longevity. Monolithic zirconia was associated with fewer veneering related complications than veneered zirconia, although this did not translate into universal clinical superiority. Biological complications did not appear substantially more frequent than with other fixed prosthetic materials. Restoration design, zirconia configuration, surface conditioning, and cementation protocols also appeared to influence clinical performance.

Conclusions

Zirconia based FDPs provide generally favorable clinical outcomes, particularly over short and medium term follow up. Long term performance is more variable and depends on multiple material, prosthetic, and clinical factors. Monolithic zirconia may reduce veneering related complications, but treatment selection should remain indication specific. Long term evidence for newer highly translucent zirconia materials remains limited.

Keywords: zirconia, fixed dental prosthesis, survival, monolithic zirconia, veneered zirconia, clinical performance, technical complications, biological complications

INTRODUCTION

Zirconia-based fixed dental prostheses (FDPs) have become an integral component of contemporary prosthodontic practice, reflecting a broader and well-documented shift toward metal-free restorative solutions. This transition is not merely driven by esthetic considerations but is also closely linked to biocompatibility concerns, patient preferences, and advancements in dental materials science. The increasing popularity of zirconia is primarily attributed to its favorable mechanical properties, including high flexural strength, superior fracture toughness, and remarkable resistance to crack propagation, combined with progressively improved optical characteristics. These features position zirconia as a versatile biomaterial capable of meeting both the functional and esthetic demands of modern restorative dentistry [1].

In their initial clinical applications, zirconia frameworks were predominantly veneered with feldspathic porcelain to enhance translucency and better mimic the optical properties of natural dentition [2]. Although this bilayered design enabled acceptable esthetic outcomes, it introduced a significant clinical limitation associated with the veneering ceramic. In particular, chipping of the veneering layer and, less frequently, delamination at the zirconia-porcelain interface emerged as the most commonly reported technical complications. These failures have been consistently documented across clinical studies and systematic reviews, raising concerns regarding the long-term predictability and reliability of veneered zirconia FDPs, especially in high-load conditions and extended observation periods [3]. Consequently, the clinical community has sought alternative approaches to mitigate these complications while preserving the mechanical advantages of zirconia.

The introduction of monolithic zirconia restorations represents a pivotal development in this context. By eliminating the veneering layer, monolithic designs significantly reduce the risk of interfacial failure and exhibit enhanced structural homogeneity, which translates into improved resistance to mechanical complications such as chipping and fracture [4]. However, early generations of monolithic zirconia were limited by their relatively high opacity, restricting their indication primarily to posterior restorations where esthetic demands are less critical. Recent advances in material engineering, including modifications in yttria content and grain size, have led to the development of high-translucency zirconia. These newer formulations allow for broader clinical application, extending into the anterior region where optical properties are of paramount importance [5].

The widespread adoption of zirconia has also been facilitated by its compatibility with computer-aided design and computer-aided manufacturing (CAD/CAM) technologies. Digital workflows enable highly precise fabrication, improved marginal accuracy, and enhanced reproducibility, while also streamlining laboratory procedures and reducing technique sensitivity [6-8]. Within this evolving technological landscape, yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) has emerged as the most extensively studied and clinically utilized zirconia variant. Its transformation toughening mechanism, which inhibits crack propagation under stress, underpins its exceptional mechanical performance and long-term durability [9,10]. As a result, zirconia-based FDPs are now routinely employed in both posterior load-bearing regions and anterior esthetic zones, further underscoring their clinical versatility [11].

Despite these substantial advancements, the long-term clinical performance of zirconia-based FDPs remains a subject of ongoing debate and investigation. While short- and medium-term outcomes are generally favorable, uncertainties persist regarding long-term survival rates, the incidence and nature of biological and technical complications, and their comparative effectiveness relative to established restorative materials such as metal-ceramic prostheses. Moreover, the growing diversity of zirconia materials (e.g., varying yttria content), restoration designs (monolithic versus veneered), surface treatment protocols, and cementation strategies introduces significant heterogeneity into the available body of evidence. This variability complicates the interpretation of clinical outcomes and limits the ability to draw definitive, generalizable conclusions.

Given the increasing clinical reliance on zirconia-based FDPs and the expanding body of heterogeneous clinical data, a critical and comprehensive synthesis of the available evidence is of considerable importance. Such an analysis is essential not only to clarify

the long-term reliability and risk profile of these restorations but also to inform evidence-based clinical decision-making and optimize patient outcomes.

Therefore, the aim of this narrative review is to critically evaluate the long-term survival and clinical performance of zirconia-based fixed dental prostheses based on available clinical studies. Specifically, this review seeks to analyze reported survival rates over extended follow-up periods, assess the prevalence and nature of biological complications, including periodontal response and secondary caries, and evaluate technical complications such as fracture, chipping, and loss of retention, with particular consideration of differences between monolithic and veneered zirconia restorations. By integrating findings from diverse clinical investigations, this review aims to provide a structured and clinically relevant overview of the long-term outcomes associated with zirconia-based FDPs and to support more predictable and evidence-based prosthodontic treatment planning.

Notwithstanding the growing number of clinical reports, important gaps remain in the literature. Long term data extending beyond ten years are still limited, particularly for newer high translucency zirconia materials. In addition, differences in outcome definitions, complication reporting, zirconia generations, restoration designs, and study methodology make direct comparison between studies difficult. This narrative review therefore examines the available clinical evidence on the long term performance of zirconia based fixed dental prostheses and considers the main factors that may influence clinical outcomes.

AIM

To critically evaluate the long term survival and clinical performance of zirconia based fixed dental prostheses.

Objectives

1. To summarize the medium term and long term survival of zirconia based fixed dental prostheses.
2. To assess the main technical and biological complications associated with zirconia based fixed dental prostheses.
3. To evaluate the influence of zirconia type, restoration design, surface treatment, and cementation protocols on clinical outcomes.

MATERIALS AND METHODS

This narrative review was conducted in accordance with the SANRA recommendations. The literature search was performed in PubMed, Web of Science, and Scopus and covered publications from January 2017 to July 2026. The search used combinations and the derivatives of the following terms: “zirconia”, “fixed dental prosthesis”, “FDP”, “monolithic zirconia”, “veneered zirconia”, “clinical performance”, “long term outcomes”, “survival rates”, and “complications”.

The following search string was applied to the PubMed database:

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( "zirconia"[Title/Abstract] OR "zirconium oxide"[Title/Abstract] OR "zirconium dioxide"[Title/Abstract] OR "yttria-stabilized zirconia"[Title/Abstract] OR "yttrium-stabilized zirconia"[Title/Abstract] OR "Y-TZP"[Title/Abstract] OR "monolithic zirconia"[Title/Abstract] OR "monolithic zirconium"[Title/Abstract] OR "veneered zirconia"[Title/Abstract] OR "zirconia-based"[Title/Abstract] )
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AND

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( "fixed dental prosthesis"[Title/Abstract] OR "fixed dental prostheses"[Title/Abstract] OR "fixed partial denture"[Title/Abstract] OR "fixed partial dentures"[Title/Abstract] OR "fixed dental bridge"[Title/Abstract] OR "fixed dental bridges"[Title/Abstract] OR "dental bridge"[Title/Abstract] OR "dental bridges"[Title/Abstract] OR "FDP"[Title/Abstract] OR "FPD"[Title/Abstract] )
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AND

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( "clinical performance"[Title/Abstract] OR "clinical outcome"[Title/Abstract] OR "clinical outcomes"[Title/Abstract] OR "long-term outcome"[Title/Abstract] OR "long-term outcomes"[Title/Abstract] OR "long term outcome"[Title/Abstract] OR "long term outcomes"[Title/Abstract] OR "clinical longevity"[Title/Abstract] OR "longevity"[Title/Abstract] OR "survival"[Title/Abstract] OR "survival rate"[Title/Abstract] OR "survival rates"[Title/Abstract] OR "failure"[Title/Abstract] OR "failure rate"[Title/Abstract] OR "failure rates"[Title/Abstract] OR "complication"[Title/Abstract] OR "complications"[Title/Abstract] OR "technical complications"[Title/Abstract] OR "biological complications"[Title/Abstract] OR "fracture"[Title/Abstract] OR "chipping"[Title/Abstract] OR "veneering fracture"[Title/Abstract] OR "debonding"[Title/Abstract] OR "loss of retention"[Title/Abstract] )
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Prospective and retrospective clinical studies, systematic reviews, meta analyses, and other relevant publications addressing zirconia based fixed dental prostheses were considered for inclusion. Eligible publications addressed clinical survival, technical and

biological complications, material characteristics, restoration design, surface treatment, or cementation protocols. Clinical studies were required to include at least 10 cases, have a minimum follow up of 3 years, and report clearly defined clinical outcomes.

In vitro studies, clinical studies involving fewer than 10 cases, and publications lacking clearly defined outcome measures were excluded. Additional relevant sources were identified through manual screening of the reference lists of selected publications.

Following the literature search, publications were selected according to their relevance to the topic of the review and the predefined inclusion and exclusion criteria.

The review included a total of 40 references. Of these, 24 publications directly reporting data on clinical survival, complications, and characteristics of zirconia restorations were selected for structured comparative analysis and summarized in Tables 1 and 2. The remaining references were used to support the Introduction, the discussion of material properties and clinical protocols, and the interpretation of the findings.

RESULTS

A total of 24 publications were included in the structured analysis of clinical outcomes. Tables 1 and 2 summarize the main characteristics and findings of these publications.

Table 1. Survival rates and main complications of included zirconia restorations in review articles

NO.	TITLE	AUTHOR [REFERENCE ID]	STUDY DESIGN	RESTORATI ON TYPE	SAMPLE SIZE	MEAN FOLLOW-UP (YEARS)	MEAN SURVIVAL RATE	TECHNICAL COMPLICAT IONS (OC- CURRENCE RATE %)	BIOLOGICAL COMPLICAT IONS (OC- CURRENCE RATE %)
1	Survival and Complications Rates of Feldspathic, Leucite-Reinforced, Lithium Disilicate and Zirconia Ceramic Laminate Veneers: A Systematic Review and Meta-Analysis	P. Klein, F. A. Spitznagel [3]	A Systematic Review and Meta-Analysis	Anterior and premolar laminate-veneers	4–6 years = 3761 ≥ 7 Years = 1688	5.0 and 10.4	4–6 years = 97.1% ≥ 7 Years = 96.1%	Marginal discoloration, bulk fracture, chipping (mid-term 16.6%, long-term 26.4%)	Secondary caries, abutment tooth loss (mid-term 0.5%, long-term 2.2%)
2	Clinical Outcomes of CAD/CAM (Lithium disilicate and Zirconia) Based and Conventional Full Crowns and Fixed Partial Dentures: A Systematic Review and Meta-Analysis	G. S. Aswal, R. Rawat, D. Dwivedi, N. Prabhakar, V. Kumar [6]	A Systematic Review and Meta-Analysis	SC FDPs	1598	3.6 (range: 1-9.3)	Not disclosed	Chipping	Tooth fracture
3	Clinical performance of zirconia-based tooth-supported fixed dental prostheses: A systematic review and meta-analysis	H. Chen, T. Li, J. Pui Z. Ng, L. Almeheni, K. Yan Li, M. F. Burrow [10]	A systematic review and meta-analysis	Bilaminar zirconia FDPs, MC FDPs	286	≤5 and 5-10 and >10	Not reported	Ceramic chipping, framework fracture, loss of retention; more failures of zirconia FDPs than MC FDPs (RR = 3.6)	Secondary caries

4	Prosthodontic Complications of Metal-Ceramic and All-Ceramic, Complete-Arch Fixed Implant Prostheses with Minimum 5 Years Mean Follow-Up Period. A Systematic Review and Meta-Analysis	C. K. K. Wong, U. Narvekar, H. Petridis [12]	A Systematic Review and Meta-Analysis	MC and AC complete-arch IS FDPs	305	5 (range up to 14.7)	100%	Porcelain veneer fracture, framework fracture	Abutment fracture
5	Long-term clinical performance and complications of zirconia-based tooth and implant-supported fixed prosthodontic restorations: A summary of systematic reviews	H. Laumbacher, T. Strasser, H. Knüttel, M. Rosentritt [13]	A summary of systematic reviews	TS or IS SC and multi-unit FDP	Approximately 10 000	5 (range 0.5 to 11)	TS SC: 91.2% - 95.9%, TS FDPs: 89.4% - 100% IS SCs: 97.1% - 97.6%, IS FDPs: 93% - 100%	Chipping, framework fracture, loss of retention, marginal discrepancies	Secondary caries, loss of vitality
6	Clinical outcomes of partial and full-arch all-ceramic implant-supported fixed dental prostheses. A systematic review and meta-analysis	S. Pieralli, R. Kohal, K. Rabel, M. von Stein-Lausnitz, K. Vach, B. C. Spies [14]	A systematic review and meta-analysis	Partial and full-arch AC IS FDP	267 partial-FDP + 273 full-arch-FDP	Partial 4.4 (range 3-10) Full-arch 3.1 (range 1.7-5.6)	5-year 98.3% (partial), 97.7% (full-arch)	Chipping (partial 22.8%, full-arch 34.8%), framework fracture, de-cementations	Implant abutment loss

7	A Systematic Review of the Survival and Complication Rates of All-Ceramic Resin-Bonded Fixed Dental Prostheses	J. Chen, H. Cai, X. Ren, L. Suo, X. Pei, Q. Wan [18]	A Systematic Review	AC resin-bonded FDPs	242	6.9	5-year 91.2%	Debonding (12.2%), framework fracture (4.8%)	Caries, periodontitis
8	A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses	I. Sailer, M. Strasding, N. A. Valente, M. Zwahlen, S. Liu, B. E. Pjetursson [19]	A systematic review	zirconia-ceramic and/or monolithic zirconia IS FDPs, MC FDPs	932 metal-ceramic and 175 zirconia-ceramic FDPs	> 3	98.7% (MC), 93% (zirconia-ceramic)	Ceramic fractures (4.1% zirconia ceramics, 0.2% monolithic zirconia)	Peri-implant mucosal lesions
9	A systematic review and meta-analysis evaluating the survival, the failure, and the complication rates of veneered and monolithic all-ceramic implant-supported single crowns	B. E. Pjetursson, I. Sailer, A. Latyshev, K. Rabel, D. Kohal, D. Karasan [23]	A systematic review and meta-analysis	veneered and monolithic AC IS SC	2160	3	3-year veneered glass-ceramic 97.6%, monolithic glass-ceramic 96.9%, veneered zirconia 96.3%, monolithic zirconia 96.1%	Chipping (veneered 1.7%, monolithic 0.4%) loss of retention (2%), loosening of the abutment or prosthetic screws (0.4%)	Soft tissue complication (2.6%)
10	Clinical outcomes of tooth-supported monolithic zirconia vs. porcelain-veneered zirconia fixed dental prosthesis, with an additional focus on the cement type: a systematic review and meta-analysis	S. Shihabi, B. R. Chrcanovic [24]	A systematic review and meta-analysis	monolithic zirconia and porcelain-veneered zirconia TS FDPs	6370 restorations (4264 porcelain-veneered zirconia; 2106 monolithic zirconia)	12.7	5 years 88.7% for porcelain-veneered zirconia 93.3% for monolithic zirconia	Minor chipping (10.4% veneered, 0.1% monolithic), major chipping (1.9% veneered, 0.1% monolithic), catastrophic fracture (0.4% veneered, 0.3% monolithic), decementation	Caries, loss of tooth vitality, periapical infection, abutment loss

11	Clinical Performanc e of CAD/CAM All-Ceramic Tooth- Supported Fixed Dental Prostheses : A Systematic Review and Meta- Analysis	B. Saravi, A. Vollmer, M. Hartmann, G. Lang, R. Kohal, M. Boeker, S. B. M. Patzelt [25]	A Systematic Review and Meta- Analysis	CAD/CAM TS zirco- nia- and lithium dis- ilicate- based FDPs	669	5, 10 (range: 1.5- 10)	5-year 89.7% to 91.1%, 10- year 79.3% to 82.2%	Chipping of the veneer- ing (1.5%), framework fracture (1.2%)	Secondary caries (1.9%)
12	Full-ceram- ic resin- bonded fixed den- tal pros- theses: A systematic review	S. Habibzade h, F. Khamisi, S. A. Mosaddad, G. V. de Oliveira Fernandes, A. Heboyan [29]	A system- atic review	AC resin- bonded FDPs	398	3 and 10	76% to 100%	Debonding (4.3%), framework fracture (3.2%), porcelain chipping (1%)	Not disclosed

Abbreviations: FDPs - fixed dental prostheses, SC - single crowns, TS - tooth-supported, IS – implant-supported, MC - metal-ceramic, AC – all-ceramic, CAD/CAM - computer aided design / computer aided manufacturing, NAC - nanostructured alumina coating.

Table 2. Survival rates and main complications of included zirconia restorations in clinical studies

NO.	TITLE	AUTHOR [REFER- ENCE ID]	STUDY DESIGN	RESTORATI ON TYPE	SAMPLE SIZE	MEAN FOLLOW-UP (YEARS)	MEAN SURVIVAL RATE	TECHNICAL COMPLICAT IONS (OC- CURRENCE RATE %)	BIOLOGICAL COMPLICAT IONS (OC- CURRENCE RATE %)
1	Long-term outcome of anterior cantilever zirconia ceramic resin-bonded fixed dental prostheses: Influence of the pontic location	M. Kern, L. Türp, C. Yazigi [11]	Clinical study	Cantilever zirconia resin-bonded FDPs	310	7.1 ($\pm$ 4.6)	15-year 97.3%	Debonding (5.5%), chipping (2.3%)	Periodontal (2.9%)
2	Long-term clinical outcomes of posterior monolithic and porcelain-fused zirconia crowns: A retrospective cohort study	Y. Takaesu, Y. Taniguchi, N. Kaga, Y. Yamaguchi, K. Kakura, N. Suzuki, T. Matsuura [15]	A retrospective cohort study	Monolithic zirconia SC and porcelain-fused zirconia SC	255	10	86% monolithic, 71% porcelain-fused	Fractures, debonding, porcelain chipping (overall 5.9%)	Root fractures, secondary caries (overall 3.5%)
3	Prospective Evaluation of Posterior Fixed Zirconia Dental Prostheses : 10-Year Clinical Results	S. Rinke, J. Wehle, X. Schulz, R. Bürgers, M. Rödiger [16]	Prospective clinical study	Three- and four-unit FDPs with zirconia frameworks	99	10 (9.9 ± 3)	75%	Core fractures, ceramic veneer fracture, loss of retention (overall 17.3%)	Secondary caries, endodontic complications (overall 14.7%)
4	Fifteen-year recall period on zirconia-based single crowns and fixed dental prostheses. A prospective observational study	S. Khijmatgar, M. Tumedei, G. Tartaglia, M. Crescentini, G. Isola, E. Sidoti, C. Sforza, M. Del Fabbro, G. M. Tartaglia [17]	A prospective observational study	TS or IS zirconia-core SC and FDPs	562	15	71.7%	Loss of retention (14.9%) veneer fracture (5%)	Loss of crown due to extraction (1.7%)

5	Long-term chipping and failure rates of implant-supported and combined tooth- and implant-supported metal-ceramic and ceramic fixed dental prostheses: A cohort study	P. Rammelsberg, A. Meyer, J. Lorenzo-Bermejo, S. Kappel, A. Zenthöfer [20]	A cohort study	MC and AC IS and combined TS-IS FDPs	434	4.3 (range: 0.5-12.6)	5 year 96%	Major chipping (1.1%), abutment screw loosening (0.2%)	Implant failure (1.3%), tooth loss (1.1%)
6	Outcome of posterior fixed dental prostheses made from veneered zirconia over an observation period of up to 13 years	N. Passia, M. S. Chaar, M. Kern [21]	Clinical study	3- to 4-unit posterior AC FDPs	24 fixed-to-fixed design, 34 cantilever design	7.12 ± 4.5 fixed-to-fixed 7.64 ± 4.16 cantilever design	13-year 43.2% (fixed-to-fixed) and 52.5% (cantilever design)	Chipping (overall 10.3%)	Secondary caries, periodontitis (overall 25.9%)
7	Ten-year survival and chipping rates and clinical quality grading of zirconia-based fixed dental prostheses	M. Teichmann, A. L. Wienert, M. Rückbeil, V. Weber, S. Wolfart, D. Edelhoff [22]	Clinical study	3- to 6-unit FDPs with zirconia frame-works, veneered with a glass-ceramic	27	10.0 ± 2.1	95%	Cracks, chipping (overall 40%)	Endodontic complications of the abutment tooth (overall 10%)
8	Resin-Bonded Fixed Dental Prostheses with Zirconia Ceramic Single Retainers Show High Survival Rates and Minimal Tissue Changes After a Mean of 10 Years of Service	N. Naenni, G. Michelotti, W. Lee, I. Sailer, C. H. F. Hämmerle, D. S. Thoma [28]	Clinical study	single-retainer resin-bonded FDPs	10	10.0 (range 7.4 to 13.3)	100%	None	None

9	Eight-Year Clinical Performance of Cantilevered Zirconia Resin-Bonded Fixed Dental Prostheses : A Randomized Controlled Trial Evaluating the Effect of Nanostructured Alumina Coating	T. Malgaj, A. Kocjan, M. Özcan, P. Jevnikar [33]	A Randomized Controlled Trial	can-tilevered zirconia resin-bonded FDPs pre-treated with NAC	64	5.1 ± 1.8	100%	Debonding (12.5%)	Periodontal (3.1%)
10	Retrospective Long-Term Survival Rate and Clinical Performance of Zirconium Oxide Restorations over the Past 5 Years: A Comparative Study Between Single Crowns and Fixed Dental Prostheses	D. Lolos, S. G. Mihali, S. Dinu, M. Mitariu, A. Tudor, R. Oancea [38]	Retrospective study	monolithic and layered zirconium oxide restorations	1143	12.7	96.3% overall, 100% monolithic, 95.8% layered	In layered zirconia: chipping (3%)	In layered zirconia: coronal and root fractures (1.2%)
11	Prospective 5-year clinical evaluation of posterior zirconia fixed dental prostheses veneered with milled lithium disilicate (CADon)	M. B. Blatz, K. Hariton-Gross, E. Anadioti, F. Mante, Y. Zhang, N. Saleh [39]	Clinical study	zirconia frameworks veneered with milled lithium disilicate glass-ceramic FDP	25	5	100%	Surface staining	None

12	Ten-year clinical performance of zirconia posterior fixed partial dentures	R. Matta, S. Eitner, S. P. Stelzer, S. Reich, M. Wichmann, L. Berger [40]	Prospective clinical study	three- and four-unit FDPs in the posterior region made of zirconium dioxide frameworks veneered with feldspathic porcelain	17	10	88.2%	Chipping	None
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Abbreviations: FDPs - fixed dental prostheses, SC - single crowns, TS - tooth-supported, IS - implant-supported, MC - metal-ceramic, AC - all-ceramic, CAD/CAM - computer aided design / computer aided manufacturing, NAC - nanostructured alumina coating.

Survival rates of zirconia fixed dental prostheses

The available body of clinical evidence consistently demonstrates high survival rates for zirconia-based fixed dental prostheses (FDPs), particularly in short- to medium-term follow-up periods. Across the majority of prospective and retrospective clinical studies, five-year survival rates exceed 90% [10,12,13], confirming the material's reliability in routine prosthodontic applications. Notably, implant-supported all-ceramic zirconia restorations have demonstrated survival rates as high as 98.3% over five years, suggesting excellent biomechanical stability under favorable clinical conditions [14].

In contrast, long-term data remain comparatively limited. The available studies reporting outcomes at ten years indicate survival rates ranging from 71% to 86% [15-17].

Technical complications

Technical complications represent a significant factor affecting the long-term success of zirconia FDPs. Among these, debonding and framework fracture are the most frequently reported issues, with estimated five-year complication rates of approximately 12% and 4.8%, respectively [18,19]. These complications are often associated with inadequate bonding protocols, suboptimal framework design, or excessive functional loading.

Chipping of the veneering ceramic is another commonly reported complication and a major contributor to compromised esthetic outcomes over time [19-22]. Comparative analyses have demonstrated that veneered zirconia tooth replacements are more susceptible to chipping than monolithic restorations. Specifically, during a three-year fol-

low-up period, veneered zirconia single crowns exhibited a chipping rate of 1.7%, compared to only 0.4% for monolithic zirconia single crowns [23]. Further five-year evaluations confirmed statistically significant differences between these two groups in both minor and major chipping events, although no significant differences were observed in the incidence of catastrophic fractures [24].

These findings suggest that while veneered zirconia may offer superior esthetics, it is associated with a higher risk of technical complications, whereas monolithic zirconia provides improved structural integrity and reduced maintenance requirements.

Biological complications

Biological complications associated with zirconia FDPs include secondary caries, periodontal disease, and endodontic complications [25]. The incidence of these complications appears to be comparable to that observed with other fixed prosthetic materials, indicating that zirconia does not pose an increased biological risk [26,27]. Importantly, long-term studies evaluating periodontal outcomes have reported stable clinical parameters around zirconia FDPs. In some investigations, periodontal indices remained comparable to those of natural control teeth over a ten-year observation period, suggesting favorable soft tissue compatibility and biocompatibility of zirconia materials [28].

Influence of restoration design and shape

Restoration design plays a crucial role in determining the long-term success of zirconia FDPs. Cantilever FDP designs have been associated with superior survival rates over extended follow-up periods (8–10 years) compared to conventional two-abutment designs [29,30]. This improved performance is largely attributed to reduced biomechanical stress resulting from minimized discrepancies in abutment tooth mobility.

Conversely, there is insufficient clinical evidence to establish the superiority of specific abutment preparation designs, such as the use of proximal boxes, grooves, pinholes, or other retentive features [29].

Influence of clinical procedure protocol

Clinical protocols significantly influence the long-term performance of zirconia FDPs, particularly with respect to surface conditioning and cementation strategies [31].

Airborne-particle abrasion (APA) remains the most extensively validated method for zirconia surface treatment. It enhances micromechanical retention and has been consistently associated with favorable long-term clinical outcomes [31,32]. Alternative surface conditioning methods, such as nanostructured alumina coating (NAC) and tribochemical silica coating, have shown promising results in achieving comparable bond strength in mid- to long-term observations [33,34]. However, their long-term impact on prosthesis survival remains insufficiently documented.

Regarding cementation, resin-based cements containing 10-methacryloyloxydecyl dihydrogen phosphate (MDP) primers are the most widely supported and clinically recommended option [32,35,36]. These systems promote durable chemical bonding to zirconia and contribute to reduced debonding rates. In contrast, conventional glass ionomer cements demonstrate limited evidence supporting their long-term effectiveness in zirconia-based restorations and are generally considered less reliable in high-stress clinical situations [37].

Influence of Material Composition

Material selection, particularly the distinction between monolithic and veneered zirconia, has a measurable impact on clinical outcomes. Monolithic zirconia FDPs generally demonstrate slightly higher survival rates compared to veneered counterparts, primarily due to a reduced incidence of technical complications such as chipping [38].

Some studies have reported near-perfect survival rates for FDPs fabricated from opaque monolithic yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) over five- and ten-year follow-up periods [39,40].

However, recent developments in zirconia technology have focused on increasing translucency to improve esthetic outcomes. While these newer materials offer enhanced optical properties, they often exhibit reduced mechanical strength, which may negatively influence long-term survival [10].

DISCUSSION

The present narrative review indicates that zirconia-based fixed dental prostheses (FDPs) generally demonstrate favorable clinical performance, particularly during short- and medium-term follow-up. Across the included studies, survival rates exceeding 90% at approximately 5 years were frequently reported, although substantial hetero-

geneity was observed across restoration types, support conditions, material configurations, and follow-up periods. In contrast, the available long-term evidence was less consistent, with reported survival rates at approximately 10 years ranging from 71% to 86% in several studies [15-17]. This variability suggests that the long-term clinical performance of zirconia FDPs cannot be adequately characterized by a single survival estimate. Rather, longevity appears to depend on a combination of restoration design, material configuration, technical procedures, functional loading, and biological factors. Importantly, survival alone may underestimate the clinical burden associated with zirconia restorations, because complications such as chipping, loss of retention, framework fracture, and biological complications may occur without necessarily resulting in complete prosthesis failure.

The generally favorable short- and medium-term survival observed in the present review is consistent with previous systematic reviews and clinical studies evaluating zirconia-based tooth- and implant-supported restorations [10,12-14]. The high survival rates reported over the first 3-5 years indicate that zirconia can provide predictable clinical service when appropriate indications, restoration designs, and clinical protocols are applied. However, the reduction in survival reported in some studies with longer observation periods warrants particular consideration. Long-term studies included in the present review demonstrated considerably greater variability than studies with shorter follow-up, with survival ranging from approximately 43% to 96% depending on restoration type and study characteristics [3,11,15-17,22,24,28,38,40]. These differences should not be interpreted solely as evidence of progressive material deterioration. They may also reflect differences in patient populations, prosthesis configuration, sample size, follow-up duration, definitions of failure and survival, as well as the distribution of technical and biological events. Consequently, comparisons between studies with substantially different designs and clinical indications should be made cautiously.

An important finding of this review is that the pattern of complications may be more informative for understanding zirconia FDP longevity than survival rates alone. Technical complications, particularly chipping of the veneering ceramic, loss of retention, and framework-related fracture, were repeatedly reported among the included studies [3,10-20,22-24]. Loss of retention appears to be particularly relevant for zirconia FDPs, with previous evidence identifying debonding as one of the principal complications affecting clinical performance [11,13,15-18,23,29,39]. The occurrence of debonding is clinically important because it may result in repeated recementation, additional clinical appointments, and, in some cases, replacement of the restoration. Its multifactorial

etiology means that it should not be attributed to the zirconia material alone. Surface treatment, cement selection, restoration geometry, preparation characteristics, functional loading, and clinical execution may all contribute to the durability of the zirconia–cement interface.

Chipping of the veneering ceramic represents another recurring technical complication and appears to be particularly relevant to veneered zirconia restorations [10,15,19,22–24,38,40]. The findings summarized in the present review consistently indicate a greater incidence of chipping in veneered compared with monolithic zirconia restorations. For example, one systematic review reported chipping rates of approximately 1.7% for veneered zirconia compared with 0.4% for monolithic zirconia during a 3-year follow-up period [23]. Similarly, longer-term comparative evidence has demonstrated significantly higher rates of both minor and major chipping in veneered zirconia, while catastrophic fracture rates did not differ significantly between the two configurations [24]. Taken together, these findings suggest that the veneering ceramic represents a particular point of mechanical vulnerability. The presence of an additional ceramic layer introduces an interface and a material with different mechanical properties from the zirconia substructure, potentially increasing susceptibility to surface damage under functional loading.

The lower incidence of veneering-related complications observed with monolithic zirconia may therefore represent an important clinical advantage, particularly in posterior regions exposed to high functional loads. However, this advantage should not be interpreted as evidence that monolithic zirconia is universally superior to veneered zirconia. Veneering remains relevant when greater control of morphology, shade, and optical characterization is required, particularly in esthetically demanding situations. Thus, material selection should involve a balance between mechanical requirements and esthetic objectives. The clinical relevance of this distinction is further increased by the continuing development of more translucent zirconia materials, which seek to overcome some of the esthetic limitations of earlier, more opaque zirconia generations.

Biological complications represented a second major category of events reported in the included literature. Secondary caries, periodontal complications, and endodontic problems were reported across different types of zirconia-supported restorations [11,13,15,16,21,25]. Overall, the available evidence summarized in this review does not indicate that zirconia-based FDPs are associated with a substantially greater biological risk than other fixed prosthetic materials [26,27]. Long-term clinical observations have additionally reported stable periodontal parameters around zirconia restorations, with some studies demonstrating periodontal outcomes comparable to those observed

around natural control teeth [28]. These findings are consistent with the generally favorable biological compatibility of zirconia. Nevertheless, biological complications should not be considered material-independent events. Oral hygiene, restoration contours, marginal adaptation, cement excess, periodontal status, endodontic condition of abutment teeth, and patient-related factors may all influence the biological outcome. Therefore, the favorable biological profile of zirconia should not be regarded as a substitute for appropriate preparation design, marginal accuracy, prosthesis contouring, and maintenance.

Restoration design also appears to influence clinical performance. The available evidence suggests that cantilever zirconia resin-bonded FDPs can achieve favorable long-term survival, with one study reporting a 15-year survival rate of 97.3% [11] and another demonstrating 100% survival over a mean follow-up of approximately 5 years, although debonding remained a relevant complication [33]. These findings are noteworthy because cantilever configurations have traditionally been considered biomechanically demanding. However, the available evidence is insufficient to conclude that cantilever designs are inherently superior to conventional fixed-fixed configurations in all clinical circumstances. Differences in patient selection, abutment characteristics, pontic location, bonding protocol, and restoration geometry may substantially influence the observed outcomes. Accordingly, the apparently favorable performance of cantilever restorations should be interpreted in the context of the specific indications and clinical protocols used in the individual studies.

In contrast, the evidence regarding specific abutment preparation features remains limited. The available literature does not provide sufficient evidence to establish the superiority of particular retentive features, such as proximal boxes, grooves, or pinholes, for zirconia FDPs [29]. This lack of evidence is clinically relevant because preparation design may influence both mechanical stability and the available bonding surface. However, the heterogeneity of preparation geometries and cementation protocols across clinical studies makes direct comparison difficult. Further controlled clinical investigations using standardized preparation designs and clearly defined bonding protocols are therefore required before firm recommendations can be made regarding the optimal preparation geometry for zirconia FDPs.

Clinical procedures, particularly surface conditioning and cementation, represent another potentially modifiable determinant of clinical performance. Airborne-particle abrasion (APA) remains the most extensively supported surface-conditioning method for zirconia and has been associated with improved micromechanical retention and favorable clinical outcomes [31,32]. The importance of surface treatment is particularly

apparent in the context of debonding, which remains one of the principal technical complications reported in zirconia FDPs. Alternative strategies, including nanostructured alumina coating and tribochemical silica coating, have demonstrated promising results with respect to bond strength and have shown encouraging clinical performance in the available mid- to long-term observations [33,34]. Nevertheless, the current evidence does not allow their long-term effect on prosthesis survival to be established with the same confidence as more extensively studied protocols. Consequently, promising laboratory or intermediate clinical results should not automatically be interpreted as evidence of superior long-term clinical effectiveness.

Cement selection is closely related to this issue. Resin-based cementation systems incorporating 10-methacryloyloxydecyl dihydrogen phosphate (MDP) primers are among the most extensively supported approaches for bonding zirconia [32,35,36]. The chemical interaction between MDP-containing systems and zirconia provides a rationale for their clinical use, particularly in situations in which reliable adhesive retention is required. Conversely, the evidence summarized in the present review provides less support for the long-term reliability of conventional glass-ionomer cementation in high-stress zirconia applications [37]. However, cementation should be considered as one component of a broader clinical protocol rather than an isolated determinant of survival. The effectiveness of a bonding strategy depends on appropriate surface preparation, contamination control, restoration fit, preparation geometry, cement handling, and clinical execution. Future clinical studies should therefore evaluate complete cementation protocols rather than individual components in isolation.

Material composition represents a further factor that may explain differences in clinical outcomes. The evidence included in this review generally favors monolithic zirconia with respect to the prevention of veneering-related complications [23,24,38]. Traditional yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) materials have demonstrated high mechanical strength and favorable clinical performance, with some studies reporting very high survival over 5- and 10-year periods [39,40]. However, the development of newer zirconia generations has increasingly emphasized improved translucency and optical properties. This evolution has created an important balance between esthetic performance and mechanical characteristics. Materials with greater translucency may provide improved optical integration but may differ from traditional high-strength zirconia in their mechanical properties [10]. Therefore, the choice of zirconia should not be based solely on the nominal material category. Instead, clinicians should consider the specific material composition, restoration location, functional de-

mands, required esthetic outcome, restoration design, and risk of technical complications.

The distinction between monolithic and veneered zirconia is particularly relevant when considering posterior restorations. In high-load areas, eliminating the veneering layer may reduce the risk of chipping and thereby decrease the need for maintenance or repair. Conversely, where esthetic demands are predominant, a veneered restoration may provide advantages that cannot be fully achieved with some monolithic materials. The appropriate clinical decision should therefore be based on a risk–benefit assessment rather than on the assumption that one zirconia configuration is universally preferable. The development of highly translucent monolithic zirconias may increasingly reduce this esthetic disadvantage, although the long-term clinical evidence for newer material generations remains less extensive than that available for established Y-TZP systems.

LIMITATIONS

An important limitation of this narrative review is the substantial heterogeneity of the evidence analyzed. The 24 publications summarized in Tables 1 and 2 included systematic reviews and meta analyses, prospective and retrospective clinical studies, and a randomized controlled trial. They evaluated markedly different clinical situations, including tooth supported and implant supported FDPs, resin bonded and conventional FDPs, cantilever and fixed fixed designs, partial and full arch restorations, and both monolithic and veneered zirconia. Some publications also reported outcomes for single crowns together with FDPs, which limits the interpretation of findings that were not reported separately for fixed dental prostheses.

Follow up periods varied considerably, from approximately 3 to 15 years. Definitions of survival, failure, technical complications, and biological complications were not uniform across the included publications. Several studies also reported relative measures, such as odds ratios or risk ratios, rather than absolute survival rates. Consequently, the reported outcomes are not directly interchangeable and should not be interpreted as a pooled estimate of zirconia FDP survival.

Further heterogeneity resulted from differences in zirconia composition, restoration design, patient selection, support type, occlusal conditions, surface treatment, cementation procedures, and maintenance protocols. These differences make it difficult

to determine whether variations in clinical outcomes are attributable primarily to the zirconia material itself or to differences in clinical indications and treatment protocols.

Long term clinical evidence remains particularly limited for newer, highly translucent zirconia generations and for some contemporary surface conditioning approaches. Therefore, the findings of this review should be interpreted as a qualitative synthesis of the available clinical evidence rather than as a quantitative estimate of the long term survival of zirconia based FDPs.

CONCLUSION

The available clinical evidence indicates that zirconia based fixed dental prostheses provide generally favorable clinical outcomes, particularly over short and medium term follow up, with survival rates commonly exceeding 90% at approximately 5 years. Long term outcomes are more heterogeneous and appear to depend on multiple factors, including restoration design, zirconia configuration, functional loading, surface conditioning, cementation, and biological conditions.

Technical complications, particularly veneering ceramic chipping, loss of retention, and framework fracture, remain important determinants of clinical longevity. Monolithic zirconia is associated with fewer veneering related complications than veneered zirconia and may offer advantages in mechanically demanding situations. However, it should not be considered universally superior, because esthetic requirements and differences among zirconia generations remain important. Surface conditioning and cementation protocols also appear to influence clinical performance, particularly the risk of loss of retention, although the available long term evidence remains heterogeneous.

Current evidence does not indicate a substantially greater biological risk for zirconia based FDPs compared with other fixed prosthetic materials. However, long term clinical evidence for newer highly translucent zirconia materials remains limited. Further well designed prospective comparative studies with standardized outcome definitions, clearly characterized materials and restoration designs, and extended follow up are needed to provide more precise indication specific recommendations.

DISCLOSURE

Author contributions

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Conflict of interest

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Ethics

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Use of Artificial Intelligence

During the preparation of this manuscript, the authors used ChatGPT by OpenAI as a language assistance tool to improve the clarity and readability of the text. The authors subsequently reviewed and edited the content and take full responsibility for the final manuscript.

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