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CASE REPORT

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Zirconia single retainer fixed dental prostheses for the posterior region—A novel preparation technique and literature review

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Key Clinical Message

The principles of tissue preservation, minimally invasiveness and approaching different clinical situations biologically rather than surgically govern today's dentistry. Thus, different clinical scenarios require procedures that offer the dentist and the patient the possibility to choose the more invasive treatment options later in life. Subsequently, the case reported refers to a minimally invasive technique that treats single tooth edentulism using single partial retainer FDPs fabricated from monolithic zirconia. This approach is conservative, biocompatible, aesthetic, strong, rapidly obtained through CAD/CAM techniques and cost-effective.

KEYWORDS

fracture resistance, inlay/onlay-retained fixed dental prostheses, minimally invasive, partial retainer, zirconia

1 | INTRODUCTION

The evolution of dental materials for fixed dental prostheses, especially those created for computer-aided design/computer-aided manufacturing (CAD/CAM) technology has led to the possibility of conceiving special designs for the restoration elements, encountering the needs and requirements of each individual case. CAD/CAM-fabricated restorations have surpassed many boundaries, achieving predictable construction, offering accurate finishing lines, excellent marginal and internal adaptation, biocompatibility, enhanced mechanical, and aesthetic properties for a great variety of CAD/CAM materials.[1,2]

Modern dentistry is oriented towards conservative treatments and minimally invasive restorations, aiming to improve the mechanical properties of the restorative materials and the design of the dental prostheses, providing adequate stress resistance and durability over time. Fixed dental prostheses (FDPs) have proven to be a reliable treatment option and a great alternative for the replacement of a missing tooth where a minimally invasive approach such as implant therapy cannot be implemented. Also, a FDP is not always easily accepted due to the many abutment teeth that are subject to preparation and the loss of a great amount of dental tissue, representing 40%–75% of the sound structure for a full-coverage crown.[3]

To reduce the dental tissue loss, inlay/onlay retained restorations have been suggested, especially when these types of restorations are designed to incorporate existing fillings on posterior teeth.[4,5] A fixed replacement strategy with minimal tooth preparation is selected whenever there is a possibility to minimize the removal of healthy tooth structure. Also, reducing the number of abutments may lead to the cantilever single-retainer design, which has at least one abutment at one end while the other end is unsupported.[6,7]

This type of FDP is frequently indicated for anterior replacement where the occlusal conditions allow it.[8] In the posterior area dislodgement forces are greater, tending to incline and move the supporting tooth, debonding the restoration from the abutment. In present days, due to the excellent adhesive cement variety, cantilever design is often preferred and is usually planned to be bonded to one abutment tooth, considering a minimally invasive approach. By lowering the number of abutments, debonding is substantially reduced, allowing some free movements of the abutment/restoration ensemble when direct forces are applied.[2]

Hybrid solutions regarding FDPs represent a combination of a conventional retainer on one abutment and a wing on the other abutment or a guide plane and rest/male–female attachment on the adjacent tooth/restoration to preserve the remnant sound structures. This type of restoration may have a variety of forms and designs, where attachments may be incorporated at one end of the bridge.[8,9]

The clinical life span of single-retainer restoration may be expected to increase when using rest seats and proximal boxes to extend support, also displacement and distortion can be prevented. To create enough space for these inserts, additional tissue removal might be necessary.[3,10] When minimally invasive FDPs are designed, especially in posterior regions, it is required to obtain a framework resistance that withstands masticatory forces.[11] One of the most utilized CAD/CAM dental biomaterials is zirconia, an excellent alternative to metal or metal-ceramic restorations. Zirconia or zirconium dioxide (ZrO_2) is a ceramic polymorphic material that has proven high strength, wear resistance and fracture toughness.[12]

2 | CASE PRESENTATION

A 38-year-old female patient visited the clinic with complaints of functional and aesthetic difficulties due to the symmetrical loss of the lower first molars.

2.1 | Case history

It was revealed that the patient lost the two molars in childhood due to the untreated decay, resulting under dimensioned gaps because of the migration of the adjacent teeth (Figure 1). Patient consent and ethical approval by the Ethics Committee of UMFT Victor Babes (No. 03/2023) were obtained.

2.2 | Examination

Intraoral examination revealed the edentulous gaps and an occlusal infiltrated direct composite resin restoration on the lower right second molar (4.7) and an asymptomatic carious lesion on the distal side of the lower left second premolar (3.5).

2.3 | Investigations

Radiographic examination of the abutment revealed normal aspect and both second molars presented adequate bone support. Also, the tooth structures presented the proper health, amount, and thickness to receive partially retained FDPs.

The occlusion examination didn't reveal any pathological modifications; therefore, no correction was needed. Temporomandibular joint and muscular palpation showed no pain during the investigation. The

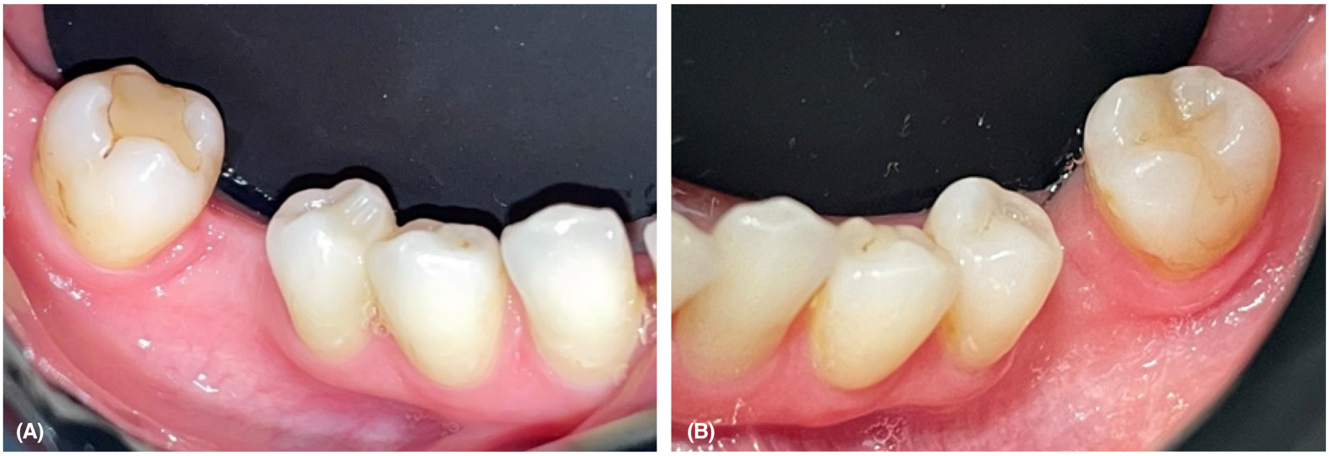

FIGURE 1 Initial intraoral view of missing lower first molars. (A) Right quadrant, (B) left quadrant.

patient's oral hygiene was good, also no bruxism patterns were detected.

3 | METHODS

3.1 | Diagnosis

Based on the clinical observations, the patient was diagnosed with class III Kennedy with one modification edentulism. Further on, the radiographic examination confirmed the initial diagnosis.

3.2 | Treatment options

Various treatment options were presented to the patient as follows: implant-supported crown, fiber-reinforced composite direct FDPs, minimally invasive single retainer FDPs, and traditional full-crown retained FDPs. Advantages and disadvantages of each treatment option were exhaustively explained (Table 1).

Implant-supported crowns were rejected due to the financial factor, also the patient did not want to wait a long time to finish the treatment and was afraid of the surgery. Thus, the patient opted for minimally invasive partially retained FDPs and onlay-retained preparations were performed following the concepts of Veneziani's morphology driven preparation technique (MDPT), including smooth surfaces, rounded internal angles and no bevelling of the margins (Figure 2).

Second molars in both quadrants were in similar condition. On the other hand, the tooth 4.5 was intact, but the distal surface of tooth 3.5 presented a carious lesion that was decided to be restored before the prosthodontic treatment. This allowed the making of a hemispherical preparation in the direct composite restoration on the occlusal-distal side of tooth 3.5. (Figure 3). This was made to ensure extra support for the single partial-retainer FDPs at this level. No bonding of the restoration was performed on tooth 3.5 offering better access for oral hygiene and the possibility to floss the mucosal side of the restoration.

The hemispherical preparation (Figure 4) was chosen because, when compared with other geometrical shapes such as boxes or grooves, it allows better access under the contact point and at the same time offers additional support at the mesial end of the partial-retainer FDP in the third quadrant. To achieve maximum resistance, teeth were prepared to receive monolithic zirconia FDPs. Previous restorations and caries were removed, and defect-oriented preparations were performed.

Both preparation designs were realized by the same operator and, at the end, were finished and smoothed to eliminate any sharp angles.

The preparations and the arches were scanned (Figure 5) separately and in occlusion, using an office

TABLE 1 Advantages and disadvantages of different treatment options.

Treatment option	Degree of invasiveness	Treatment cost	Clinical steps	Prognosis
Implant-supported crown	0	++++	++++	Long-term
Fiber reinforced composite direct FDP	+	+	+	Short to mid-term
Partial retainer FDP	+	++	++	Long-term
Traditional full crown retained FDP	++++	+++	++	Long-term

Note: The symbol + suggests the increase in value of the specified parameters.

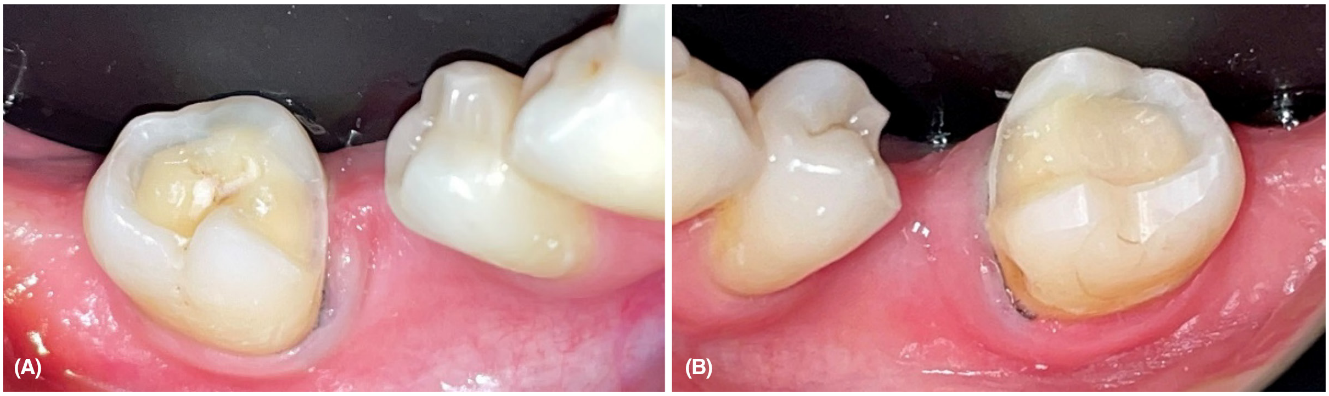

FIGURE 2 Minimally invasive teeth preparation. (A) Right quadrant, (B) left quadrant.

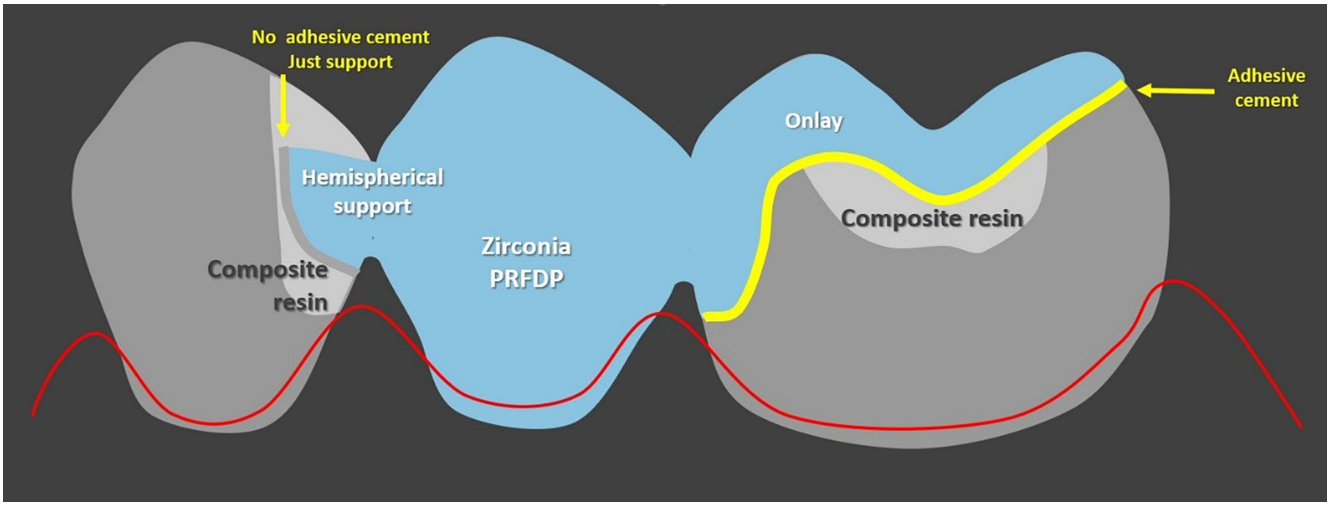

FIGURE 3 A schematic representation of direct and indirect restorations in the left quadrant. No bonding was performed for the mesial additional support of the restoration on tooth 3.5.

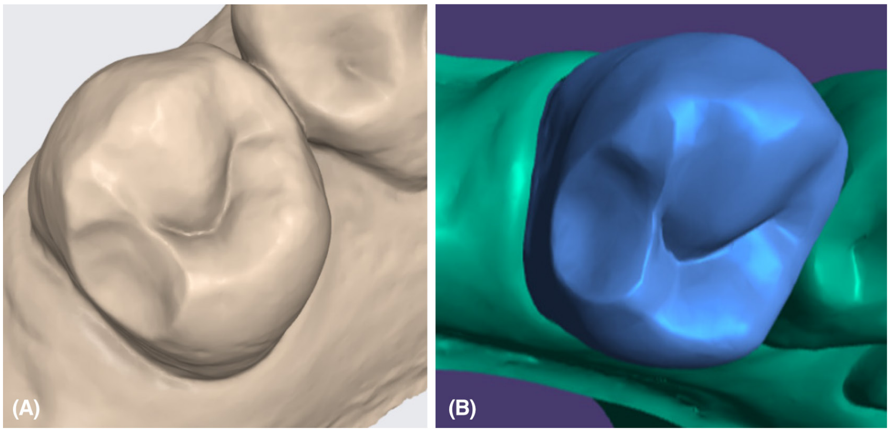

FIGURE 4 Hemispherical preparation of the lower left premolar (3.5). (A) Medit, (B) Exocad software.

CAD/CAM scanning system (Medit I500 intraoral scanner, Medit, Seoul, South Korea). Bite registration was also performed with the scanning procedures. The digital impression was exported through the MeditLink platform to the technical laboratory. For provisional restoration, resin filling material was utilized (Pro-Fill, WP Dental, Willmann & Pein GmbH Schusterring, Barmstedt, Germany) to avoid dental pulp alterations and to preserve the abutment cavities from fracture during the laboratory procedures.

A resin master model was generated and printed (Asiga Max UV printer, Asiga, Alexandria, NSW, Australia), then the restorations were digitally designed (exocad software, exocad GmbH, Darmstadt, Germany) (Figure 6).

The restorations were milled using an A2-shaded zirconia ceramic block (Vita YZ T, Vita Zahnfabrik, Bad Säckingen, Germany). The restorations were sintered and then sandblasted with alumina particles (50 μm, 2.8 bar, 1 cm). A detailed verification of the restorations was performed before cementation. Integrity, retention, stability, internal and marginal fit, occlusion, and aesthetics were evaluated first on the master model, then in the oral cavity (Figure 7).

Consecutively, the temporary fillings were removed, the abutments were cleaned, and the try-in was performed with glycerine paste (Variolink Aesthetic Try In, Ivoclar Vivadent, Schaan, Liechtenstein).

Restorations were bonded under rubber dam isolation. After try-in, final minor adjustments were made and the restorations were cleaned using 2% chlorhexidine digluconate (Consepsis, Ultradent, South Jordan, UT, USA), then transferred to an ultrasonic cleaning bath in 96% alcohol for 5 min.

The adhesion surfaces of the restoration were alumina air-particle abraded at a low pressure (2 bar) with small particles (30–60 μm) from 1 cm at 75°–90° angle for 10 s, to roughen and decontaminate the bonding surfaces of the FDP's.To avoid recontamination the 10-MDP primer (Clearfil Ceramic Primer Plus, Kuraray, Tokyo, Japan)

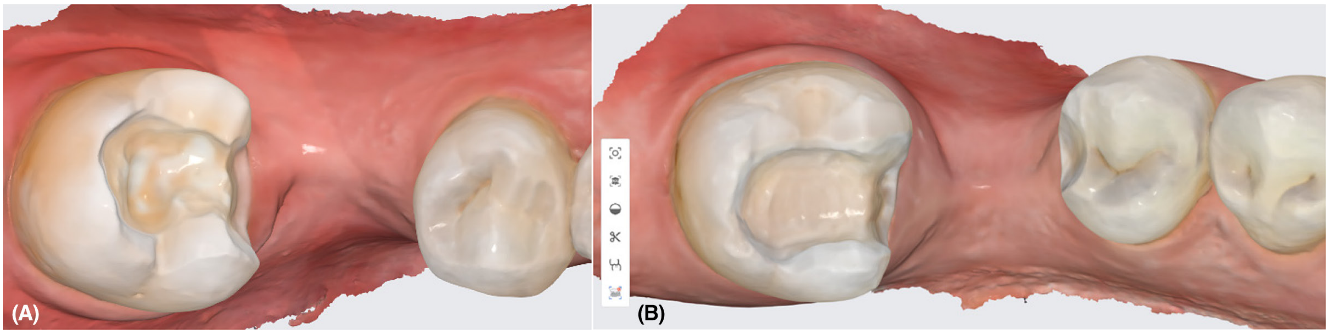

FIGURE 5 Scanned preparations. (A) Right quadrant, (B) left quadrant.

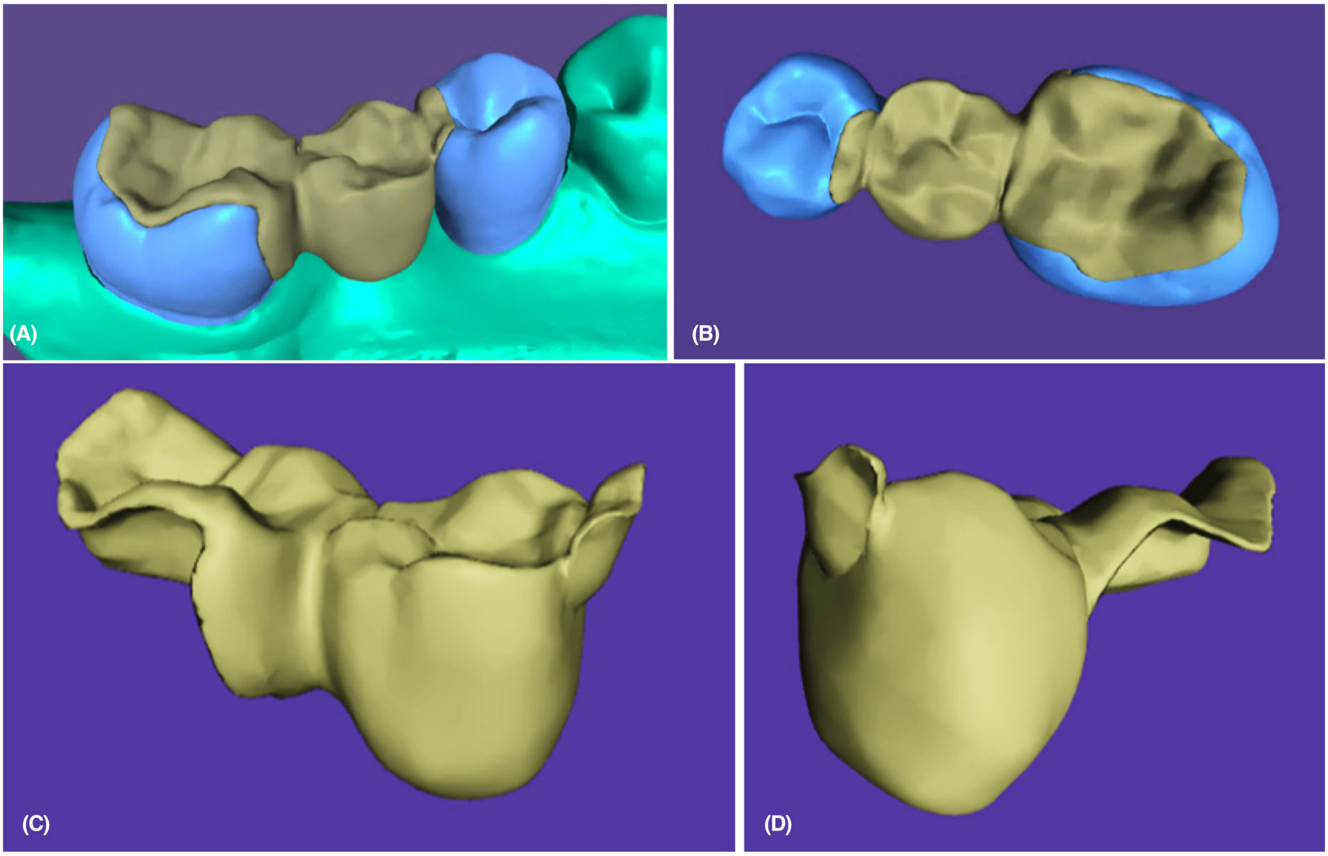

FIGURE 6 Digital model and design of the left quadrant restoration. (A) Lingual view of the restoration on the model, (B) occlusal view of the restoration on the model, (C) lingual view of the restoration, (D) buccal view of the restoration.

was immediately applied following the manufacturer's instructions.

The abutment teeth were etched with 35% phosphoric acid (Blue Etch, PPH Cerkamed Wojciech Pawlowski, Stalowa Wola, Poland) for 30s, then rinsed and dried thoroughly. Bonding (Clearfil Universal Bond Quick, Kuraray, Tokyo, Japan) was applied to the preparations and air dried for 5–10s. Cementation (Figure 8) was performed using resin cement (Panavia SA Cement Universal Translucent, Kuraray, Tokyo, Japan). Adhesive resin was applied directly into the preparations with an auto mix syringe and excess cement was carefully removed. The cement was light-cured for 60s.

Following the cementation, occlusion was checked, and final adjustments were made using diamond rotary instruments (Edenta, Au, St. Gallen, Switzerland) and then polished with dental polishers (Dimanto, Voco, Cuxhaven, Germany). In the end, the patient was given useful information regarding oral hygiene procedures (brushing, flossing, oral irrigator) and was presented with a follow-up schedule.

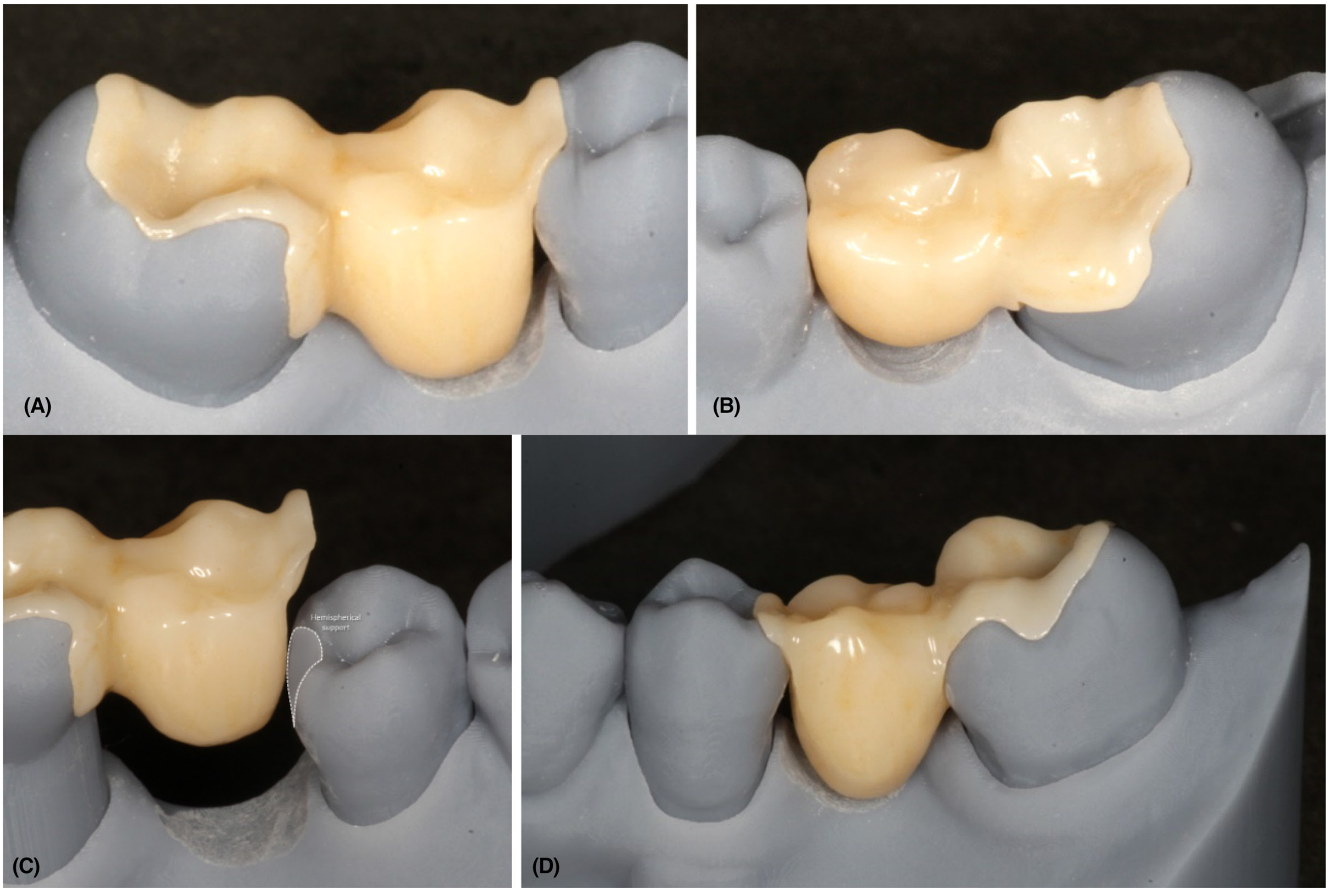

FIGURE 7 Monolithic zirconia restoration placed on resin model. (A) Left quadrant restoration, (B) right quadrant restoration, (C) hemispherical support on premolar, (D) buccal view of restoration.

3.3 | Follow-up

During the 3, 6 and 12-month follow-up visits no complication was reported. Also, the patient displayed a high level of satisfaction regarding the restorations. (Figure 9).

4 | LITERATURE REVIEW

A literature search was performed manually using the PubMed and Google Scholar databases. The focus was on minimally invasive zirconia restorations for the posterior region.

Publications accepted in this review were in-vivo studies, case presentations, reviews, and finite element analysis (FEA). Other inclusion criteria considered in the selection were English language, date (from 2014 to 2023) and keywords such as: ceramic restoration, zirconia inlay/onlay restorations, cantilever FDPs, fracture resistance, inlay/onlay retained fixed dental prosthesis (I/ORFDPs), monolithic zirconia, resin bonded, finite element analysis, posterior resin bonded fixed partial dentures, preparation designs.

The exclusion criteria were studies that did not correspond to the inclusion criteria, articles presenting only anterior restorations, crown retained FDPs, articles that did not provide the required data or protocols.

The database research initially comprised 110 studies. The review ultimately included 27 articles, from which quantitative and qualitative data were extracted and analyzed. Six studies presented retained cantilever fixed dental prostheses as minimally invasive treatments, 14 articles investigated the preparation design and mechanical properties of I/ORFDPs, 6 of them utilized FEA, 4 articles contained case reports, 1 article represented a clinical trial and 2 articles displayed systematic reviews (Table 2).

5 | RESULTS

This literature review focuses mainly upon the minimally invasive FDPs design, fracture resistance and debonding of monolithic zirconia. Also, some of the aspects highlighted in in-vitro studies and in case reports were tested in some *in-silico* studies utilizing FEA. One of the crucial

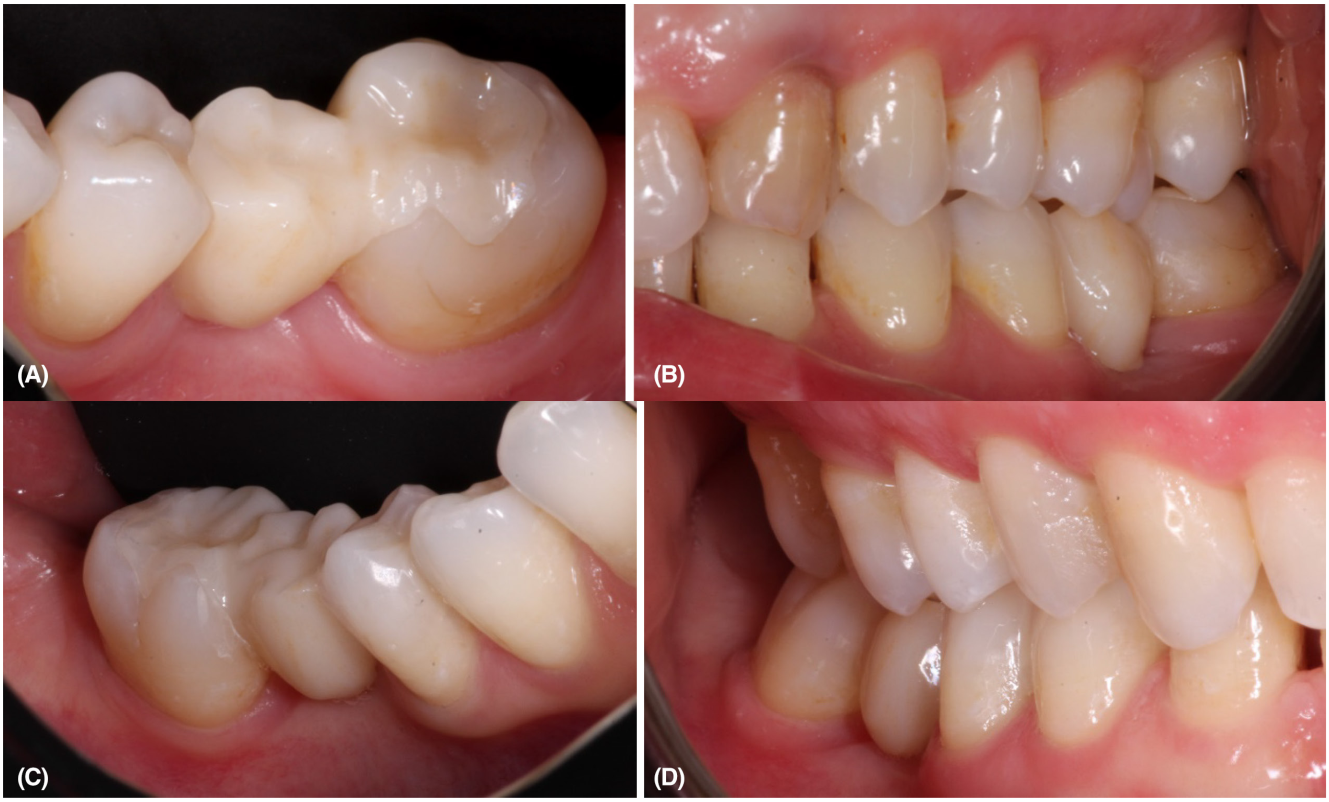

FIGURE 8 Monolithic zirconia restorations after cementation (A) occlusal-buccal view—left quadrant, (B) occlusion—left quadrant, (C) occlusal-buccal view—right quadrant, (D) occlusion—right quadrant.

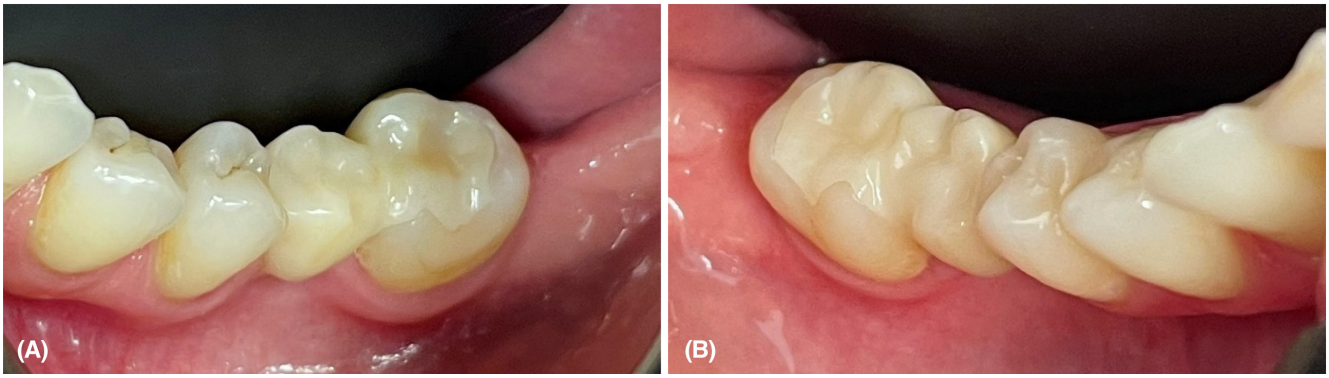

FIGURE 9 One year recall (A) left quadrant, (B) right quadrant.

characteristics of monolithic zirconia FDPs is the material resistance to fracture and debonding.

Different restoration and wing designs were tested, particularly in posterior region, which is a highly solicited area where occlusal loads are greater.[10,11,13,15,20,26] High failure load means were reported (500-800 N) when the retainer design was extended as in mesial-occlusal-distal (MOD) restorations or was modified to increase the isthmus space. Attachments and supplementary retentions such as wings or double wings also positively affected the fracture resistance of FDPs.[3,10,20,21]

The depth of restorations did not make a major contribution to the fracture strength of minimally invasive prostheses, but expanding the adhesion surface into the enamel enhanced the fracture resistance and reduced debonding. When adhesion is excellent, the restoration will not debond, but it is possible to fracture.

It is worth mentioning that these outcomes suggest more invasive preparations. Extensive preparation design increases the risk of developing carious lesions under the restoration in case of debonding. Another aspect is materials' selection. Various testing methods that evaluated

TABLE 2 Summary of the studies included in the literature review.

No	Authors	Year	Journal	Citations	Study type	Restoration type	Design
1	Al-Dwairi et al.[11]	2023	J Mech Behav Biomed Mater	2	in-vitro 72 maxillary premolars	Inlay-retained fixed partial dentures	1.mesial-occlusal inlay + palatal wings. 2. mesial-occlusal inlay + long palatal wing 3. mesial-occlusal inlay + long palatal wing and occlusal extension
2	Kasem et al.[3]	2023	Clin Oral Investig	52	in-vitro 40 mandibular molars	Cantilever resin-bonded fixed dental prostheses	1. inlay ring retainer 2. lingual coverage retainer
3	Chen YC and Fok A[7]	2023	J Prosthet Dent		in-vitro mandibular first molar 3D 720 projec-tions	Cantilevered resin-bonded fixed dental prosthesis	Cantilevered fiber-reinforced RBFDP with optimized and conventional designs
4	Bishti et al.[13]	2019	J Prosthodont Res	10	in-vitro 64 first molars	Inlay-retained cantilever fixed dental prosthesis	1. shallow inlay/one lingual retainer wing 2. shallow inlay/two retainer wings (lingual/ buccal) 3. deep inlay/one lingual retainer wing 4. deep inlay/two retainer wings (lingual/ buccal)
5	Kasem et al.[14]	2023	J Prosthodont Res	1	in-vitro 100 mandibular molars	Cantilever resin-bonded fixed dental prosthesis	1. one wing 2. two wings 3.inlay ring 4. lingual coverage 5. occlusal coverage
6	Shahin et al.[15]	2014	Eur J Oral Sci	19	in-vitro 48 premolars	Inlay-retained cantilever fixed dental prosthesis	1. occlusal–distal inlay 2. occlusal–distal inlay with an oral retainer wing 3. occlusal–distal inlay with two retainer wings 4. mesial–occlusal–distal inlay 5. mesial–occlusal–distal inlay with an oral retainer ring
7	Tagami et al.[16]	2021	J Mech Behav Biomed Mater	5	in-vitro 48 upper premolars 48 upper third molars	Resin bonded fixed dental prosthesis	Narrow or wide rest, combined with 0, 1 or 2 retainer wings
8	Waldecker et al.[17]	2019	Dent Mater	11	in-vitro reverse engineering 230,000 finite element (FE)	Inlay-retained fixed partial dentures	
9	Zhang et al.[18]	2016	J Mech Behav Biomed Mater	34	Theoretical study 300,173 inla/onlay models	Inlay/onlay finite element	
10	Samhan TM and Zaghloul H.[10]	2020	Brazilian Dental Science	2	in-vitro 45 IRFDPs 45 Resin models	Inlay-retained fixed dental prosthesis	1. box design 2. inlay-box design 3. butterfly wing design
11	Harsha et al. [19]	2017	J Clin Diagn Res	28	In vitro 40 maxillary premolars	Inlay/onlay retained fixed dental prosthesis	1.sound teeth no preparation 2. mesial–occlusal–distal inlay 3. partial onlay 4. complete onlay
12	Bömicke et al.[20]	2018	J Prosthet Dent	25	In vitro 32 specimens	Resin bonded fixed dental prostheses	Inlay-retained IR-RBFDPs Wing-retained WR-RBFDPs

Mechanical test	Aging	Additional tests	Material	Manufact-urer	Fabrication	Cementation
Dynamic fatigue 1.2×10^6 cycles, 49 N Mechanical test vertical loading	Thermocycling (5000)	Stereomicroscope examina-tion	Multilayered monolithic High translucent zirconia	IPS e.max ZirCAD, Prime Zolid Gen-X	CAD/CAM	Dual-cure resin cement Panavia, Kuraray Noritake
Fracture resistance test Dynamic loading 50 N, 240,000, and 1.6 Hz	Thermocycling (10000)	Finite-element analysis	Monolithic high translucent zirconia Fiber-reinforced composite	Katana HT, Kuarary Noritake TriLor, Bioloren	CAD/CAM	Dual polymerizing adhesive Clear Panavia V5, Kuraray Noritake
Stress analyses		Finite-element analysis	Composite resin Glass fiber reinforcement			
Quasi-static fracture strength Dynamic loading (50 N/1,200,000 cycles)	Thermocycling (37500)		Yttrium-oxide partially-stabilized zirconia framework (Y-TZP)	Vita In-Ceram YZ, Vita	CAD/CAM	Adhesive resin Panavia 21 TC, Kuraray Noritake
Dynamic loading (240.000 cycles, 1.6 Hz) unidirectional vertical force of 50 N Fracture resistance compressive test	Thermocycling (10,000)	Scanning electron microscope (SEM) examina-tion	Monolithic high translucent zirconia Zirconia-reinforced lithium disilicate (ZLS2)	Katana HT, Kuarary Noritake ZLS2 Vita Ambria, Vita	CAD/ CAM	Resin cement Panavia V5, Kuraray Noritake Dent., Japan
Dynamic load 600,000 cycles, 1.2 Hz, 5 kg, lateral movement Fracture resistance test	150-day water storage Thermocycling (37500)		Zirconia ceramic	e.max ZirCAD, Ivoclar Vivadent	CAD/CAM	Resin cement Multilink automix Ivoclar Vivadent
Dynamic load 1,200,000 cycles, vertical load,98 N, 30 mm/s.		Stereo-microscope evaluation	Monolithic zirconia ceramic	Katana Zirconia ML, Kuraray Noritake	CAD/CAM	Resin cement Panavia V5, Kuraray Noritake
Fracture resistance finite		Finite element analyses (FEA)	Zirconia Veneered ceramic		CAD Dental design STL-data files	
Fracture resistance crack initiation and propagation		Extended finite element method (XFEM)	Partially sintered Y-TZP		CAD/CAM STL files FPD models	
Fracture resistance test Vertical load		Stereomicroscope examina-tion	Monolithic translucent zirconia	inCoris TZI C, Sirona	CAD/CAM	Adhesive resin cement Rely X U200 automix, 3 M ESPE
Fracture resistance test	21-day water Storage	Stereomicroscope examina-tion	Monolithic partially sintered zirconia	NexxZr, Sagemax	CAD/CAM	Resin cement Multilink automix, Ivoclar Vivadent
Mastication simulation (30-degree oblique;1,200,000 × 108 N) Fracture resistance test	Thermocycling (10000) (6.5°C/60°C)		Monolithic zirconia Veneered zirconia Metal-ceramic veneered cobalt-chromium	VZr-IR-RBFDPs, DeguDent GmbH Remanium star; Dentaurum GmbH and Co KG	CAD/CAM	Resin cement Panavia 21, Kuraray Noritake

(Continues)

TABLE 2 (Continued)

No	Authors	Year	Journal	Citations	Study type	Restoration type	Design
13	Gumus et al.[21]	2018	J Prosthet Dent	18	in vitro 144 specimens	Inlay-retained fixed partial dentures	Tube-shaped cavity Box-shaped cavity
14	Lakshmi et al.[22]	2015	Tanta Dental Journal	24	Theoretic-cal study	Inlay-retained fixed partial dentures	3D finite element (FE)
15	Assaf et al.[23]	2021	Polymers	7	Theoretic-cal study 9680 tetrah-edral elements	Resin-bonded fixed partial denture	3D finite element (FE)
16	Tribst et al.[24]	2019	J Mech Behav Biomed Mater	11	Theoretic-cal study 3D finite element (FE)	Inlay-retained fixed partial dentures	
17	Güngör et al.[25]	2023	Dent Mater J	0	in vitro 180 specimens 180 typodont teeth	Inlay-retained fixed partial dentures	3 different connector dimensions 12 mm2 14 mm2 16 mm2
18	Kermanshah et al.[26]	2020	Biomater Investig Dent	8	in vitro 64 maxillary premolars maxillary molars	Inlay-retained fixed partial dentures Full-coverage fixed dental prostheses	1. full-coverage FPD (control group) 2. IRFPD
19	Keçeci and Büyükerkmen[5]	2022	Int J Prosthodont	0	in vitro 64 specimens	Inlay-retained fixed partial dentures	1. disto- occlusal mesial-occlusal cavity 2. mesio-occlusodistal- mesio-occlusodistal cavity 3. disto- occlusal mesial-occlusal cavity + wings 4. mesio-occlusodistal- mesio-occlusodistal cavity + wings
20	Çelik Köycü et al.[27]	2016	Dent Mater J	0	3D finite element (FE)	iIlay-retained fixed partial dentures	Mesio-occluso-distal inlay 3D finite element (FE)
21	Bin-Rubayan et al.[28]	2021	Dent	0	Case report	Inlay- retained fixed partial dentures	Inlay retainer with buccal and lingual retainer wings
22	Augusti et al.[29]	2014	Epub	25	Case report	Inlay- retained fixed partial dentures	
23	Mustafaoğlu, et al.[30]	2018	International Journal of Prosthodontics and Restorative Dentistry			Onlay- fixed partial denture	
24	Samran et al.[31]	2015	Dent	4	Case report	Inlay-retained fixed dental prosthesis	Metal luted to zirconia modified inlay design
25	Soliman et al.[32]	2022	Braz. dent. Sci	0	Randomi-zed clinical trial 70 subjects 70 IRFPDs	Inlay- retained fixed partial dentures	Proximal box-shaped Inlay shaped

Mechanical test	Aging	Additional tests	Material	Manufact-urer	Fabrication	Cementation
Fracture resistance test	Thermocycling (10000)	Scanning electron microscope (SEM) examina-tion	Monolithic zirconia	Prettau, Zirkonzahn Copran Zr, White Peaks Dental Katana Noritake	CAD/CAM	Adhesive cement Panavia F 2.0, Kuraray Noritake
Vertical load			Monolithic zirconia Lithium-di-silicate			
Axial load on occlusal surface			Zirconium dioxide		CBCT sys-tem Ansys Work-bench Soft-ware	Resin cement Panavia F2.0, Kuraray Noritake Variolink II, Ivoclar
Axial load			Zirconia Titanium Lithium Disilicate Composite resin		CAD software Rhinoceros ANSYS software	Resin cement Panavia F2.0, Kuraray Noritake Variolink II, Ivoclar Vivadent
Fracture resistance test Vertical load	Thermo-mechanical-aging (1,200,000) Periapical radiography analyses		Monolithic zirconia Lithium disilicate Zirconia-reinforced lithium silicate	inCoris TZI, Sirona IPS e. max CAD, Ivoclar Vivadent Vita Suprinity; Vita	CAD-CAM	Resin cement Panavia SA, Kuraray Noritake
Fracture resistance test	Thermocycling (5000)	Microscope examina-tion	Zirconia-reinforced lithium silicate ceramic Super-high translucent zirconia	Vita Suprinity, Vita Ceramill Zolid FX Multilayer, Ammann Girrbach	CAD/CAM	Resin cement Panavia F 2.0, Kuraray Noritake
Dynamic loading (600.000 cycles, 50 N, 2.1 Hz) Fracture resistance test	Thermocycling (6000)		Monolithic zirconia	VITA YZ T VITA Zahnfabrik, Bad Säckingen, Germany	CAD/CAM	Resin cement Panavia F 2.0, Kuraray Noritake Calibra Universal Self-Adhesive Resin Cement, Dentsply
	Thermo-mechanical simulation 4°C -60°C2 s + oblique load of 40 N		Gold alloy Ceramic Composite resin	Type II gold alloy IPS Empress 2, Ivoclar Vivadent	Hypermes, Altair Engineering	Adhesive resin
			Zirconia	Cercon HT Full Contour Zirconia, Dentsply Sirona	CAD/CAM	Cement Aureocem DC Automix, Promedica
			Monolithic zirconia	Prettau Zirconia, Zirkonzahn	CAD/CAM	Resin cement Panavia SA, Kuraray Noritake
			Feldspathic ceramic multilayer monolithic zirconia	Vita Mark II, Vita DD cubeX2, 5Y-TZP, Dental Direkt	CAD/CAM	Dual-cure resin cement Panavia F 2.0 Light, Kuraray Noritake
			Metal/zirconia	Metal alloy, Wirbond C		Resin cement Bistite, Tokoyama
			PMMA resin try-in stage Monolithic zirconia	PMMA, *Yamahachi* Katana, Kuraray		Self-adhesive resin cement Theracem, Bisco

TABLE 2 (Continued)

No	Authors	Year	Journal	Citations	Study type	Restoration type	Design
26	Chen et al.[33]	2017	J Dent.	42	Systema-tic review 11 articles	Inlay onlay Overlay	Short wing Slot retainer Tub-shaped Box-shaped Hybrid-retainer
27	Castillo-Oyagüe et al.[34]	2018	J Prosthodont Res.		Systema-tic review 23 articles	Inlay-retained fixed dental prostheses	Inlay/onlay

the mechanical properties of different types of ceramic materials, exhibited the highest fracture resistance values under the static and dynamic loading for zirconia.[3] It was observed that when such a restoration is chosen, the occlusal contact should be reduced to increase the FDP's longevity and avoid fractures and debonding.[7]

One of the most utilized and examined resin cements is Panavia, which has a bond strength to enamel between 22.1 and 42 MPa and is preferred when bonding zirconia. Another concern brought up in discussion is the surface treatment of zirconia. Air-abrasion of zirconia's intaglio surface with 50 μm alumina particles increases the bonding quality.[13] Still, under dynamic tests simulating 5 years of use, the debonding rate was found in more than 22% of failures.[16]

When the evaluation of material strength and fractures toughness were made through the FEA the weakest points were found in the connector area. It was observed that the fracture load was considerably influenced by the material type used for the abutment reconstruction. A strong material in the abutments, such as metal alloy or titanium, will lead to more accurate results for the tested ceramics. A week core material like unfilled resin will decrease the outcomes almost 60%. The design of the study is also important. When periodontal structures or tooth resilience are not properly simulated, the rigid support will also offer higher values of fracture resistance. These are some of the aspects of conducting an FEA *in-silico* study.[17] XFEM (extended finite element method) was utilized to determine the cracking initiation point and its direction, and to identify mechanical flaws that can induce differences in fracture propagation. This program can simulate multiple occlusal loading points, failure modes and how these may affect different FPDs designs. As shown in previous studies, connectors are the points where the stress concentration is the greatest. XFEM simulations confirm the findings of other studies that the fractures are initiated in this area, thus for minimally invasive restorations additional support will improve the FDPs resistance.[18] Bömicke et al. confirms that not only restoration design should be improved, but also the connectors should be designed to distribute stress more evenly.[20]

Mechanical test	Aging	Additional tests	Material	Manufact-urer	Fabrication	Cementation
			Zirconia ceramic Ni-Cr alloy Glass-FRC Fiber-reinforced Composite Polyethylene-FRC			Panavia 21 Concise Clearfil SE Bond Variolink II Clearfil AP-X Tetric Panavia EX; ABC cement MI, Kerr
		Prospective (1–8 years) laboratory experiment FEA	(*only those with zirconia content*) Zirconia+ veneer Zirconia+ veneer All-ceramic zirconia-based IRFPDs Zirconia inlay/onlay Zirconia+ veneer Zirconia+ veneer Zirconia+ veneer Zirconia+ veneer Zirconia+ veneer Partially stabilized zirconia+ veneer Zirconia+ veneer Zirconia+ veneer Zirconia Zirconia+ veneer	IPS e.max ZirCAD/IPS e.max ZirPress, Ivoclar Vita In-Ceram YZ-Cubes /Vita VM 9 Not relevant in FEA study Not relevant in FEA study Zirkon, Lava/Sinfony, 3 M Cercon/CerconCeramS, Degudent Industrial prefabricated Y-TZP/ Artglass, Heraeus Kulzer Industrial prefabricated Y-TZP/IPS. e. max ZirPress, Ivoclar Cercon, Degudent/ Silica-based ceramic DC-Leolux, DCS Dental/ Silica-based ceramic Cercon base 30/ CerconCeramS, Degudent Vita In-Ceram YZ-Cubes /Vita VM 9 ICE Zirkon, Zirkonzahn ICE Zirkon /ICE Ceramik, Zirkonzahn		Adhesive cementation for zirconia restorations

Reviewed articles confirm that minimally invasive alternatives are viable treatment options and some aspects, such as connectors, retainers, bonded interfaces, and abutments' selection should, be carefully decided for an extended life-span and clinical success of FDPs.[33–35]

6 | DISCUSSION

This clinical report demonstrates a minimally invasive approach for missing lower left and right first molars. Monolithic zirconia FDPs were fabricated for both edentulous spaces. The clinical situation dictated a two-element with a mesial additional support for the lower left quadrant and a simple/conventional retainer-cantilever design for the lower right quadrant.

To increase stability and retention, a wing or two are usually designed for cantilever restorations to the buccal and/or lingual side of the adjacent tooth. In this case, the additional support of the FDP in the left quadrant was modified. It was attached to the mesial side of the cantilever, oriented directly to the distal marginal ridge of the lower left second premolar, placed in a small globular depression executed in an already existing filling and positioned in place without cement, allowing individual movement of the neighboring abutments and facilitating oral hygiene.

This technique was imagined and developed as a solution to the demand to increase dental tissue preservation for short and long term. Short-term refers to supplementary reduction of the sound enamel to obtain additional space for side wings. Long-term deals with problems such as abutment dislodgment, supporting tooth fractures and carious lesions evolving under the wings. Normally, the wing in some cases or the auxiliary supporting mechanism in others is cemented in place. In this case presentation, enamel loss was eliminated because the mesial hemispherical support preparation was made in the resin restoration used for treating the previous caries, thus a potential caries development under the supplementary support was also reduced due to the already existence of a filling in that certain area (Figure 3). The mesial support was not cemented in place to facilitate free movement at this end under the masticatory forces.

A single-retainer prosthesis with a special design represents a minimally invasive treatment option for a single missing tooth. The requirement for inlay/onlay retained restorations has increased due to the better preservation of intact remaining tooth structure and because of the long-lasting results and high survival rates.[36] Very important considerations for clinical success when this type of restoration is planned are stress distribution, physiologic limitations, complexity of supporting structures, adhesion possibilities and materials' properties.[37,38]

To avoid tooth fracture and restoration debonding, it is necessary to assist the supporting structures to allow a minimum mobility, so when subjected to high occlusal forces, the entire construction will regain the physiologic periodontal movements.[11]

Taking into consideration these requirements, the additional supporting element was designed to confer the abutment and adjacent structures a slight degree of physiological occlusal dynamic mobility. Also, the absence of the adhesive makes possible a smooth frictional gliding in its space.

In their study, Dupagne et al. show that the mechanical strength of the prosthesis had a significant impact on the preparation design. To optimize occlusal stress distribution, a rest seat was created on the distal surface of the adjacent tooth. This minimal modification helps stress to be uniformly distributed throughout the restoration and surrounding tissues, also offering additional support for cantilever fixed dental prostheses.[39]

It is important to facilitate the optimal dispersion of the occlusal forces whenever possible, even for short-span restorations. Additional attachments will contribute to the decrease in leverage effect for the single retainer.[40] A non-rigid connection can dissipate some of the occlusal forces and reduce stress accumulation in the abutment tooth.[41,42]

Although the space created for the additional rest might be considered concave, dental floss could still reach the entire area due to the attachment that reproduces the exact configuration of the space in which it is inserted, guiding the floss through the small concavity. Studies reported that, according to the American Dental Association (ADA), dental floss can eliminate up to 80% of interproximal plaque, being able to penetrate narrow spaces.[43,44] Besides dental floss, oral irrigation is an efficient method of plaque control.[45]

In their review, Botelho et al. showed that after one-year, the cantilever FDPs have survived by a percentage of over 97%, and there was no record of deterioration of dental tissue after debonding of the prosthesis, such as abutment fracture, caries or vitality loss due to the minimally invasive approach.[46]

The cantilever's configuration and construction, such as lengths and thicknesses, connectors, or material, contact points and abutment's periodontal situation, significantly determine the durability of the prosthesis.[1] Clinical longevity is extended when using additional support to limit distortion and displacement.[3]

Sailer et al. demonstrated that modifying the design to single-retainer cantilever restorations has raised the durability of fixed prosthesis in contrast with two or multiple-retainer fixed partial dentures for both anterior and posterior regions.[47]

In a randomized clinical trial, Soliman et al. observed that inserting additional lingual and buccal wings into the design of zirconia-based inlay retained restorations enhanced the survival rate to 94.5% for a period of 5 years.[36]

Al-Dwairi et al. have studied different designs for monolithic zirconia inlay retained FDPs, including several types of wings and found that those modifications influenced the fracture resistance as much as the mechanical properties of the material and adhesive. Previous studies found that retainer wings gain resistance and bonding surface, reducing adhesive detachments.[11]

Cantilever fixed dental prostheses were suggested as a provisional solution for missing teeth, especially where the edentulous space is reduced, but with the new generations of materials and adhesives, they may be considered a long-term reliable solution.[28]

Widely used in dentistry, zirconia became one of the most popular materials in the dental field thanks to its properties and advantages. Known for its superior mechanical properties and biocompatibility, it is ideal for medical applications, especially in prosthetic dentistry and implantology. The mechanical properties of zirconia have been compared to those of stainless steel, iron and titanium and have become a strong alternative to other durable ceramic materials such as glass-infiltrated alumina or lithium disilicate.[12,36,48,49] This highly resistant, polycrystalline ceramic has in its structure yttria-stabilized tetragonal zirconium oxide polycrystalline phase (Y-TZP) allowing high mechanical properties.[50]

Compared to glass ceramics, polycrystalline ceramics have no glass matrix in their structure due to the compact crystalline phase.[51] This characteristic neutralizes crack propagation and prevents the surface roughness.[48] Dental zirconia is an opaque ceramic, which led to various modifications that were aimed to enhance content formulas to obtain a strong yet translucent material.[52,53] With the increase of yttria proportion, a greater translucency was obtained, detrimental to fracture toughness and flexural strength. The last formulation of zirconia, the fourth generation—4-mol% yttria-stabilized tetragonal zirconia polycrystals (4Y-TZP), corrected the flexural strength and fracture toughness, but reduced the translucency of the material, which makes it suitable for posterior, minimally invasive restorations.[49]

7 | CONCLUSION

The clinical case presented demonstrates the implementation of a conservative tooth preparation and a minimally invasive design of posterior cantilever single partial retainer zirconia FDPs. The reviewed articles reveal that additional support for a minimally invasive restoration increases the fracture resistance and reduces the risk of debonding for the FDPs. The unbonded additional support allows abutments' individual freedom of movement and facilitates optimal oral hygiene through flossing. Such restorations represent a reliable minimally invasive approach in cases where implant therapy is not possible or indicated.

AUTHOR CONTRIBUTIONS

Adam Dragoș Andrei: Resources; writing – review and editing. **Cândea Adrian Constantin:** Data curation; methodology; project administration; resources. **Avram Liane Tabitha:** Investigation; writing – original draft. **Jivănescu Anca:** Conceptualization; supervision; validation.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The study was conducted according to the Declaration of Helsinki. The patient was treated in accordance with his clinical needs. All procedures were approved by the Faculty Ethics Committee.

CONSENT

Written informed consent was obtained from the patient to publish this report in accordance with the journal's patient consent policy.

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