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Fourteen-year evaluation of posterior zirconia-based three-unit fixed dental prostheses
A Prospective clinical study of all ceramic prosthesis

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ABSTRACT

Objectives: the purpose of the present prospective trial was to evaluate the clinical performance of posterior 3-unit zirconia-based fixed dental prostheses (FDPs) after 14 years of clinical function.
Methods: thirty-seven patients needing to replace either premolars or molars were involved and 48 FDPs were fabricated (Procera Zirconia, Nobel Biocare AB). Frameworks with a9 mm^2 cross section of the connectors and 0.6 mm minimum thickness of the retainers were made by means of Procera Forte CAD-CAM System (Nobel Biocare AB). The patients were recalled after 6 and 12 months and then yearly up to a total follow-up of 14 years. Two independent survival curves for patients wearing 1 or 2 FDPs were calculated by means of Kaplan-Meier analysis and a log-rank test was performed in order to compare these curves. The United States Public Health Service criteria were used to examine technical and esthetic outcomes. The biological examination was performed evaluating plaque control, pocket depth, attachment level, bleeding on probing at both abutments and contralateral teeth and evaluated by means of the Wilcoxon test ($p < 0.05$) between the baseline and the 14-year follow-up.
Results: descriptive statistics resulted in 91 % and 99 % cumulative survival rates for patients wearing 1 and 2 FDPs, respectively. There were no significant differences in periodontal parameters between control and test teeth. Both function and esthetic results were successful for FDPs over a 14-year follow-up period.
Conclusions: the results of this prospective clinical study confirmed the effectiveness of zirconia as a clinical option to fabricate short-span posterior FDPs.

Clinical significance: within the limitations of the present prospective clinical study, zirconia-based three-unit fixed dental prostheses perform satisfactorily on long term, in posterior areas and in patients with standard biomechanical conditions.

1. Introduction

Zirconia (ZrO2) is a polycrystalline high-strength ceramic and is considered a suitable material for single crowns (SCs) and fixed dental prostheses (FDPs), since it tolerates higher occlusal loads than conventional ceramics and satisfies the high esthetic demands of patients [1–4]. In particular, zirconia ceramics exhibits favorable mechanical properties (toughness: 5–10 MPa√m, flexural strength: 500 − 1200 MPa, Young's modulus: 210 GPa) and good optical characteristics [2,4–8]. Several studies proved the high biocompatibility of such material. Furthermore, it does not heighten bacterial adhesion and eases clinical procedures thanks to the possibility of using conventional cementation [2,8–10]. Several authors investigated zirconia as substitute material to metal frameworks for FDPs both onto teeth and implants [2,11–15]. Even if the most frequent reported complication is the cohesive fracture (i.e. chipping) of the veneering porcelain [15–20], zirconia frameworks seem to perform successfully, particularly for 3-unit FDPs [21–23]. Recent clinical investigations suggested favorable potentialities of zirconia-based FDPs for posterior regions, showing a cumulative survival rate of 85.0 % after 10 years of function, although a high rate of technical complications on long term, particularly chipping, can be expected [24]. Other medium- and long-term studies reported good survival rates of zirconia FDPs, confirming satisfactory clinical performances and showing a low incidence of biological complications and

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mechanical failures, like debonding and major fractures [25–34]. The use of zirconia frameworks for extended FDPs is a topic of discussion: it is important to secure the proper cross-sectional area of connectors to increase the mechanical resistance to fracture but further long-term *in vivo* clinical trials would be advisable to evaluate the clinical performances of 4- and 5-unit zirconia FDPs [35].

The primary purpose of the present prospective study was to examine the clinical performances of 3-unit zirconia FDPs after 14 years of function. The secondary aim was to evaluate both biological and technical complications throughout the whole period of observation.

2. Materials and methods

In the present prospective clinical study, 37 patients (16 males, 21 females) needing at least 1 posterior FDP in the maxillary and/or the mandibular arches were recruited. The mean age of patients was 45.3 ± 11.6 years, with a minimum age of 21 and a maximum of 68 years. All patients were recruited at the Department of Prosthodontics of the University "Federico II" of Naples (Italy) from November 2004 to April 2005 (baseline) and provided a written informed consent. The study fulfilled the requirements of the Helsinki declaration and was approved by the ethical committee of the same University. The present clinical study was recorded on the website *clinicaltrials.gov* with the identification number NCT04374201. All the included patients met the following inclusion criteria:

- good general health;
- ASA I or ASA II according to the American Society of Anesthesiologists;
- good periodontal health;
- Angle class I occlusal relationship;
- minimum of 20 teeth;
- good oral hygiene;
- no evident signs of occlusal parafunctions and/or temporo-mandibular disorders.

Moreover, the abutment teeth had to fulfill the following inclusion criteria:

- periodontal health (absence of tooth mobility, absence of furcation involvement);
- proper positioning in the dental arch (tooth axes adequate for a FDP);
- sufficient occlusal-cervical height of the clinical crown (≥ 4 mm) for the retention of a FDP;
- vital or endodontically treated to a clinically sound state;
- opposing natural teeth or fixed prostheses.

The following conditions caused the patients exclusion from the study:

- subjects preferring implant-supported prostheses;
- high caries activity (according to the American Dental Association Caries Risk Assessment Form for age > 6) [36];
- occlusal-gingival height of the abutment teeth < 4 mm;
- reduced interocclusal distance or supraerupted opposing teeth;
- unfavorable crown-to-root ratio (up to 1:1 as minimum ratio) [37];
- severe wear facets, clenching, bruxism (identifiable during clinical examinations or reported during anamnestic interviews) [38];
- presence of removable partial dentures;
- pregnancy or lactation.

Forty-eight 3-unit posterior zirconia FDPs were fabricated; 11 patients received 2 FDPs each. The pontic element replaced either a first or a second premolar or a first molar. Twenty-four FDPs were located in the maxilla replacing 12 premolars and 12 molars; the other 24 FDPs were placed in the mandible substituting 9 premolars and 15 molars. A first premolar mesial cantilever was designed for a maxillary prosthesis.

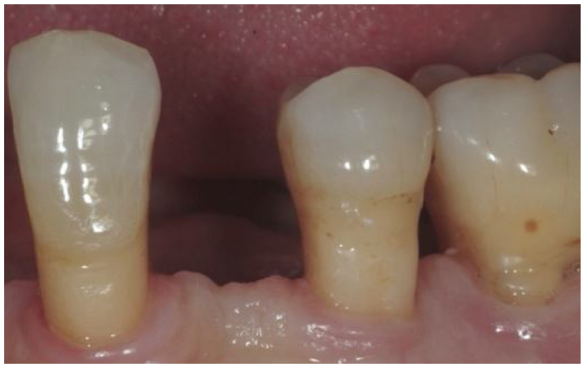

Fig. 1. Clinical case 1: pre-operative view of a missing mandibular first premolar.

2.1. Prosthodontic procedures

Four experienced and calibrated prosthodontists performed all the clinical procedures. The patients were prepared by means of professional oral hygiene and core build-ups, endodontic therapies and post-and-core placement if necessary were performed before the prosthodontic procedures (Fig. 1). Alginate impressions were made in order to obtain study gypsum casts and fabricate diagnostic wax-ups, self-polymerizing resin (Elite SC Tray, Zhermack, Badia Polesine, Italy) customized impression trays and acrylic temporary restorations. Silicon indexes obtained from the diagnostic wax-up were used to check proper tooth preparation and achieve abutments fulfilling the requirements of the CAD-CAM workflow for framework production:

- margin design: 1 mm circumferential rounded chamfer and rounded cavo-surface angles to prevent stress concentrations;
- axial reduction: 1.5 mm;
- occlusal reduction: 1.5 – 2 mm;
- total occlusal convergence angle: 10°-14°.

The supragingival or slightly subgingival margins of the preparations respected the biologic width (Fig. 2). A self-polymerizing resin (Jet Kit, Lang, Wheeling, IL, USA) was used to reline intraorally the acrylic resin temporary restorations that were then cemented with a eugenol-free luting agent (TempBond NE, Kerr Corporation, Orange, CA, USA). Occlusal adjustments of the provisional restorations were performed when necessary. After tooth preparation, 10 to 14 days were waited in order to consent the recover of soft tissues from possible preparation injuries before making the final impressions. Two non-impregnated retraction cords (Ultrapak, Ultradent, South Jordan, UT,

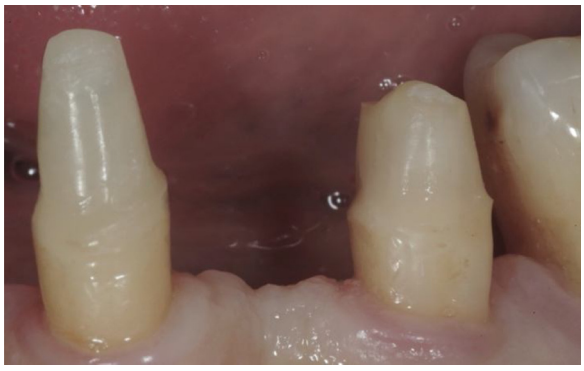

Fig. 2. Clinical case 1: supraginigval tooth preparations for zirconia FDP.

USA) were positioned around abutment teeth before the full-arch impression procedure. Customized autopolymerizing acrylic impression trays and polyether materials (Impregum and Permadyne-L, 3 M ESPE, Seefeld, Germany) were used. A self-polymerizing A-silicone (Occlufast, Zhermack) was used to register the interocclusal relationships. Then, the provisional restorations were cemented. Master casts of super hard gypsum (Elite Rock, Zhermack) were mounted in a semi-adjustable articulator (Whip Mix 8500, Whip Mix Co., Louisville, KY, USA) with a die spacer (< 30-μm thick) applied at the occlusal and axial surfaces of the abutments, starting 1 mm above the preparation margins. The CAD-CAM system (Procera Forte CAD-CAM System, Nobel Biocare AB, Goteborg, Sweden), was used to digitize the master casts. The sintering shrinkage was compensated by enlarging the scanned data by 20–25 %. The milling center used first generation presintered partially stabilized tetragonal zirconia blanks (3Y-TZP Procera Zirconia, Nobel Biocare AB), then sintered to full density. An ovate pontic was used to replace missing premolars, while a modified ridge-lap pontic was designed for missing molars. The minimum retainer thickness was 0.6 mm and the minimum connector surface area was 9 mm^2. A digital caliper with an accuracy of 0.01 mm was used to measure the framework thickness. Then, the accuracy of fit of zirconia frameworks was evaluated intraorally using a silicon disclosing agent (Fit Checker, GC, Leuven, Belgium); if necessary, geometry adjustments were made on the abutments transferring any pressure spot to teeth surfaces. The same experienced dental technician veneered all the frameworks; a feldspathic ceramic specifically dedicated to zirconia (Procera All Zircon, Nobel Biocare AB) and a conventional powder build-up veneering technique were used and the adequacy of the coefficient of thermal expansion (CTE) of the veneering ceramics was carefully checked. Then, the FDPs were glazed and polished. The thickness of veneering ceramics was measured with a digital caliper with an accuracy of 0.01 mm and ranged between 0.55 and 0.98 mm on the retaining abutments and the connectors; particularly, it was calculated by subtraction of the framework thickness from the completed restoration thickness.

As regards the precision of fit, both the frameworks and the final restorations were carefully inspected on the master casts with a stereomicroscope at 20x magnification and tried-in intraorally using a silicon disclosing agent to eliminate possible friction areas from the abutments and verify a clinically acceptable marginal fit according to the ADA specification nr. 8 and validated literature (40–120 μm).

The final zirconia FDPs were tried-in intraorally to evaluate internal and marginal adaption using a silicon disclosing agent. Furthermore, proximal and occlusal contacts were checked with articulating ribbon; occlusal adjustments were performed when necessary. Abutments were degreased with 80 % ethanol. In order to ease the removal of cement remnants, the external surfaces of the FDPs were isolated using liquid paraffin before cementation. The intaglio surfaces of zirconia FDPs were conditioned by means of mild sandblasting with 110 μm alumina particles at 0.2 MPa [39]. A resin luting agent (RelyX Unicem, 3 M ESPE) was used to cement the FDPs and the cement excesses were removed by means of a plastic scaler. If necessary, fine-grit diamond burs were used to make further occlusal adjustments and the modified surfaces were meticulously polished with a ceramic polishing system (Komet nos. 9425, 9426, and 9547; Brasseler, Savannah, GA, USA).

2.2. Baseline evaluation

Two external, calibrated and experienced clinicians blind to the prosthodontics procedures performed the baseline evaluation, recorded 7 days after the cementation of FDPs (Fig. 3).

As regards periodontal evaluation, tooth mobility, plaque control record, probing pocket depth, probing attachment level, bleeding on probing (BOP) at the abutment sites (test) and at the contralateral, not restored teeth (control) were assessed. Cold carbon dioxide was used to evaluate pulp vitality of test and control teeth. After making alginate impressions for study casts, the clinical evaluators recorded the occlusal relationships between the FDPs and the opposing arches. Clinical photographs of the FDPs and periapical X-rays of the abutment teeth were taken. Furthermore, the static and dynamic and the static occlusal contacts were checked and recorded photographically. All the patients rated the overall functional and esthetic outcomes of the restorations by means of Visual Analog Scales (VASs) ranging from 0 to 10.

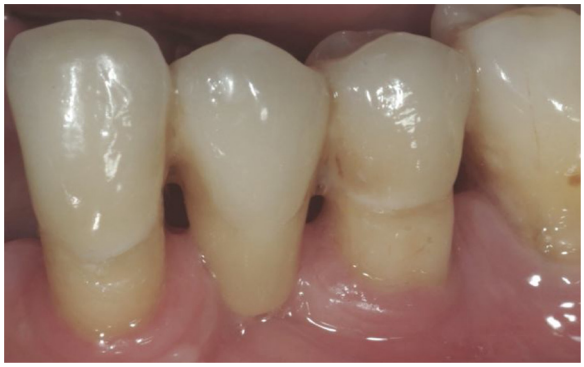

Fig. 3. Clinical case 1: post-operative view of a zirconia FPD replacing a mandibular first premolar (1 week after cementation).

2.3. Follow up-examinations

After the baseline evaluation, all the patients were recalled after 6 months and then annually, over a whole observational period of 14 years. The same evaluations assessed at the baseline were repeated and the relative data were recorded. Any proximal recurrent decays and/or periapical pathologies were checked by means of X-rays. The United States Public Health Service (USPHS) criteria were used to report technical and esthetic complications (Table 1); the FDPs were examined entirely and the worst record was used for rating.

2.4. Statistical analysis

A dedicated software (SPSS 17, SPSS Inc., Chicago, IL, USA) was used to make descriptive statistics. The 14-year cumulative survival rate of the zirconia FDPs was calculated by means of Kaplan-Meier analysis. Two independent curves for patients wearing 1 or 2 FDPs were analyzed separately. In order to compare these curves, a log-rank test was performed. The patient receiving the only cantilevered restorations was excluded from the statistical analysis, in order not to introduce a pure confounder. The periodontal parameters of control and test teeth between the baseline and the 14-year follow-up were evaluated using the Wilcoxon test, with a level of significance set at $p < 0.05$.

3. Results

After 14 years of clinical function, no patient was lost at follow-up or censored and consequently all the 48 3-unit zirconia FDPs were available for examination. The survival rate was 98 % while the success rates were 91 % and 99 % for patients wearing 1 and 2 FDPs, respectively, as reported in the Kaplan-Meier graph considering complications as events (Fig. 4).

There were no statistically significant differences between the survival curves of patients with 1 or 2 FDPs, as shown by the log-rank test ($p < 0.05$). During the entire period of observation, 5 minor cohesive fractures of the veneering ceramics were observed (10.4 %): at the 1-year recall, the first chipping was detected on the distal connector of a maxillary premolar; after 2 years of clinical function, the examiners detected 2 more chippings of the veneering ceramics, 1 on the occlusal surface of a mandibular molar and 1 on the distal connector of a maxillary molar in a patient wearing 2 FDPs; at the 9-year recall, the examiners observed 1 mesial-lingual chipping on a maxillary first

Table 1
United States Public Health Service (USPHS) criteria.

USPHS criteria	Alpha (A)	Bravo (B)	Charlie (C)	Delta (D)
Framework fracture	No fracture of framework	–	–	Fracture of framework
Veneering fracture	No fracture	Chipping but polishing possible	Chipping down to the framework	New restoration is needed
Occlusal wear	No occlusal wear on restoration or on opposite teeth	Occlusal wear on restoration or on opposite teeth < 2 mm	Occlusal wear on restoration or on opposite teeth > 2 mm	New restoration is needed
Marginal adaptation	No probe catch	Slight probe catch but no gap	Gap with some dentin or cement exposure	New restoration is needed
Anatomical form	Ideal anatomical shape, good proximal contacts	Slightly over- or undercontoured, weak proximal contacts	Highly over- or undercontoured, open proximal contacts	New restoration is needed

Fig. 4. Kaplan-Meier graph of complications in relation to time. Two different survival curves are reported for patients wearing 1 and 2 FDPs, respectively.

Fig. 5. Representative clinical evidence of a cohesive fracture (chipping) on the mesial-lingual aspect of a mandibular second premolar at the 9-year follow-up (white arrow).

premolar and 1 mesial-lingual chipping on a mandibular second premolar (Fig. 5). The patients did not notice such cohesive fractures since the chipped areas did not impair function; consequently, the surfaces were carefully rounded and polished and the FDPs remained in situ for further observation.

Moreover, 1 decementation (2.1 %) of a mandibular FDP was detected after 10 years of clinical function; after thoroughly cleaning and degreasing both the abutment teeth and the restoration, the FDP was cemented using the same resin cement (RelyX Unicem, 3 M ESPE). After 11 years of serviceability, 1 catastrophic fracture (2.1 %) was detected in the same patient experiencing the previous decementation (Fig. 6); the abutment teeth were intact and the soft tissues were stable, consequently, the restorations was replaced by a new zirconia FDP.

At the baseline, 82 abutments (85.5 %) were vital and they all remained vital, after 14 years of observation. The follow-up examinations showed no significant differences in the average periodontal parameters between test and control teeth. Moreover, neither signs or symptoms of proximal decay nor radiographic evidence of periapical pathologies were detected during the entire follow-up period.

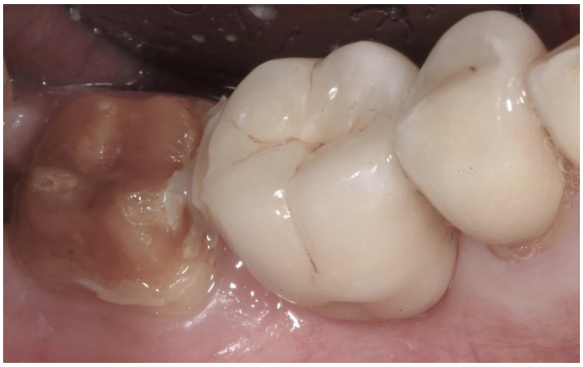

Fig. 6. Representative clinical evidence of a catastrophic failure of a mandibular zirconia FDP at the 11-year follow-up.

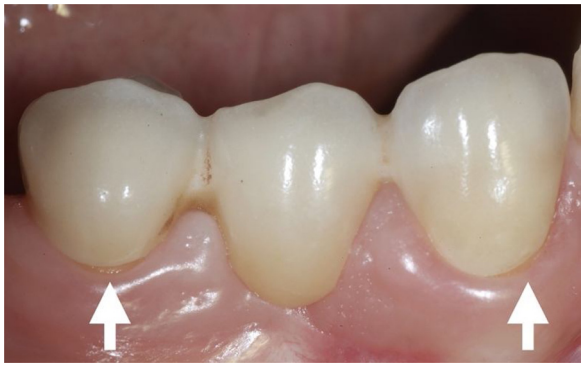

Fig. 8. Clinical case 2: 14-year follow-up evaluation showing slight gingival recessions onto both the mesial and distal abutment teeth (white arrows).

According to the ADA specification nr. 8, the accuracy of the FDPs was inspected clinically fulfilling the criteria of clinical acceptability. Particularly, the mean absolute marginal gap was measured using stereomicroscopic analysis at 20x magnification and was reported to be 39.2 (± 0.6) μm.

The mean values of the outcomes reported by patients were recorded using VAS judgments: the overall functional score was 9.3 (± 1.4) while the average esthetic value was 9.0 (± 0.9), where 0 meant "not satisfied at all" and 10 meant "fully satisfied". All the patients declared to be pleased with chewing efficiency and esthetics of the restorations, although slight gingival recession were observed in some cases at 14-year follow-up evaluation (Figs. 7 and 8); this report was probably due to the absence of grey metal frameworks that allowed the patients not to complain about esthetics. Excluding the subject who experienced a catastrophic fracture, all the patients in which chipping occurred did not report any significative functional discomfort, apart from minimal surface roughness that was polished and sporadic food impaction on the lingual aspect of connectors and in contact areas. Table 2 shows the technical evaluation of the zirconia FDPs by means of the USPHS criteria, showing very good clinical performance. As regards mechanical resistance to fracture, all the frameworks but the fractured one scored Alpha. In terms of occlusal wear, 6 restorations opposing natural teeth rated Bravo; 2 of them opposed previous chipped restorations. The Wilcoxon test performed for the analyzed periodontal parameters at baseline vs 14-year recall on test and contralateral control teeth showed no statistically significant differences ($p > 0.05$) for probing pocket depth, probing attachment level, plaque control record and bleeding on probing.

Table 2
USPHS criteria scores for the FDPs.

USPHS criteria	Alpha (A)	Bravo (B)	Charlie (C)	Delta (D)
Framework fracture	98 %	0	0	2%
Veneering fracture	89.6 %	10.4 %	0	0
Occlusal wear	83.3 %	16.7 %	0	0
Marginal adaptation	91.7 %	8.3 %	0	0
Anatomical form	91.7 %	8.3 %	0	0

4. Discussion

The present long-term prospective clinical study evaluated the clinical performance of 1 st generation presintered partially stabilized tetragonal zirconia (3Y-TZP) restorations in posterior areas. Although this solution has been replaced by more recent prosthetic configurations targeting the elimination of cohesive features of veneering ceramics just like monolithic zirconia restorations, the results of the present investigation could be helpful in better understanding the biological integration and mechanical reliability of zirconia as restorative material in the long-term.

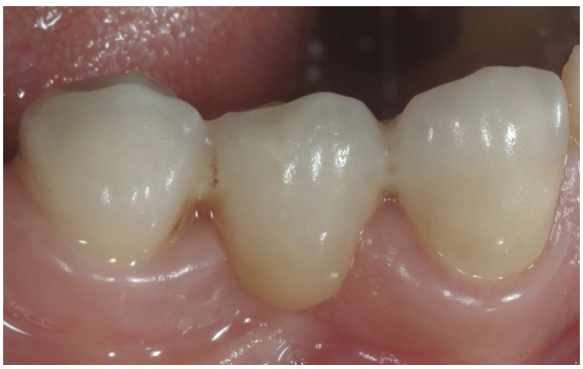

Fig. 7. Clinical case 2: baseline evaluation of a zirconia FDP replacing a mandibular first premolar.

Partially stabilized zirconia is characterized by a series of factors that undeniably contribute to the long-term success of FDPs, such as excellent biocompatibility, optimal flexural strength and fracture toughness, satisfactory marginal and internal adaption of restorations [2]. From a clinical point of view, several reviews pointed out that zirconia ceramics perform properly over time and could be a valid alternative to traditional porcelain-fused-to-metal prostheses [1–3,40]. The most frequent complications reported for zirconia FDPs are technical problems just like chipping of the veneering ceramics or core fractures, which are strongly related to framework architecture [2,24,25,41]. Furthermore, the flexural strength of the veneering porcelain, the CTE mismatch between veneering ceramics and zirconia core, the incorporation of voids or flaws and the influence of furnace firing program are possible variables affecting the chipping rate [8,42]. The meticulous control of all these aspects may explain the low chipping rate of the present study compared to other similar investigations on zirconia FDPs. Chipping of the ceramic surface can be cohesive in the porcelain or adhesive at the interface; it represents the most common complication and, when it affects the esthetics of anterior regions, may lead to psychologic trauma and uncertainty for patients [43]. At the same time, the exposure of the zirconia framework, resultant from the adjustment of the occlusal surface after damages or flaws, could induce or contribute to the onset of fracture [42]. Insufficient connectors height could induce a significant decrease of flexural strength and could lead to the fracture of zirconia frameworks, thus a minimum cross section of of 9 mm^2 is strongly recommended for 3-unit prostheses [2,8,42]. Similarly to most of the literature, the most frequent complication detected in the present 14-year prospective clinical study was the chipping of the veneering ceramics. Furthermore, 1 chipping detected on a mandibular molar after 2 years of clinical function was observed in a female patient with an evident hypertrophy of the elevator muscles (i.e. temporalis, masseter), which was a family

factor showed also by her mother and daughter; after checking and polishing accurately the chipped area, no further problems were detected. Therefore, monolithic zirconia restorations have been proposed to reduce the incidence of chipping [2]. After 11 years of serviceability, another patient returned to the clinic with a catastrophic fracture of a zirconia FDP that had already experienced a loss of retention; the core fracture occurred while he was eating and required a new restoration (Fig. 6).

As regards monolithic zirconia prostheses, although such type of prosthetic restorations show very good outcomes in terms of marginal fit and wear of opposing teeth [2,44], to date its use is supported by limited evidence in the long term. Furthermore, monolithic full-contour zirconia restorations are characterized by poor optical properties and show less satisfactory esthetic outcomes [2,42]. Further long-term randomized clinical trials are required, especially about monolithic zirconia FDPs to validate the clinical performances and serviceability over time. The results of the present prospective clinical study agreed with those investigations reporting an effective and predictable bond strength between zirconia frameworks and veneering ceramics; no adhesive failures at the interface were observed. This study confirms the satisfactory long-term performances of 3-unit zirconia FDPs, as previously reported in other clinical trials [19,20,24].

Furthermore, the satisfaction of patients for the natural appearance of restorations and the healthy periodontal status observed at the control teeth confirmed the excellent biocompatibility of zirconia restorations, as suggested in other investigations [4,9,10]. In a few cases, a positive BOP was detected with a slight gingival inflammation but there was no involvement of deep periodontal structures during the whole period of observation. Undeniably, the careful management of both clinical and technical factors is mandatory to avoid biological complications and periodontal drawbacks: accurate abutment preparation, precise provisional prosthesis and careful relining to condition the soft tissues, flawless impression making from 10 to 14 days after tooth preparation to allow soft tissues to recover completely an healthy condition, careful cementation procedures and precise design and check of restorations. Doubtless, the strict and careful management of all these steps together with a comprehensive and motivated compliance of patients dramatically contributed to the optimal biological, technical and esthetic outcomes recorded in the present prospective clinical study.

The clinical evidences obtained in the present investigation showed satisfactory long-term results similarly to previous clinical trials, which reported cumulative survival rates of 85 % [24] and 95 % [19] for zirconia FDPs after 10 years of clinical function. Differently, the present results showed better outcomes than those noticed in other investigations dealing with bilayered zirconia restorations [16,18–20,22–32]. In particular, Passia et al. [32] reported 66.2 % survival rate after 10 years and an overall 13-year survival rate of 47 % for zirconia FDPs, irrespectively of the prosthetic design while Sax et al. [27] noticed a survival rate of 67 % and a complication rate of 32 %, after 10 years of clinical function.

The good clinical results obtained in the present investigation can be explained by several factors that are obviously associated with operator-sensitivity of both laboratory and operative procedures as well as with patient-related factors.

Particularly, the FDPs used in the present prospective clinical study were designed anatomically to support properly the ceramics and obtain an even thickness of the veneering layer, in order to better withstand the occlusal forces and reduce the risk of internal ceramic flaws due to vitrification clusters during ceramics cooling [2,42,43]. Moreover, according to the validated clinical experiences developed with conventional porcelain-fused-to-metal restorations, the frameworks were provided with supporting ribbings to convert shear forces potentially damaging the veneering ceramics into compressive stresses much better tolerated by glassy layers [2].

The restorations were veneered by means of a conventional powder buildup technique but using a feldspathic ceramics especially dedicated to zirconia; it could be speculated that its specific and compatible CTE could have improved the shrinkage of the veneering layer upon a rigorous slow cooling process and the mechanical adaptation between glass ceramics and zirconia through uniform compressive stresses, contributing in reducing interfacial voids and intrinsic flaws and creating a kind of prosthetic monoblock, consequently enhancing the clinical performances of the prostheses [1,2,42,43].

In addition, in the present study a high portion of replaced teeth were premolars as compared to molars in other similar investigations [16,18,19,22–24,26,28–30]; the reduced occlusal forces usually loading premolars could have contributed to the reduced number of clinical complications reported in the present study.

Taking into consideration their operator-sensitivity, it is worth noticing that the meticulous adherence to the manufacturers' specifications during the laboratory procedures and the strict fulfillment and check of good clinical practice during the operative steps could have contributed significantly to the good results of the present investigation [2].

Moreover, patients' compliance to clinical recommendations and to oral hygiene maintenance are paramount to guarantee the serviceability of restorations over time. Particularly, the patients involved in the present study entered a customized supportive periodontal therapy program typical of a university hospital, that contributed to have no drop-outs and allowed to recall them at follow-up regularly, intercepting any possible complication and providing prompt interventions.

5. Conclusions

Within the limitations of the present prospective clinical study, the satisfying survival and success rates recorded for 3-unit posterior zirconia FDPs allow to consider this type of restoration as a viable and validated clinical option in patients with standard biomechanical conditions.

The present prospective clinical trial permits to draw the following conclusions:

chipping of the veneering ceramics was the most frequent complication recorded for bilayered posterior zirconia FDPs;

in absence of parafunctional occlusal loads, 3-unit zirconia FDPs exhibited a predictable serviceability;

3-unit zirconia FDPs showed very good marginal integrity and mechanical resistance to fracture;

the optimal biocompatibility of zirconia was proven by the excellent response of soft tissues;

patients' satisfaction regarding both functional and esthetic outcomes was fully satisfactory in the long-term.

Further randomized controlled trials with more extended zirconia spans up to full-arch restorations and longer observational period would be advisable to assess the long-term serviceability and predictability of zirconia FDPs.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Fernando Zarone: Conceptualization, Project administration, Writing - review & editing, Visualization. **Maria Irene Di Mauro:**

Formal analysis, Data curation, Writing - original draft. **Gianrico Spagnuolo:** Formal analysis, Data curation, Writing - original draft. **Enrico Gherlone:** Conceptualization, Investigation, Writing - review & editing. **Roberto Sorrentino:** Conceptualization, Project administration, Writing - review & editing, Visualization.

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