ZIRCONIA MINIMALLY INVASIVE PARTIAL RETAINER FIXED DENTAL PROSTHESES: UP TO TEN YEAR FOLLOW-UP

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Abstract

Purpose: To assess the survival rate of 3 mol % yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP) minimally invasive anterior and posterior single and double partial retainer fixed dental prostheses (PRFDPs). Materials and Methods: Twenty-three patients (18 women and 5 men, age range: 20 to 66 years) with single-tooth gaps received 28 3Y-TZP PRFDPs. Eight PRFDPs had two partial retainers and one pontic, two PRFDPs had two partial
retainers and one pontic with a mesial cantilever, and 18 PRFDPs had one retainer and one cantilever. The abutment teeth were prepared following specific guidelines for all-ceramic restorations, considering existing direct restorations, carious processes, and occlusal conditions. The restorations were made of 3Y-TZP using CAD/CAM technology. Cementation was performed either conventionally, using resin-modified glass-ionomer (n = 6), or adhesively, using dual-polymerized resin cement (n = 22). Kaplan-Meier survival analysis was conducted. A P value of .05 was considered statistically significant. Results: During the observation period (5.92 ± 1.74 years, minimum = 2 years, maximum = 10 years), three debondings occurred, all in the two-retainer group and the mandible. The survival rates for the two types of intervention were different, with 100% for a single retainer and 70% for a double retainer, but without a significant difference (log-rank test χ²(1) = 0.200, P = .655).

Conclusion: The 3Y-TZP PRFDPs presented in this study showed no failure when bonded and not conventionally cemented. Therefore, they can be used in cases where implant therapy is not possible or indicated. *Int J Prosthodont* 2021. doi: 10.11607/ijp.7061

Introduction

There is now a tremendous variety of restorative materials and techniques in the dental field. Due to patients’ aesthetic demands increasing, all-ceramic fixed dental prostheses (FDPs) have become popular due to their high biocompatibility and fracture strength. Restoring the aesthetics and functionality of the dentition can be particularly urgent after losing a tooth in the anterior region.¹

However, in the posterior region, functionality prevails, and other indirect restorations are available, such as traditional full-crown-retained FDPs, inlay-retained FDPs
(IRFDPs), and implant-supported crowns. Traditional FDPs require extensive preparation and are associated with 63-73% tissue loss, depending on the margin preparation.²,³

Resin-bonded fixed dental prostheses (RBFDPs) require a minimally invasive technique, reducing tooth structure removal and making IRFDPs an ultraconservative option.⁴ Cantilever RBFDPs also represent a conservative approach to replacing single missing tooth areas, generally in the anterior region, and are associated with good clinical outcomes, high resistance rates, and high patient satisfaction. RBFDPs present several advantages: they require simple preparation, minimal removal of the tooth structure, optional anaesthesia, and result in no pulp injuries. Furthermore, RBFDPs can be a reversible treatment option and are associated with a low risk for caries. Young patients with large pulp chambers are eligible for this treatment, which can maintain teeth vitality.¹

Zirconia is the most resistant ceramic framework material currently available,⁵ and is therefore recommended for aesthetic restorations in the posterior area.⁴,⁶ Although considered the most unaesthetic dental ceramic, zirconia has been upgraded through several colour infiltration techniques, expanding the indications of monolithic zirconia restorations.⁴,⁷ Zirconia is also highly biocompatible and non-allergenic⁸, ⁹ and favourable towards the soft tissue.⁸,¹⁰,¹¹

We aim to assess the medium and long-term survival rate of 3Y-TZP minimally invasive PRFDPs.

Note: The name 'partial retainer' will be used for any retainer that requires minimal preparation compared to the full-coverage retainers, thus minimising tooth structure loss and increasing hard tissue preservation. These include inlays, onlays, wings, inlay and wing, or partial crowns.
Materials and methods

Study design

Patients with single tooth gaps were selected. Some of the patients presented two single tooth gaps that needed to be restored. Otherwise, they were in good general and oral health condition.

The study population consisted of 23 patients that were selected and treated after signing an informed consent form. The study design was approved by the University Ethics Committee.

Inclusion and exclusion criteria

The patient inclusion criteria were as follows:

- Age over 18
- One-tooth class III Kennedy edentulous ridge
- Sagittal gap sizes of less than 12 mm
- Favourable occlusion
- Good oral hygiene
- Absence of active periodontitis
- Availability for check-ups

Patients with extreme bruxism, parafunction symptoms, and excessive wear exposing the dentin were not included, as the vast majority of them required full-arch prosthodontic treatment.

Clinical procedures, design, and fabrication of 3Y-TZP PRFDPs

All PRFDPs treated single tooth gaps with either a single-retainer (n=18) or double-retainer mechanism (n=10). The abutments were caries-free or presented resin restorations, glass-ionomer restorations, or superficial caries. Most of the abutments were vital, but some non-
vital teeth were also considered. Retainer selection was relative to the previous restorations, carious processes, and occlusal conditions. This included inlays, onlays, wings, inlay and wing, or partial crowns. For gaps under 9 mm in size, only one partial retainer was used. Otherwise, for gaps of 9 to 12mm, two partial retainers were used.

**Preparation** In most cases, previous restorations and caries were removed, and defect-oriented preparations were performed. The basic preparation guidelines for all-ceramic restorations, such as smooth surfaces, rounded internal angles, and no bevelling of the margins, were followed (Fig 1).

**PRFDPs design** For both single-retainer and double-retainer groups, a full-contour design was used for the retainers. The cantilever/pontic was designed to ensure maximum support for the veneering ceramics. Thus, the mucosal aspect was full-3Y-TZP, with a small buccal and high oral collar. In some cases, the oral cusps were full-contour designed, and only the buccal cusps were veneered to achieve higher aesthetics.

**PRFDPs fabrication** Different systems were used in the making of the restorations. Patients treated between 2009 and 2012 received ZenoTec (Wieland, Pforzheim, Germany) 3Y-TZP PRFDPs and cementation was performed with resin-modified glass-ionomer (RMGI) (Fuji Plus, GC, Tokyo, Japan). Those treated after 2013 received Lava (3M ESPE, Seefeld, Germany) 3Y-TZP PRFDPs that were bonded with resin cement (G-Cem, GC).

**ZENO group** (n=4) Impressions were taken by the same operator with vinylpolysiloxane (Express XT, 3M ESPE), using a one-step technique. Standard metal impression trays were used to carry the impression material. The impressions were poured in a class IV die stone (Fujirock, GC) (Fig 2). The models were scanned using 3ShapeD200 (Wieland), thus resulting in digital models. The restorations were designed using CAD DentalDesigner (Wieland). A standardised protocol was used (full-contour modelling for the
retainer, virtual cement layer of 25µm, and connector size of 9 to 16mm²). Milling was performed with ZenoPremium 4030. Subsequently, the restorations were sintered in a ZenoFire oven. The pontics were then veneered with Zirox (Wieland) hi-dense, non-leucite ceramics.

**LAVA group** (n=24) Impressions were taken by the same operator with vinylpolysiloxane (Express XT, 3M ESPE), using a one-step technique. Standard metal impression trays were used to carry the impression material. The impressions were poured in a class IV die stone (Elite Rock, Zhermack, Badia Polesine, Italy).

The models were scanned using Lava Scan ST (3M ESPE), thus resulting in digital models. The restorations were designed using Lava Design CAD 7.2 software (3M ESPE). A standardised protocol was used (full-contour modelling for the retainer, virtual cement layer of 25µm, and connector size of 9 to 16mm²) (Fig 3). Lava Plus semi-sintered 3Y-TZP blocks were milled, and the restorations were immersed into Lava Frame Shade (3M ESPE) for 2 min.

The milled blocks were then left to dry at room temperature. The sintering process to full density was completed in the Lava Therm oven for 10.5 h at 1450 °C. Adjustments were performed under 6X magnification (Mantis, Vision Engineering, Surrey, England) using a Presto Aqua II (NSK, Tokyo, Japan) handpiece and code red rotary instruments (NTI, Kahla, Germany). The individualisation of the abutments was achieved using Lava Plus shades and pigments (3M ESPE). The pontics were also veneered with IPS e.max Ceram (Ivoclar Vivadent, Schaan, Lichtenstein)(Fig 4).

Before cementation, all PRFDPs were sandblasted with 50 microns of Al₂O₃ and 0.25MPa and cleaned with isopropyl alcohol (96%). Then, the restorations were coated with silane to increase the critical surface tension and wettability. The preparations were isolated
using a rubber dam and cleaned with Consepsis 2% chlorhexidine gluconate (Ultradent, South Jordan, UT, USA).

**Conventional cementation** (n=6) The abutments were conditioned with GC Fuji Plus conditioner (GC) for 20 s, rinsed with water spray, and then air-dried. The Fuji Plus (GC) RMGI cement was applied to the preparations, and the restorations were seated and maintained in position while the cement set.

**Adhesive cementation** (n=22) The abutments were selectively-etched with 37% phosphoric acid, rinsed with water spray, and then air-dried. Consequently, G-Bond (GC) was applied, the excess was removed with the aid of a suction unit, thoroughly air-dried for 10 s, and photopolymerised. Also, the internal aspects of the PRFDPs were bonded and photopolymerised. Then, G-Cem (GC) was applied to the preparation and on the internal aspect of the PRFDPs, and the restoration was seated and maintained in position while the cement set.

On the final check after cementation, some areas were finished using fine and superfine diamond instruments, and *in situ* polishing was performed with Dimanto polishers (VOCO, Cuxhaven, Germany).

All restorations were seated under rubber dam protection (Fig 5).

**Follow-up** Patients were recalled at six months and one year, followed by yearly follow-ups. (Fig 6, 7).

**Data analysis**

Continuous variables with normal distribution were presented as the mean ± standard deviation, while continuous variables without normal distribution were described as the median (interquartile range). Categorical variables were presented as a percentage (absolute frequency). A Kaplan-Meier survival analysis was conducted using two criteria of
failure as endpoints, i.e., when either a repair was needed or complete failure occurred, discriminated according to retainer type. In addition, restorations not meeting the failure criterion during the follow-up period were labelled as "censored." The statistical analysis was performed using SPSS version 20 (SPSS Inc., Chicago, IL) and R project packages for statistical computing. A $p$-value of 0.05 was considered statistically significant.

**Results**

**Patients**

The first patient was treated in February 2009, and the final data were collected in July 2019. The included patients presented with one tooth class III Kennedy edentulous ridges. In total 23 patients, 18 females and five males, received 28 minimally invasive 3Y-TZP PRFDPs. Five of them received two restorations each. Fifteen PRFDPs were placed on the maxillary and 13 on the mandible. Eight PRFDPs had two partial retainers and one pontic, two PRFDPs had two partial retainers and one pontic with mesial cantilever, and 18 had one retainer and one cantilever.

The PRFDPs replaced one lower incisor (3.33%), four upper incisors (13.33%), two lower premolars (6.66%), five upper premolars (16.66%), ten lower first molars (33.33%), and eight upper first molars (26.66%). Of these, 46.42% and 53.57% were in the mandibular and edentulous maxillary ridges, respectively. The patients ranged in age from 20-66 years, with a mean of 27.93 (± 8.28), 95% CI (24.72; 31.14). Most of the patients were female, with five of them receiving two restorations each (82.1%). The restorations were classified according to Kennedy class, with 53.6% and 46.4% being K III maxillary and K III mandibular, respectively. Most of the occlusions were on natural teeth (89.3%), while two occlusions were on natural teeth and PFM FDPs, and one occlusion was on PFM FDP. Tables 1 and 2 summarise these characteristics.
During the observation period (5.92±1.74 years, minimum = two years, maximum = ten years), three debondings occurred, all of which were in the two-retainer group and the mandible. Each of these restorations used occluso-proximal inlays as retainers. Two of them replaced lower second premolars in the same patient and were fabricated with the ZenoTec system, while the other replaced a lower first molar and was fabricated with the Lava system. All three of the debonded restorations were initially fixed with Fuji Plus (GC) RMGI. The preparations and corresponding restorations were all cleaned, sandblasted, and related. None of the single-retainer restorations debonded, regardless of the retainer’s design, the computer-aided design and manufacturing system, or the cementation protocol. Two abutments developed caries on the aspect/face of the tooth not related to the 3Y-TZP PRFDPs. No cracking or chipping of the porcelain veneer was observed, or fracture of the 3Y-TZP framework. No mobility of the abutments, no secondary caries, gingivitis, or periodontitis were detected. All vital abutments had a normal response to thermal vitality tests. The PRFDPs were grouped into two categories, i.e., 'single-retainer,' which includes only one partial retainer, and 'double-retainer,' which includes two partial retainers. A survival analysis was conducted considering the two categories.

The mean survival time in years was longer for double retainers, 7.400 (± 1.647) years, compared to single retainers, 5.110 (± 1.183) years (Table 3). The Kaplan-Meier survival curves are shown in Figure 8.

The survival rates for the two types of intervention were different, with 100% for the single-retainer group and 70% for the double-retainer group. However, this was not statistically different (Log-rank test $\chi^2 (1) = 0.200, p = 0.655$). Therefore, the survival rates for both the single and double retainers were at a good level, without significant differences between them.
Discussion

The restorations presented in this study performed well, with a 100% survival rate for the single-retainer group, both in the anterior and posterior areas. The survival rate for the double-retainer group was 70%, with three restorations debonding after a mean of 2.8 (1.5, 4.5) years. All three debondings occurred in the mandible, in the second premolar/first molar area, most probably because of higher distortion, as suggested in other studies.12,13 Two of the debondings occurred in the same patient. All three restorations were initially fixed with Fuji Plus (GC) RMGI. This was considered a relative failure, and the restorations were rebonded afterwards with (G-Cem) GC. All three restorations were still functional at the final follow-up.

Other authors also found debonding to be the most common complication of these restorations.8 Our findings are in accordance with studies that stated that cantilevered zirconia PRFDPs present a promising alternative for replacing missing incisors.14 Other studies confirmed that cantilevered, single-retainer restorations perform better than the two-retainer type. No side effects regarding abutment movement have been reported.8,15 Also, single-retainer 3Y-TZP PRFDPs performed well in replacing premolars and molars, where the gap is under dimensioned through adjacent teeth migration/translation. No fracture of the 3Y-TZP zirconia framework was detected, as opposed to lithium-disilicate ceramic restorations with similar designs presented in other studies.16

3Y-TZP PRFDPs, regardless of the single or double retaining mechanism, can be a viable treatment alternative when indications are respected and when the design of the restoration is properly conceived. An important aspect to mention is that when caries and direct restorations are already present, this treatment option proves almost non-invasive.
It is widely accepted that the long-term success of a restoration is determined by its cementation. Thus, a limitation of the present study might be that no MDP-based cementation protocol was used. Although a few debondings occurred, at the beginning of the study, it was only hypothesised that sandblasting promoted micromechanical adhesion, but no cementation protocol for zirconia had been validated. Currently, it has been scientifically proven that better bonding might be obtained using the 3-step APC (air particle abrasion/zirconia primer/adhesive composite resin) concept.

There is evidence that a durable bonding to zirconia in the intraoral environment is achievable using air abrasion at a moderate pressure and phosphate monomer containing primers.

The relatively low number of cases (n=28) is a limiting factor of the current study. Thus, further investigation of this treatment modality is needed before these restorations could be recommended on a large scale. Also, thorough research is imperative to systematise the wide variety of conventional and translucent zirconia ceramics currently available on the market and to draw clear guidelines for their clinical use.

Conclusion

In conclusion, the 3Y-TZP PRFDPs presented in this study showed no failure when bonded and not conventionally cemented. Therefore, they could be used in cases where implant therapy is not possible or indicated.

The authors declare no conflict of interest related to this study.
References


Figures legend

Fig 1a

Fig 1b
Fig 1c

**Fig 1 a.** Radiograph of the initial situation; **b.** Occlusal aspect; **c.** View of the preparation.
Fig 2a

Fig 2b

**Fig 2 a.** One-step impression; **b.** View of the preparation on the cast model.
Fig 3a

Fig 3b

**Fig 3 a.** Design of the framework; **b.** Milled framework, prior to sintering.
Fig 4a

Fig 4b
Fig 4c

**Fig 4.** 3Y-TZP framework – internal aspect; **b.** Framework on the model; **c.** PRFDP after veneering of the cantilever pontic.
Fig 5a

Fig 5b

**Fig 5** a. PRFDP upon cementation; b. PRFDP after insertion.
Fig 6a
Fig 6b

**Fig 6 a.** Buccal aspect of the PRFDP after 6 years of clinical service; **b.** Occlusal aspect of the PRFDP after 6 years of clinical service.
Fig 7a
Fig 7b
Fig 7c

Fig 7 a. Lava Zirconia PRFDP replacing right upper first molar upon cementation; b. Occlusal aspect of the PRFDP after 6 years of clinical service; c. Occluso-buccal aspect of the PRFDP after 6 years of clinical service.
Fig 8. The Kaplan-Mayer survival functions.
Tables

**Table 1. General characteristics of the patients included in the current study**

<table>
<thead>
<tr>
<th>Variable</th>
<th>n = 28</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>27.93 ± 8.28&lt;sup&gt;(1)&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>5 (17.9%)</td>
</tr>
<tr>
<td>Females</td>
<td>18+5 (82.1%)</td>
</tr>
<tr>
<td><strong>Jaw</strong></td>
<td></td>
</tr>
<tr>
<td>Maxilla</td>
<td>15 (53.6%)</td>
</tr>
<tr>
<td>Mandibula</td>
<td>13 (46.4%)</td>
</tr>
<tr>
<td><strong>Occlusion</strong></td>
<td></td>
</tr>
<tr>
<td>Natural teeth</td>
<td>25 (89.3%)</td>
</tr>
<tr>
<td>Natural teeth and PFM FDP</td>
<td>2 (7.1%)</td>
</tr>
<tr>
<td>PFM FDP</td>
<td>1 (3.6%)</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> mean ± standard deviation
**Table 2.** Characteristics of the PRFDPs

<table>
<thead>
<tr>
<th>Type of PRFDP</th>
<th>Occlusion</th>
<th></th>
<th></th>
<th></th>
<th>Jaw</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural teeth</td>
<td>Natural teeth and PFM FDP</td>
<td>PFM FDP</td>
<td>Maxilla</td>
<td>Mandible</td>
<td></td>
</tr>
<tr>
<td>Single-retainer</td>
<td>18</td>
<td>17</td>
<td>0</td>
<td>1</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Double-retainer</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

**Table 3.** Results of the survival analysis

<table>
<thead>
<tr>
<th>Survival time</th>
<th>Survival rate [%]</th>
<th>Log-rank test</th>
</tr>
</thead>
<tbody>
<tr>
<td>X [years]</td>
<td>95% CI</td>
<td></td>
</tr>
<tr>
<td>Single-retainer</td>
<td>$5.110 \pm 1.183^{[1]}$</td>
<td>(4.520; 5.700)</td>
</tr>
<tr>
<td>Double-retainer</td>
<td>$7.400 \pm 1.647^{[1]}$</td>
<td>(6.220; 8.580)</td>
</tr>
</tbody>
</table>

$^{[1]}$ mean ± standard deviation