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Original Article

Performance of posterior third-generation monolithic zirconia crowns in a complete digital workflow: A three-year prospective clinical study

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Abstract *Background/purpose:* Translucent monolithic zirconia restorations have recently introduced. The purpose of this study was to evaluate the clinical behavior and the survival rate of the posterior third-generation monolithic zirconia crowns (MZCs) during three years of clinical service.
Materials and methods: Twenty-four patients who needed thirty crowns were enrolled in this study. Digital impressions were made, and the crowns were milled and cemented with a resin cement. The crowns outcomes were assessed using the California Dental Association's (CDA) criteria. Gingival index (GI), plaque index (PI), and periodontal probing depth (PPD) for MZCs and contralateral natural teeth (control) were assessed. Margin index (MI) for MZCs was also assessed. Data analysis was conducted using the Wilcoxon signed-rank and the Friedman tests.
Results: The 3-year survival rate was 100%. All MZCs were rated as satisfactory throughout the follow-up period, and no biological or mechanical complications were observed. No differences were recorded when GI, PI and PPD at 3-year of follow-up were compared to baseline. No differences were recorded between crowned and control teeth. The MI remained stable throughout the study period.
Conclusion: The third-generation monolithic zirconia appears to be a good treatment option for the rehabilitation of posterior single teeth.

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Introduction

Over the years, ceramic has been considered the basis of aesthetic dentistry due to its high aesthetic properties,[1] but over the time it has shown some deficiencies in its mechanical properties.[2]

In the recent decades and as a result of continuous research, zirconia has become known in the field of dentistry, and it is considered the strongest ceramic material, due to its good mechanical characteristics.[1,3,4] First-generation zirconia had a high opacity, being mainly indicated for the fabrication of frameworks that must be covered with veneering ceramic.[1–3,5] However, the core-veneering ceramic interface is one of the most weakness points of this type of restorations, being the chipping or fracture of the veneering ceramic the most frequent cause of their failure.[3–6] Nevertheless, to solve this problem monolithic zirconia has been introduced. Monolithic zirconia offers more advantages such as reducing the time of production and the improvement in the cost—effectiveness relation compared to veneered zirconia.[7]

Zirconia is an opaque material, due to its chemical nature. Zirconia lacks the glass-matrix phase and their particles are large in size,[8] so when zirconia is exposed to the light, the light will profoundly scatter and diffuse. Conversely, glass ceramic materials are able to absorb and transmit the exposed light, because their glass-matrix phase and their smaller particles in size, being more translucent than zirconia 9. The recent research led to the introduction of the third-generation monolithic zirconia with the goal of improving the optical properties without changing the chemical characteristics of the second-generation monolithic zirconia.[1,3,10]

The third-generation zirconia, with an increase in yttria content to 5% mol, is metastable in the tetragonal phase with a content of cubic phase up to 53%, and is described as fully stabilized zirconia.[3,11] The cubic grains are larger in size (1.5 μm) than the tetragonal grains (0.5—1 μm) and for this reason the third-generation is less opaque than the second-generation.[3,9,11] in addition, the cubic crystal structures are more isotropic which also has significant influence on translucency.[3] Moreover, due to the stable cubic phase and the increase of yttria content the third-generation has high aging resistance.[3,11–13]

However, one disadvantage of the third-generation affects its mechanical properties. Previous studies alert on its lower flexural strength and fracture toughness,[1,3,5,9,11,12,14] and it has been reported that care should be taken in areas or situations with high stresses.[14]

Besides the advances in zirconia ceramics, digital dentistry is a reality and one of the most important changes in prosthodontics. Monolithic zirconia restorations can be fabricated by CAD-CAM technology or 3D printing techniques, and in a complete digital workflow.[15–17] The introduction of digital workflow has allowed to obtain restorations more automated, more time efficient, and accurate, improving the quality of treatment provided.[15,17] However so far, limited clinical evidence is available, and there is a need of clinical trials to accurate implementation in daily practice.[15,17]

This prospective clinical trial aimed to evaluate the survival and clinical performance of posterior third-generation MZCs fabricated in a digital workflow. The null hypothesis tested was that no differences would be found from baseline and 3-year follow-up among the assessed parameters.

Materials and methods

Study design and selection criteria

A total of 64 patients in need of a full coverage posterior crown were screened among those who attended at the dental clinic of the Master in Buccofacial Prosthesis and Occlusion (Faculty of Odontology, University Complutense of Madrid, Spain). Out of the 64 examined patients, 24 fulfilled the inclusion criteria and were enrolled in the study. No power analysis was performed, and the sample size was determined according to previous studies.[6,10,15,16,18–21] Patients were treated from January 2019 to May 2019. All patients signed an informed consent prior to the treatment. The present prospective clinical trial was conducted in conformity with the Declaration of Helsinki, and the study protocol was approved by the Ethical Committee of Clinical Trial at San Carlos University Clinical Hospital (Madrid—Spain/Internal Code:19/002-E). The study was registered in ClinicalTrials.gov (Identifier NCT 04943315).

The patient inclusion criteria were as follow: 1) patients who required at least one mandibular or maxillary full coverage restoration in premolar or molar region, 2) vital abutment or with appropriate endodontic treatment, 3) absence of periodontal and gingival diseases, 4) acceptable abutment height (at least 4 mm), 5) stable occlusion, and 6) the presence of a natural antagonist teeth. The patient exclusion criteria were as follow: 1) abutment previously crowned, 2) reduced crown length, 3) active periodontal pathology, 4) signs of probable bruxism, and 5) poor oral hygiene.

Treatment procedures

All patients received oral hygiene instructions prior to the treatment. Teeth preparations were made as follows: isogingival chamfer finish line, axial and occlusal reduction of approximately 1 mm, and a tapering angle of approximately 6° to 10°. Digital impressions were taken with an intraoral scanner (IOS). Temporary restorations were fabricated and cemented with a temporary cement. Monolithic zirconia crowns were fabricated from pre-sintered high translucent zirconia blanks, sintered, characterized, and glazed following the manufacturer's recommendation. The crowns were evaluated intraorally prior to cementation with a self-adhesive resin cement. After cementation occlusal contacts were evaluated, and when adjustments were necessary the surfaces were carefully polished. Table 1 displays details of materials and instruments used in clinical and laboratory procedures. All the clinical procedures were performed by the same experienced prosthodontist.

Table 1 Materials and instruments used in clinical and laboratory procedures.

Procedure	Proprietary name	Company
Retraction cord	Ultrapak E	Ultradent, South Jordan, UT, USA
Lip and cheek retractor	OptraGate	Ivoclar Vivadent, Schaan, Liechtenstein
Impression	Trios 3	3Shape, Copenhagen, Denmark
Temporary restorations	Protemp Crown	3M ESPE, Seefeld, Germany
Temporary cement	RelyX tem	3M ESPE, Seefeld, Germany
Shade selection	VITA Easyshade V	Vita Zahnfabrik, Bad Säckingen, Germany
Restoration designs	3Shape software	3Shape, Copenhagen, Denmark
Restoration milling	Zenotec select hybrid	Wieland Dental, Pforzheim, Germany
Zirconia blanks	KATANA Zirconia, STML	Kuraray Europe, Hattersheim, Germany
Restoration sintering	Programat CS4	Ivoclar Vivadent, Schaan, Liechtenstein
Restoration glazing	Cerabien ZR	Kuraray Europe, Hattersheim, Germany
Treatment of the internal surface	CoJet	3M ESPE, Seefeld, Germany
Definitive cement	Panavia SA	Kuraray Europe, Hattersheim, Germany
Occlusal surface polishing	KATANA Zirconia TWIST DIA	Kuraray Europe, Hattersheim, Germany

Follow-up examination

Two calibrated clinicians not involved in the restorative treatment examined the crowns at 1 week (baseline), 6 months, and 1, 2, and 3 years after the end of the treatment. California Dental Association's quality assessment system (CDA) was used to assess the crowns.[6,10,15–17,22–25] The periodontal status was assessed by scoring the margin index (MI), plaque index (PI), gingival index (GI), and periodontal probing depth (PPD) of the crowns and the corresponding contralateral natural teeth, which were used as a control for the periodontal evaluation.

CDA criteria were ranked on a scale from 1 to 4, where 4 = excellent, 3 = acceptable, 2 = repair, and 1 = substitution. The periodontal parameters were catalogued by assigning a score from 0 to 3 (PI and GI) or from 1 to 4 (MI and PPD). Survival was defined as the permanence of the crowns in situ, with or without modification, in all examination recalls.[7]

Statistical analysis

The data were statistically analyzed with a software (IBM SPSS Statistics 22.0, IBM Corp, Armonk, NY, USA). Descriptive analysis were used to evaluate the crowns and the control teeth outcomes. The Friedman test was applied for the comparisons of the baseline and the follow-up scores of each variable. The Wilcoxon signed-rank test was applied to compare variables for matched pairs in periodontal parameters between abutments and the control teeth, and to evaluate the differences considering the periodontal parameters and the CDA ratings. The level of significance was established at 0.05.

Results

Between January 2019 and May 2019, 24 patients (17 female, 7 male) received 30 posterior zirconia crowns, with mean age of 55.3 ± 13.9 years. Crowns distributions are shown in Table 2. All crowns were evaluated for 36 months. The survival rate at 3 years was 100%. No biological or technical complications were observed. No cracks were observed in the antagonist teeth (Fig. 1).

All crowns were rated as satisfactory at each recall, and no differences were observed from baseline to the 3-year follow-up evaluation ($P > 0.05$). Surface roughness was observed in three crowns from baseline. With respect anatomical form, three crows were assessed as acceptable at the three-year follow-up due to slight wear at the occlusal surface. The marginal integrity was rated as excellent in all examination periods. Deviations from the excellent scores are displayed in Fig. 2.

Changes in the periodontal parameters were recorded throughout the observation period (Fig. 3). The GI was worse at 6 months ($P = 0.025$), 1-year ($P = 0.008$) and 2-year ($P = 0.02$) compared to baseline. In the same way, PI was worse at 6 months ($P = 0.046$), 1-year ($P = 0.011$), and 2-year ($P = 0.004$) compared to baseline. However, no differences were observed in GI and PI between baseline and 3 years results ($P = 0.26$). Regarding PPD, better score was observed at baseline compared to 3-year evaluation. No differences were observed between crowns and control teeth. The MI for monolithic zirconia crowns remained stable at the 3-year follow-up.

Discussion

The results of the study support the rejection of the null hypothesis as differences in the periodontal parameters were observed.

Table 2 Distribution of restorations.

Tooth	Number of restorations
Upper first premolar	3
Upper second premolar	7
Upper first molar	7
Upper second premolar	3
Lower first premolar	2
Lower second premolar	3
Lower first molar	4
Lower second molar	1

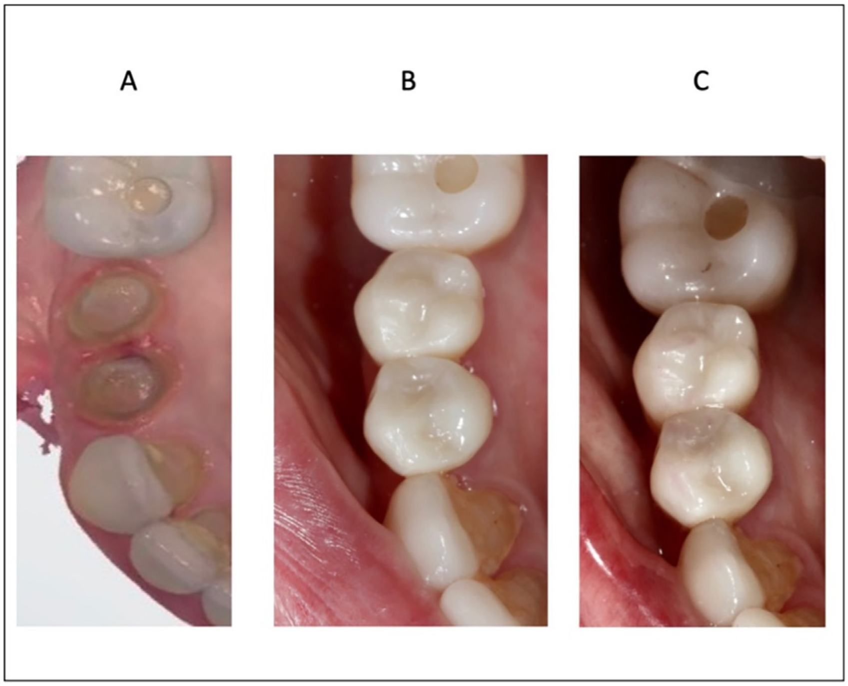

Figure 1 Monolithic zirconia crowns (A) Digital impression. (B) Baseline. (C) 3-Year follow-up.

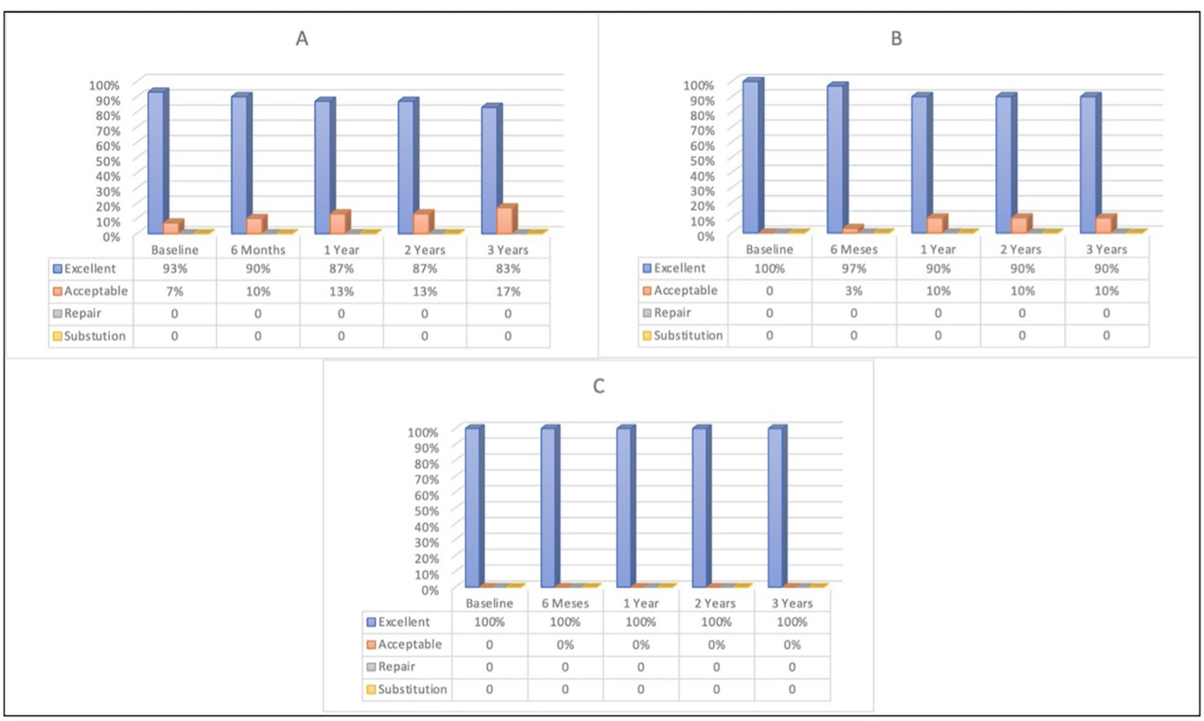

Figure 2 California Dental Association's criteria rating at baseline, 6 months, 1 year, 2 years and 3 years. (A) Color and surface (B) Anatomic form. (C) Marginal integrity.

Previous clinical studies evaluating the third-generation zirconia are very, very scarce, and with short follow-up time in the range of 1 to 3 years. The survival rate recorded in this study was consistent with previous studies which evaluated the same zirconia generation in a similar observation period.[17,21,26,27] The short observation period of these studies could explain these findings. In addition, the recorded survival rate in this study was similar to that recorded in previous studies which evaluated the second-generation MZCs.[19,20,22,23,26–33]

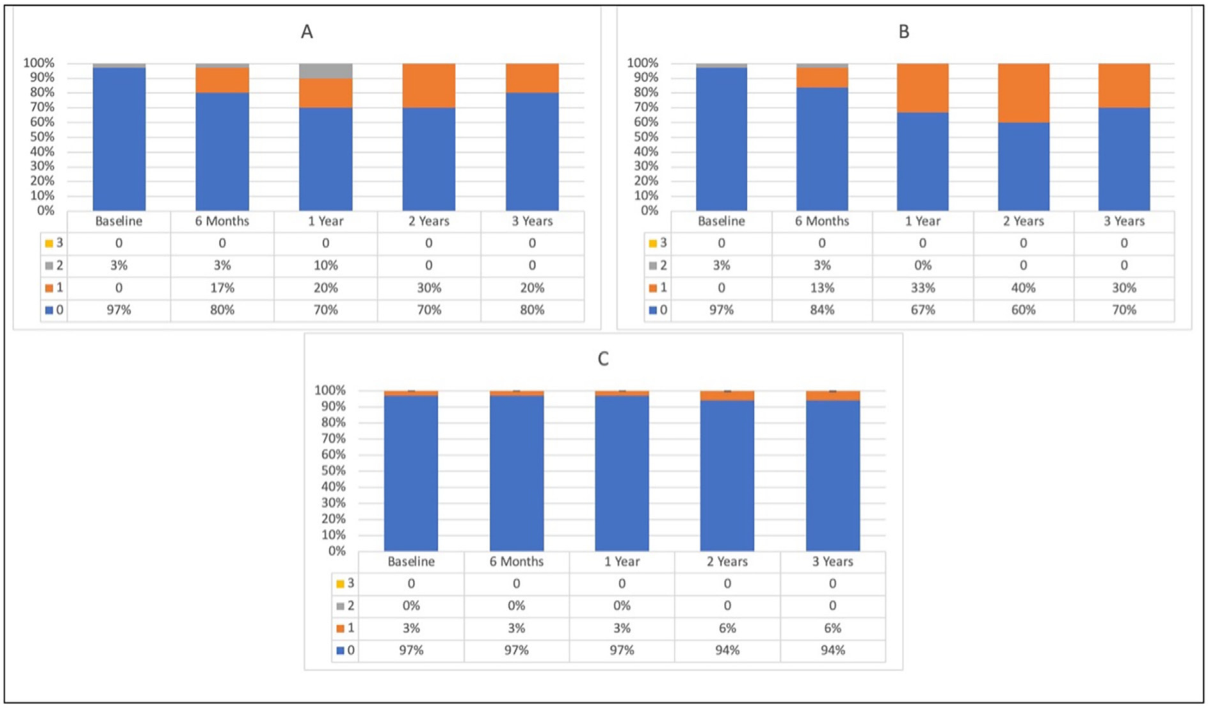

Figure 3 Periodontal parameters results at baseline, 6 months, 1 year, 2 years and 3 years. (A) Gingival index. (B) Plaque index. (C) Periodontal probing depth.

In the presented study, no biological or mechanical complications were observed with the exception of slight wear at the occlusal surface in 3 crowns (10%), consistent with previous findings.[21,26,27,29,34] Conversely, other studies reported some biological and mechanical complications. Barile et al.,[27] in their prospective study with 5-year of follow-up on third-generation MZCs reported a survival rate of 95% and some complications, such as: fracture of 1 crown and secondary caries in another crow. The longer observation time of this study could explain the slight differences with the results of the present study. Valenti et al.,[35] presented a multicentric retrospective study of 621 MZCs up to 7 years and reported 5 failed crowns (4 abutment tooth fracture and 1 crown fracture) in endodontically treated teeth. They analyzed second and third-generation monolithic zirconia, but the authors did not mention which generation the failed crowns were made of. Other previous studies in second-generation zirconia reported more complications, such as: abrasion of the occlusal surface, pulpitis, loss of retention, abutment fracture, cracks, periodontal problems, and marginal discoloration.[19,20,28,30–32,36,37] Moreover, some authors noted a number of complications in the antagonist teeth, such as: wear, cracks and fractures.[19,22,23]

Patients with signs of bruxism were excluded in the presented study. Weldecker et al.,[37] performed a prospective observational study with 5 years of follow-up, including both monolithic and partially veneered zirconia single crowns made of second-generation zirconia, and reported a survival rate of 93.1% for MZCs. The authors did not exclude patients with signs of bruxism, and they recommended the use of second-generation zirconia on these patients. Koenig et al.,[30] in their prospective clinical study evaluated single crowns, implant-supported crowns, and posterior partial fixed prostheses of second-generation monolithic zirconia reporting a survival rate of 76.9% for tooth-supported crowns. The authors included patients with signs of bruxism, and this low survival rate was related to bruxism. Pontevedra et al., evaluated 3-unit posterior fixed partial dentures reporting a survival rate of 90% due to biological reasons. The failures were observed in patients with probably bruxism. Therefore, further long-term clinical trials are essential to validate the outcome of the third-generation MZCs on patients with bruxism.

Regarding CDA criteria, in the present study all crowns were assessed as satisfactory in all appointment recalls. These results are consistent with previous studies.[6,15,17,24,25] In relation to anatomical form, three crowns dropped from excellent to acceptable due to slight wear at the occlusal surface, which is similar to previous findings.[10,15,23,25–27,30,33] These could be due to excessive chewing force or loss of the surface coating of the glass after intraoral occlusal adjustment, since two crowns was occlusally adjusted after cementation. With respect to marginal integrity, all crowns showed good marginal adaptation with no evidence of secondary caries or marginal gaps, which was largely attributed to the good fit of zirconia restorations.[6,15,21–26,29,32,34]

With respect to periodontal parameters, no differences were recorded between the crowns and the control natural teeth, indicating a good response in the soft tissue that was consistent with previous studies.[15,20,21,29,34,38] Conversely, other authors observed differences with a decrease in bleeding around the control teeth.[24,32,33] However, the present study showed that PI and GI scores became worse in the first two years of follow-up, and they got better at the third year evaluation. A possible explication for these results is the adequate oral-hygiene control after reinstructions and motivations. Throughout the study period PPD remained stable in 94% of the evaluated crowns, and no changes in the marginal location in any of the crowns were observed. These results are consistent to those reported in previous studies,[6,15,20,21,29,30,38] and could reflect the high biocompatibility of monolithic zirconia. Nevertheless, marginal adaptation and position, gingival biotype and patients' control can play an important role in soft tissue responses.[25,39]

Even though the study presents the limitations that no power analysis was performed to determine sample size and the short follow-up period, the results suggest that the crowns fabricated from translucent zirconia in a digital workflow are a clinically accepted treatment option for posterior single crowns, improving disadvantages as optical properties, and overcoming the chipping risk of metal-ceramic and veneered zirconia restorations. However, to extend the experimental cohort sample size, and larger observational period comparing the different evaluating periods is needed for deeper and credible study in the future.

In conclusion, during the 3-year follow-up no biological nor mechanical complications were observed. The results of the present study suggest that the third-generation monolithic zirconia fabricated in a digital workflow is a reliable option and appears to be a viable alternative to metal-ceramic and veneered zirconia for the rehabilitation of posterior single teeth.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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