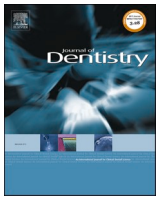
Journal of Dentistry 148 (2024) 104953

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent



Clinical evaluation of posterior zirconia-based and porcelain-fused-to-metal crowns with a vertical preparation technique: an up to 5-year retrospective cohort study

M Gonzalez-Bonilla [a], S Berrendero [b,*], B Moron-Conejo [b], F Martinez-Rus [b], MP Salido [b]

[a] Carrer 9 d'Octubre, 1, Altea, 03590, Alicante, Spain
[b] Department of Conservative and Prosthetic Dentistry, Faculty of Dentistry, Complutense University of Madrid, Plaza Ramón y Cajal, s/n. Madrid, 28040, Spain

ARTICLE INFO

Keywords:
Vertical preparation
Crown
Zirconia
Porcelain-fused-to-metal
Periodontal parameters

ABSTRACT

Objective: To evaluate the clinical conditions of single-unit posterior restorations on teeth prepared without finishing line, after 5.6 years of clinical service.
Materials and methods: 50 crowns (25 zirconia-based (Zr) and 25 porcelain-fused-to-metal (PFM)) were selected from 34 patients. The restorations were evaluated according to the California Dental Association (CDA) Quality Criteria, and periodontal variables were studied in the abutment teeth compared with the unrestored contralateral teeth. Variables were examined using Mann-Whitney and Pearsońs Chi-Square tests ($\alpha = 0.05$). The success of the prosthesis was calculated using Kaplan-Meier test.
Results: CDA Quality Criteria was considered satisfactory-excellent in all restorations except for one of them, due to chipping on a PFM crown. At, 66 months, the success rates for PFM and Zr crowns were 85.7 % and 100 %, respectively. The plaque index (PI) showed that the restored abutment teeth accumulated significantly less plaque than the control teeth, but the gingival index (GI) was statistically higher in the abutment teeth. In 80 % of cases the probing depth (PB) was $\leq$3 mm. In addition, in 21 % of the cases, gingival recession was less than 2 mm. The restoration material had a statistically significant effect on GI and PB, with Zr crowns showing less inflammation and less deep pockets than PFM restorations. On the contrary, greater gingival recession was found at the margins of the Zr crowns when compared to the PFM. No statistical differences were found between the two materials in the GI.
Conclusions: Cemented crowns on vertical preparations show good clinical behavior after 5 years. The periodontal parameters (PI, GI, PD) of the Zr restorations are significantly better than those of PFM, with the exception of gingival recession.
Clinical relevance: The use of restorations on vertically prepared teeth is a suitable alternative to classical horizontal preparations.

Introduction

Full coverage crown are still a widely used resource for restoring damaged teeth, or for replacing missing teeth [1]. Traditionally, when clinicians prepare dental abutments to receive full coverage crowns they create a finish line on the tooth on which the prosthetic restoration will rest [2]. These finish lines can be classified into 2 main groups: 1) horizontal finish lines, which include curved chamfers, flat chamfers, and straight or rounded shoulders; 2) or vertical finish lines, which include feather, knife-edge margins or no finish line [3,4].

For many years, horizontal finishing lines have been the preparation of choice. These preparations have demonstrated good clinical survival of restoration [5]. The significant reduction of dental tissue during their preparation or the difficulty in reproducing these margins with impression materials are other disadvantages [6–8]. In addition, the most common problem over time is the migration of the gingival margin, which leads to serious aesthetic and sensitivity problems, increased probability of dental caries, periodontal problems, etc [9]. Vertical preparation techniques have traditionally been used on periodontally compromised teeth because these preparations allow greater

* Corresponding author at: Department of Conservative and Prosthetic Dentistry, Faculty of Dentistry, Complutense University of Madrid, Plaza Ramón y Cajal, s/n. Madrid, 28040, Spain.
E-mail addresses: sberrendero@ucm.es (S. Berrendero), mpsalido@ucm.es (M. Salido).

https://doi.org/10.1016/j.jdent.2024.104953
Received 28 January 2024; Received in revised form 9 March 2024; Accepted 17 March 2024
Available online 28 March 2024

preservation of the remaining dental tissue [10,11]. However, in recent years their use has been extended to periodontally healthy teeth, due to the appearance Biological Orientated Preparation Technique (B.O.P.T.) described by Ignazio Loi and Antonello Di Felice [4]. This technique offers the possibility of redesigning the gingival contour of the teeth to create an ideal gingival architecture and allow an increase in gingival thickness with great stability of the surrounding tissues over time [4,12]. B.O.P.T. also improves prosthetic retention, allows an optimal fit between the tooth and restoration and simplifies the impression procedure compared to dental preparation with horizontal finish lines [13]. Provisional restorations are an essential element in the control of gingival tissues, as they facilitate the stabilization of the blood clot created during tooth preparation and the maturation of the soft tissues. In the B.O.P.T. technique, the provisional is left in place for eight weeks before final impressions are taken [4,12,13]. However, there are vertical preparation techniques similar to B.O.P.T that differ mainly in this time. There are authors who wait 12 weeks with the provisional restorations [14]. However, some studies take the impressions on the same day as the preparation [15] or 15 days later [16] and wait for the final maturation of the tissue with the final restorations.

The materials used in fixed prosthodontics in general have evolved over the decades due to the desire for an aesthetic and natural appearance of the restorations. Porcelain-fused-to-metal (PFM) restorations were introduced in the 1960s, followed by glass-reinforced ceramics and polycrystalline ceramics a few decades later [17], with zirconia being the gold standard today, thanks to its biocompatibility, aesthetics and mechanical properties. Both PFM and zirconium oxide-based restorations (Zr) can be used in vertical preparations, which have become widespread in recent years, but there are few studies that analyzing the performance of these restorations in the medium and long term.

Therefore, the aim of this study is to retrospectively evaluate the clinical behavior of cemented crowns on teeth prepared with a vertical finishing line preparation, after 5 years of clinical service, on both materials. The tested null hypothesis tested was that no differences would be found between the clinical behavior of cemented restorations on teeth prepared with a vertical finishing line and that reported in the scientific literature for horizontal finishing line restorations. Also, no differences would be found in the periodontal conditions between the abutment teeth and unrestored contralateral teeth after 5 years of clinical service, regardless of the material used.

Material and methods

Study design

The study was a retrospective cohort study with up to 87 months of follow up medical data of patients who had been treated in a private clinic (Private Practice, Altea, Spain) between January 2011 and December 2013, using the management software Carmen Dental (UX, Freshmind SL, Spain). Patients who met the inclusion criteria were invited by telephone for a follow-up visit. The inclusion criteria were patients treated with a PFM or Zr unitary full-coverage crown on molar or premolar teeth prepared with a vertical finishing line, older than 18 years, non-smokers or smoker <10 cigarettes per day, with gingival health (defined as full-mouth plaque score and full-mouth bleeding score < 20 % with periodontal probing depths ≤ 4 mm), a unrestored contralateral natural tooth, and a stable occlusion with a natural dentition in the opposing arch. Patient exclusion criteria were any medical history contraindicating any dental intervention; any local or systemic disease, condition, or medication that could compromise healing and affect the periodontal tissues; high caries activity; bruxism; and failure of the patient to comply with a proper recall system every 6 months.

Initially, 81 patients were selected and called in alphabetical order, between July 2017 and August 2018. They were included in the study if they met the selection criteria until obtaining 50 crowns (25 PFM and 25 Zr). Finally, 34 patients were included in the study and all of them signed the informed consent form. The research protocol was approved by the Ethics Committee for Clinical Research of the Hospital Sant Joan d'Alacant (Alicante, Spain) (approval number: 17/318 Tut). This study was conducted in accordance with the Helsinki Declaration of 1964 and its subsequent amendments. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines for cohort studies were followed in the preparation of this manuscript.

Prosthodontic procedures

All the patients were treated by a single experienced prosthodontist (MG) following a standardized protocol. Prior to tooth preparation, periodontal probing was performed to assess the attachment level of the periodontal tissues using a periodontal probe (PCPUNC15; Hu-Friedy, Chicago, IL, USA). Treatment procedures were performed under local anaesthesia with 2 % lidocaine hydrochloride-epinephrine 1:80.000 (Xilonibsa; Inibsa, Lliçà de Vall, Spain) using 2.5x magnification loupes (EyeMag Smart; Carl Zeiss, Jena, Germany). All teeth were prepared vertically without finishing line, with an occlusal reduction of 2 mm and an axial reduction of 1.5 mm to maximize the preservation of tooth structure. Long, flame-shape diamond burs (862.534.012, 862.514.012; Sweden & Martina, Padova, Italy) were used to create a vertical axial plane between the anatomical crown and the root area, thus erasing the anatomical cementoenamel junction (CEJ). Finally, a 20 μm grit (862.504.012, 868.504.023 Sweden & Martina) was used for the polishing. After tooth preparation, a provisional restoration was fabricated using polymethylmethacrylate (PMMA) acrylic resin. The technician had previously prepared a hollowed acrylic crown with a contour that followed the gingival margin, and the restoration was relined with autopolymerizing PMMA acrylic resin (Sintodent Resin, C&B, Rome, Italy). When the acrylic had set, the margins were trimmed with an emergence profile of approximately 45° and placed 0.5 mm below the gingival sulcus. After occlusal adjustment and polishing, they were cemented with a non-eugenol temporary agent (Temp-Bond; Kerr, Salerno-Italy).

The provisional restoration was removed 2 weeks after tooth preparation. Final impressions were taken with a vinyl polysiloxane (VPS) material using a two-step impression technique (Elite HD+ Putty soft-fast set as tray and Elite HD+ Light body-fast set as wash material; Zhermack, Badia Polesine, RO, Italy) in a standard metal tray (Rimlock, ASA Dental, Manssarosa, LU, Italy). Retraction cords (Ultrapak #000 and Ultrapak #00, Ultradent, South Jordan, UT, USA) were placed in the gingival sulcus and the upper retraction cord was removed before taking the impression. The antagonist arch impression was taken with irreversible hydrocolloid impression material (Kromopan, Lascod, Florence, Italy). After removal, the impressions were disinfected (Zeta 7 Spray, Zhermack, Badia Polesine, RO, Italy) and cast with type IV plaster (Fuji Rock, GC Corp, Tokyo, Japan) after 1 hour. Face-bow transfers were made and the resulting casts were mounted in maximum intercuspation in a semi-adjustable, Arcon type, articulator (Quick Master B2M, Fag Dentaire, Cluses, France).

All restorations were designed and fabricated in the same dental laboratory (Albident S.A, Alicante, Spain). The dental technician individualized the dies on the master model and marked the contour of the marginal gingiva. After trimming to expose the subgingival area of the preparations, another line was marked at the bottom of the gingival sulcus. The margin of the restorations was placed between these two lines, 0.5-1mm subgingival, according to the aesthetic requirements of the restoration. The crowns were fabricated in two materials: PFM or Zr. The operator considered the functional, aesthetic, and economic requirements of each patient when selecting the material. The PFM's metal frameworks were fabricated in chromium-cobalt (Ugirex C; Ugin Dentaire, France) using the lost wax technique. They were then veneered (VitaVM®13, Bad Sächinger, Germany) using the layering technique. The Zirconium Zenostar® system (Wieland, Germany) was used for the Zr restorations. Models were digitalized using an extraoral

scanner (3shape D250, 3shape, Copenhagen, Denmark) and the frameworks were designed using the CAD software program Dental System (2010, 3Shape, Copenhagen, Denmark). The copings were milled on a 5-axis milling machine (Wieland Zenotec®Mini). After sintering, the zirconia core was veneered with a feldspathic ceramic (VitaVM®9, Bad Sächinger, Germany) using the layering technique. For both materials, the gingival margins were adjusted until an emergence profile of approximately 45º angle was achieved, reproducing the angle generated at the level of the cementoenamel junction in the natural tooth. All crowns have a uniform design, featuring a coping that is fully covered with veneering ceramic, without any metal or polished zirconia margins (Figs. 1 and 2.)

Marginal fit, contact points and occlusion were checked prior to cementation to ensure the success of the restoration. If thickness or depth of the margin of the final restorations caused slight ischemia of the gingival tissue during the final check, the restoration was left in the mouth for 5 to 10 minutes until the ischemia disappeared before definitive cementation. All restorations were cemented with glass ionomer cement (Ketac Cem Easymix, 3M Espe, Germany).

Clinical evaluation

The study's selected crowns were evaluated by two external operators (EHC and GLP) who had been calibrated to assess the clinical parameters. Both examiners received a theoretical class on the aspects to be evaluated and conducted clinical trials to familiarize themselves with the parameters to be measured. To evaluate the calibration results, the examiners separately assessed the clinical parameters in 15 new patients who were not related to the present study. They continued to assess until they reached a Kappa agreement index of 0.83 ($p = 0.001$), which was interpreted with the Landis and Koch [18] concordance table.

The parameters restorations studied were recorded including surface and color, anatomical shape and marginal integrity, according to of the California Dental Association Quality Criteria (CDA) [19]. The evaluation of each section was conducted on a scale of 1 to 4. A score of 1 indicates satisfactory-excellent, 2 indicates satisfactory-acceptable, 3 indicates not acceptable-repair and 4 indicates not acceptable-replace. The periodontal parameters evaluated were plaque index (PI) of Silness and Löe, gingival index (GI) of Löe and Silness [20,21], probing depth (PD) [22], and the margin index (MI) of Silness [23] for all teeth present in the mouth. These parameters were scored from 0 to 3 (PI, GI and MI) and from 1 to 3 (PD). Values were collected from four positions per tooth: buccal, lingual, mesial and distal. PI was recorded by visual inspection using a conventional exploratory probe (EXD57, Hu-Friedy, Chicago, IL, USA) and the other indices were recorded using a millimeter calibrated periodontal probe (CP-15, Hu-Friedy, Chicago, IL, USA). Periodontal assessment was also performed on the contralateral tooth that was not restorated. In addition, complications such as chipping of the veneering ceramic, loss of retention (dislodgement), root fracture, and abutment tooth fracture were used for the analysis. The

Fig. 1. Zirconia based crown. Patient number 36.

Fig. 2. Porcelain fused to metal crown. Patient number 19.

type of chipping was classified as "minor" (ceramic fracture was <2 mm^2) or "major" chipping according to previous studies [24]. All the data were collected dedicated file. Gender, age, tooth position, restoration material, and cementation date were also recorded.

Statistical analysis

The sample size used was calculated for 80 % power, using software G Power 3 version 3.1.9 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The sample size was calculated using a standard formula for prevalence studies [25] as follows:

$$n = \frac{Z^2 P(1-P)}{d^2}$$

where n is sample size, Z is the value of standard normal deviation corresponding to the level of confidence (for a 95 % confidence level, the value of Z is 1.96), P is the expected prevalence, and d is the absolute precision. Assuming 30 % as a clinically relevant difference and given at least one crown for each subject enrolled, the calculated sample size was 25 restorations per group to achieve a confidence level of 95 % and an absolute precision of 5 %.

The data obtained were archived in a Microsoft Office Excel 2000 spreadsheet, which contained the measurements of the abutment teeth, the contralateral teeth, and the evaluated restorations. Statistical analysis was performed using the PASW Statistics 22 program (IBM SPSS Statistics).

Descriptive statistics were used to analyze the data. Fisher's exact test was used to assess any possible associations with the presence of crown complications. Survival was defined as the crown remaining in place during the follow-up examination visit without any absolute failures. Absolute failure was defined as a fracture of the restorarion that was clinically unacceptable or a biological event (such as caries, tooth fracture, or periodontal issues) that required the replacement of the entire restoration or extraction of the tooth. The survival time of a restoration was defined as the period between the day of cementation and either the final follow-up appointment or, in the case of a failure, the appointment scheduled to address the failure, as documented in the patient's file. Success was defined as a crown that remained unchanged and that did not require any intervention to maintain function throughout the entire observational period. The success of the prosthesis was calculated using Kaplan-Meier modeling and non-parametric tests were used after checking for normality. To study the influence of the material on the periodontal parameters, the Mann-Whitney test was applied. The impact of the restorations on the periodontal health was studied using Pearson's Chi-square test was used, which was compared with the contralateral unrestored teeth. The level of significance was set at $\alpha = 0.05$.

Results

The study involved 34 participants, comprising 26 women and 8 men, with ages ranging from 35 to 75 years and a mean age of 56.32 ± 11.8 years. The study analyzed 50 posterior unitary crowns contributed by the patients, consisting of 25 PFM and 25 Zr crowns. Table 1 shows the distribution of crown arches over an observation period of 50-87 months, with a mean of 64.26 ± 10.92 months.

None of the restorations presented biological complications such as caries, need for endodontic treatment or fracture of the abutment tooth. The periodontal parameters, including PI, GI, PD, and MI, were recorded for the 50 abutment teeth as shown in Fig. 3. A majority of the teeth (82 %) were found to be free of dental plaque. Among the abutments, 52 % presented normal gingiva, 28 % showed slight inflammation without bleeding, and 20 % had moderate inflammation with bleeding on probing. No severely inflamed teeth (with spontaneous bleeding) were recorded. 80 % of the abutment teeth presented a PB of 3 mm or less. During the observation period, the margins remained stable subgingival in 52 % of cases, were juxtagingival in 26 % of cases, and experienced gingival recession of less than 2 mm in 22 % of cases.

To study the influence of the material on the periodontal parameters, the Mann-Whitney test was applied. Fig. 4 shows the results. The Zr restorations showed significantly lower values for the PI, PG and PD, indicating less bacterial plaque, less gingival inflammation, and fewer pockets >3 mm compared to the PFM restorations. No statistically significant differences were found in the MI between both materials. The margins of the PFM restorations showed less changes after time of use.

The periodontal parameters were also recorded in the contralateral teeth to examine the impact of restorations on the gingival health. Table 2 presents the results as percentages for both test and control teeth. The Pearson's Chi-square test was used to determine whether there was agreement between the periodontal indices of the abutments and their contralateral teeth. The results indicate that there was no statistically significant association in the PI ($p = 0.164$) and GI ($p = 0.696$) of the abutment teeth and their contralateral. These findings suggest that the accumulation of dental plaque and the presence of inflammation differ between abutment and contralateral teeth. Restored teeth accumulate less biofilm than unrestored teeth, but they have more inflammation and bleeding than control teeth. In addition, a statistically significant association was found in PD ($p = 0.004$), indicating that both types of teeth behaved similarly over time.

The CDA Quality Criteria were used to evaluate the crowns. Surface, color and anatomical shape were judged as satisfactory to excellent in all restorations except for one of them. A case of chipping on the palatal cusp of a PFM crown in position 1.4 was recorded, representing 4 % of the PFM group. This fracture did not affect the marginal integrity, and it was not necessary to replace the crown; only polishing was carried out. The study found that the marginal integrity criterion was satisfactory to excellent in all of the restorations, with no misfit or color changes detected in the margins of the restorations. The Kaplan-Meier estimated cumulative success rates for PFM and Zr crowns were 85.7 % and 100 %, respectively, at 66 months (as shown in Fig. 5). The Log-Rank test did not reveal any significant differences between the two materials ($p = 0.173$).

Table 1
Location and type of teeth of single crowns according to material.

		First Premolar	Second Premolar	First Molar	Second Molar	Total
Maxila	Zr	4	3	6	3	16
	PFM	3	2	1	4	10
Mandibula	Zr	0	3	3	3	9
	PFM	3	3	5	4	14
Total	Zr	4	6	9	6	25
	PFM	6	5	6	8	25

Discussion

The aim of this retrospective study was to evaluate the clinical conditions of single-unit posterior restorations on teeth that were prepared without finishing line, after 5.6 years of clinical service. The quality of the restorations were evaluated using the CDA quality criteria. Periodontal variables such as PI, GI, PD, and MI were studied in the abutment teeth. In addition, the periodontal situation was compared to that of the contralateral teeth, which did not have restorations. Ensuring an optimal relationship between restoration and periodontium is essential to guarantee the long-term functionality and esthetics of the fixed prosthesis [26]. The biological, mechanical, and aesthetic problems associated with the misfit of crowns on the horizontal finishing lines were attempted to be solved with the use of vertical preparations, which are believed to provide a superior marginal fit [27,28]. Traditionally, vertical preparations were indicated for teeth affected by periodontal disease. However, the use of vertical preparation in healthy teeth has become more common in recent years due to the emergence of the BOPT technique [4]. Subsequently, both retrospective [11,16,29,30] and prospective studies [12,14,31–34] on the clinical behavior of vertical preparation have been published. Although prospective studies provide more scientific evidence and are better controlled, we chose a retrospective design to study the changes that occur over time in a population of patients treated with crowns seated on a vertical preparation of various materials. This study demonstrates the clinical reality of these crowns after five years of use, and the data can be easily extrapolated to daily clinical practice. Furthermore, it is necessary to evaluate modification in the technique studied, which differs in the timing of the use of the provisional from the original BOPT technique.

In our study, 18 % of the restorations had bacterial plaque, with 6 % with having index 1 and 12 % having index 2. These results are similar to those of Paniz et al. [14,33] who recorded 17.4 % of plaque in teeth with vertical preparations and are lower than other authors who registered PI between 20 and 38 % [16,31,34,35]. High percentages of plaque are typically recorded in horizontal preparations, as seen in studies by Agustín-Panadero et al. [34] and Peláez et al. [35]. The study participants in our study received instructions on oral hygiene techniques on the day of crown placement and during their annual check-ups. This may have contributed to the low plaque accumulation observed. Ceramic is one of the most biocompatible restorative material that retains minimal plaque, especially when compared to natural teeth. Our study found that the restored abutment teeth accumulated significantly less plaque (18 %) than their control teeth (40 %). These results are similar to those obtained by Schmitt et al. [36], but differ from those of Carnevale et al. [10], who found no significant differences. No differences were found in the plaque index recorded between the two groups, despite there being more restorations without plaque in the Zr group (92 %) compared to the PFM group (72 %).

The gingival index (GI) is a crucial parameter for assessing gingival health. The study's findings indicate that 28 % of the abutment teeth exhibit mild inflammation (without bleeding), while 20 % exhibit moderate inflammation with bleeding on probing. These results are consistent with those of Serra-Pastor et al. [31] and Scutellà et al. [16], who reported 18 % of abutment teeth with a GI index of 2. Our results found that the inflammation and bleeding on probing were statistically higher in restored teeth compared to contralateral teeth, as indicated a higher GI. This is also consistent with previous studies by of Schmitt et al. [36] and Carnevalle et al. [10], which reported statistically higher GI in restored teeth. However, the literature suggests that inflammation is always higher in teeth with horizontal preparations [5,35]. Regarding the influence of the material, in our study, Zr crowns showed significantly less inflammation than the PFM group. However, Peláez et al. [35] did not find any significant differences in this regard.

After 5.6 years of use, 80 % of the abutment teeth in the present study had a probing depth (PB) of ≤ 3mm, while the remaining teeth had a PB between 3 and 5 mm. These results are consisted with those reported by

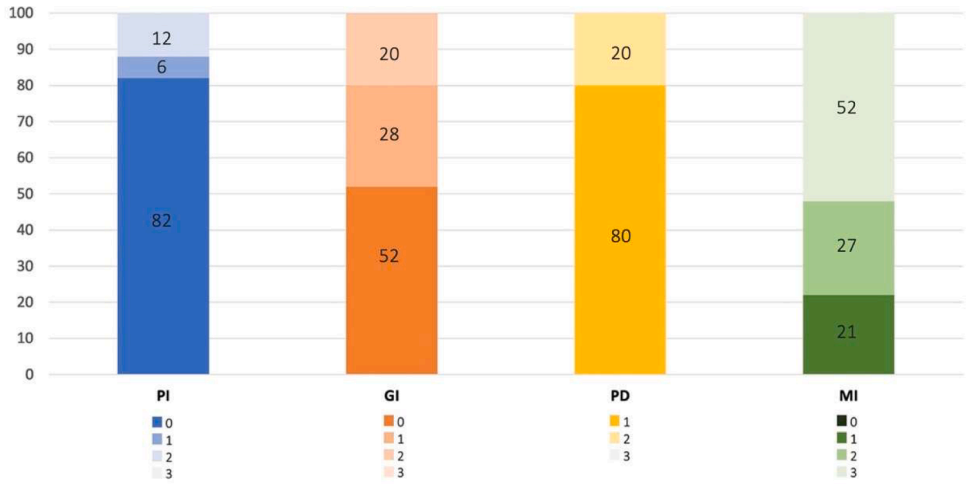


Fig. 3. Periodontal parameters (PG, GI, PD and MI) in the abutment teeth, expressed as a percentage. (N=50).

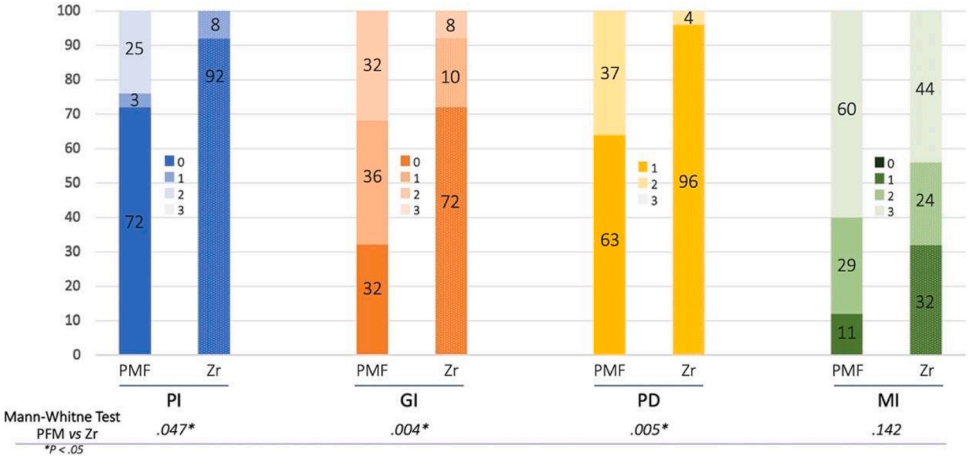


Fig. 4. Periodontal parameters (PG, GI, PD and MI) in the abutment teeth divided by restorative materials expressed as a percentage: PFM (N=25) and Zr (N=25), and results of U Mann-Whitney Test.

Table 2
Results of all Periodontal parameters (%) of the test and control teeth and The Pearson's Chi-square test.

Value		0	1	2	3	Significant Association
PI	**Control**	60	28	12	0	No
	Test	82	6	12	0	*p=0,164*
GI	**Control**	58	26	16	0	No
	Test	52	28	20	0	*p=0,696*
PD	**Control**	-	68	32	0	Yes
	Test	-	80	20	0	*p=0,004*

Agustín-Panadero et al. [34] and Serra-Pastor et al. [31], who found that 90 % and 97.1 % of teeth with vertical preparation crowns had a PD of less than 3 mm after 5 years of service. Previous studies [12,14,16,33] have found the PB to be located in the 94 %-100 % of the abutments studied at depths below 3mm. This is likely due to the shorter observation time, as the probing depth is known to increase over time [37]. The restoration material has a statistically significant impact on PD. PFM crowns have a higher percentage of pockets ranging from 3 to 5 mm (37 %) compared to Zr restorations (4 %). Zirconia-based restorations made with CAD/CAM technology have been shown to provide better results than crowns made by the conventional lost-wax method, such as our PFM crowns [38]. These benefits include improved marginal fit, reduced of inflammation, and better maintenance and restoration of periodontal health and oral hygiene. In addition, the presence of metal induces changes in the composition of the subgingival microbiota, producing a more dysbiotic biofilm with a higher prevalence of periodontopathogenic bacteria. This may explain why abutment teeth with porcelain-fused-to-metal crowns have greater periodontal problems and therefore higher PD. [39] There have been no studies comparing these two materials in restorations with vertical preparation. These results are consisten with those reported by Schmitt et al. [36]

The abutment teeth observed in this study presented gingival recession of less than 2 mm in 21 % of the cases, while the rest maintained the margins of the restoration either juxtally or subgingivally. These results are inferior to than those described in the literature, where only 0-5.1 % of the cases presented recession in the first two years of service [12,14,16,33]. However, the results are much better than those offered by classic restorations with horizontal finish line [35,40]. Some studies report a recession of up to 90 % of cases [34].

When comparing the materials used, we have observed a significantly greater gingival recesion in the margins of Zr crowns compared to PFM. This was due to fact that the margins were exposed in 32 % of the Zr and 11 % of the PFM. No studies have been found that compare these materials in vertical preparation, but there are studies with horizontal finish lines that reach the same conclusion [35]. The negative effect of ceramic veneering of zirconia frameworks has been well studied. Numerous studies have reported significant increases in marginal misfit of the frameworks after ceramic veneering, resultin in greater

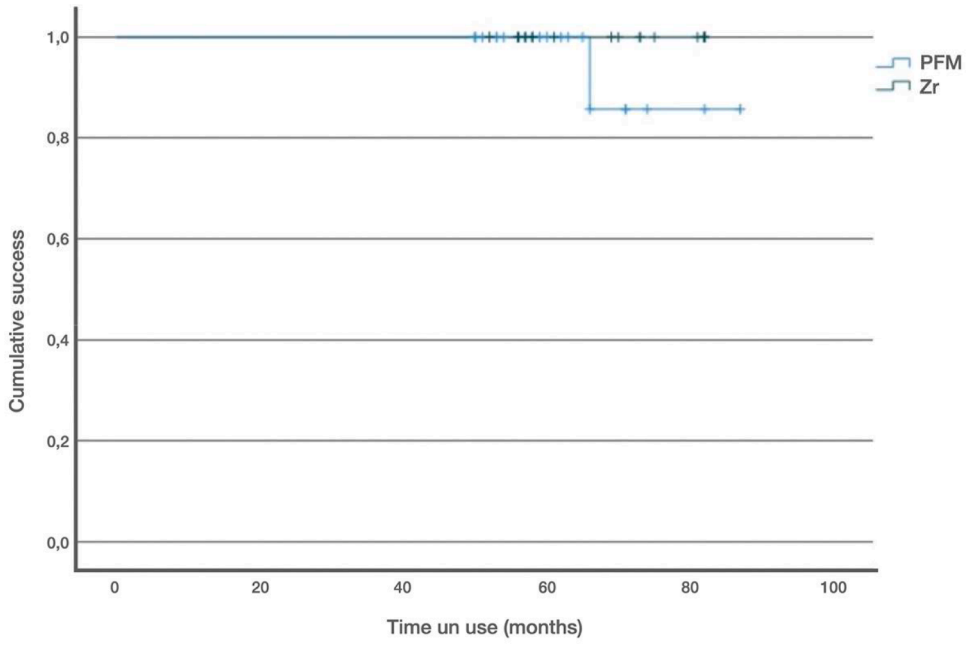


Fig. 5. The Kaplan-Meier cumulative success rates for PFM and Zr crowns at 66 months

periodontal problems and increased microleakage [41,42]. A comparison between veneered restorations and monolithic restorations reveals that monolithic restorations have superior fit and fewer mechanical problems, leading to better long-term stability and a higher survival rates [43].

The most common mechanical complication in the fixed dental protheses (FDPs), with or without finish lines, is chipping. This study revealed that chipping affected 4 % of the PFM crowns (which correspond to a single crown) and 0 % of the Zr restorations. In contrast, similar studies with a clinical observation period of 5 years, reported chipping values in vertical zirconia FDPs ranging from 8.8 % to 16 % [16,29,34,37]. The chipping was reported on the palatal cusp of a premolar, but did not compromise the survival of the restoration. However, some authors refered chipping at the level of the gingival margin of the crowns [44,45], which is due to the minimal thickness of the restorations at that level in teeth with vertical preparation.

After reviewing the results and comparing them with the literature, it can be concluded that that the null hypothesis is rejected. Clear differences in the clinical behavior of restorations with and without a finish line were observed. Vertical restorations without a finish line offeried better results at the periodontal level. Additionally, significant differences were established in the plaque index and the gingival index when comparing retored teeth with contralateral teeth. An important limitation of this study is the absence of a control group with a finish line preparation to compare the results. The clinical behavior of the restoration was also not differentiated considering its position in the arch. In addition, the sample size and the follow-up period should be increased to obtain more conclusive findings.

Conclusions

Given the limitations of this retrospective study, it can be concluded that the cemented restorations on preparations without finish line present good clinical behavior after 5 years. The restorations show a low presence of plaque, probing depth of $\leq$3 mm in 80 % of the cases, great marginal stability, and bleeding on probing in 20 % of cases.

Both crown survival and the occurrence of biological and aesthetic complications were not affected by the material used. However, differences in periodontal parameters were found. The zirconia vertical restorations show significantly better periodontal parameters (PI, GI, PD) than porcelain-fused-to-metal, except for gingival recession.

Therefore, the use of restorations on vertically prepared teeth is a reliable option. However, more long-term studies are needed.

Funding

This project was no supported by industry. All funds came from dental private clinic “G&H Odontólogos” (Altea, Alicante, Spain) and University Complutense of Madrid.

Ethical approval

All procedures performed in the present study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The present study has the approval of the Clinical Research Ethics Committee of the Sant Joan d’Alacant Hospital (Alicante, Spain) (Approval Number: 17/318 Tut)

Informed consent

Informed consent was obtained from all individual participants included in the present study. They were informed verbally and in writing of the advantages and disadvantages of participating in the study.

CRediT authorship contribution statement

M Gonzalez-Bonilla: Writing – original draft, Investigation, Conceptualization. **S Berrendero:** Writing – review & editing. **B Moron-Conejo:** Writing – review & editing, Validation, Formal analysis. **F Martinez-Rus:** Writing – review & editing, Supervision, Formal analysis, Data curation. **MP Salido:** Supervision, Project administration, Investigation, Formal analysis.

Declaration of competing interest

Mario Gonzalez-Bonilla declares that he has no conflict of interest. Santiago Berrendero declares that he has no conflict of interest. Belen

Moron-Conejo declares that she has no conflict of interest. Francisco Martinez-Rus declares that he has no conflict of interest. Maria Paz Salido declares that she has no conflict of interest.

References

[1] J. Tanner, H. Niemi, E. Ojala, M. Tolvanen, T. Närhi, J. Hjerppe, Zirconia single crowns and multiple-unit FDPs-An up to 8 -year retrospective clinical study, J. Dent. 79 (2018) 96–101, https://doi.org/10.1016/j.jdent.2018.10.012.

[2] D.A. Orkin, J. Reddy, D. Bradshaw, The relationship of the position of crown margins to gingival health, J. Prosthet. Dent. 57 (1987) 421–424, https://doi.org/10.1016/0022-3913(87)90006-0.

[3] E.A. Tsitrou, S.E. Northeast, R. van Noort, Evaluation of the marginal fit of three margin designs of resin composite crowns using CAD/CAM, J. Dent. 35 (2007) 68–73, https://doi.org/10.1016/j.jdent.2006.04.008.

[4] I. Loi, A. Di Felice, Biologically oriented preparation technique (BOPT): a new approach for prosthetic restoration of periodontically healthy teeth, Eur. J. Esthet. Dent. 8 (2013) 10–23.

[5] I. Sailer, N.A. Makarov, D.S. Thoma, M. Zwahlen, B.E. Pjetursson, All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: single crowns (SCs), Dent. Mater. 31 (2015) 603–623, https://doi.org/10.1016/j.dental.2015.02.011.

[6] E.O. Schweikert, Feather-edged or knife-edged preparation and impression technique, J. Prosthet. Dent. 52 (1984) 243–246, https://doi.org/10.1016/0022-3913(84)90104-5.

[7] S. Patroni, G. Chiodera, C. Caliceti, P. Ferrari, CAD/CAM technology and zirconium oxide with feather-edge marginal preparation, Eur. J. Esthet. Dent. 5 (2010) 78–100.

[8] D. Edelhoff, J.A. Sorensen, Tooth structure removal associated with various preparation designs for anterior teeth, J. Prosthet. Dent. 87 (2002) 503–509, https://doi.org/10.1067/mpr.2002.124094.

[9] I. Sailer, A. Fehér, F. Filser, L.J. Gauckler, H. Lüthy, C.H.F. Hämmerle, Five-year clinical results of zirconia frameworks for posterior fixed partial dentures, Int. J. Prosthodont. 20 (2007) 383–388.

[10] G. Carnevale, G. di Febo, M. Fuzzi, A retrospective analysis of the perio-prosthetic aspect of teeth re-prepared during periodontal surgery, J. Clin. Periodontol. 17 (1990) 313–316, https://doi.org/10.1111/j.1600-051x.1990.tb01095.x.

[11] G. Di Febo, A. Bedendo, F. Romano, F. Cairo, G. Carnevale, Fixed prosthodontic treatment outcomes in the long-term management of patients with periodontal disease: a 20-year follow-up report, Int. J. Prosthodont. 28 (2015) 246–251, https://doi.org/10.11607/ijp.3995.

[12] R. Agustín-Panadero, B. Serra-Pastor, A. Fons-Font, M. Solá-Ruíz, Prospective clinical study of zirconia full-coverage restorations on teeth prepared with biologically oriented preparation technique on gingival health: results after two-year follow-up, Oper. Dent. 43 (2018) 482–487, https://doi.org/10.2341/17-124-C.

[13] R. Agustín-Panadero, M.F. Solá-Ruíz, C. Chust, A. Ferreiroa, Fixed dental prostheses with vertical tooth preparations without finish lines: a report of two patients, J. Prosthetic Dent. 115 (2016) 520–526, https://doi.org/10.1016/j.prosdent.2015.11.011.

[14] G. Paniz, J. Nart, L. Gobbato, A. Chierico, D. Lops, K. Michalakis, Periodontal response to two different subgingival restorative margin designs: a 12-month randomized clinical trial, Clin. Oral Invest. 20 (2016) 1243–1252, https://doi.org/10.1007/s00784-015-1616-z.

[15] F.W. Kamansky, T.R. Tempel, A.C. Post, Gingival tissue response to rotary curettage, J. Prosthetic Dent. 52 (1984) 380–383, https://doi.org/10.1016/0022-3913(84)90449-9.

[16] F. Scutellà, T. Weinstein, G. Zucchelli, T. Testori, M.D. Fabbro, A retrospective periodontal assessment of 137 teeth after featheredge preparation and Gingittage, Restorative Dent. 37 (2017).

[17] J.R. Kelly, P. Benetti, Ceramic materials in dentistry: historical evolution and current practice, Aust. Dent. J. 56 (Suppl 1) (2011) 84–96, https://doi.org/10.1111/j.1834-7819.2010.01299.x.

[18] J.R. Landis, G.G. Koch, The measurement of observer agreement for categorical data, Biometrics 33 (1977) 159–174.

[19] California Dental Asociation, Quality evaluation for dental care: guidelines for the assessment of clinical quality and professional performance, 1995.

[20] H. Loe, J. Silness, Periodontal disease in pregnancy. I. Prevalence and severity, Acta Odontol. Scand. 21 (1963) 533–551, https://doi.org/10.3109/00016356309011240.

[21] J. Silness, H. Loe, Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condtion, Acta Odontol. Scand. 22 (1964) 121–135, https://doi.org/10.3109/00016356408993968.

[22] L. Glavind, H. Löe, Errors in the clinical assessment of periodontal destruction, J. Periodontal. Res. 2 (1967) 180–184, https://doi.org/10.1111/j.1600-0765.1967.tb01887.x.

[23] J. Silness, Periodontal conditions in patients treated with dental bridges. 2. The influence of full and partial crowns on plaque accumulation, development of gingivitis and pocket formation, J. Periodontal. Res. 5 (1970) 219–224, https://doi.org/10.1111/j.1600-0765.1970.tb00720.x.

[24] S.D. Heintze, V. Rousson, Survival of zirconia- and metal-supported fixed dental prostheses: a systematic review, Int. J. Prosthodont. 23 (2010) 493–502.

[25] L. Naing, R.B. Nordin, H. Abdul Rahman, Y.T. Naing, Sample size calculation for prevalence studies using Scalex and ScalaR calculators, BMC. Med. Res. Methodol. 22 (2022) 209, https://doi.org/10.1186/s12874-022-01694-7.

[26] M. Schätzle, N.P. Land, A. Anerud, H. Boysen, W. Bürgin, H. Löe, The influence of margins of restorations of the periodontal tissues over 26 years, J. Clin. Periodontol. 28 (2001) 57–64, https://doi.org/10.1034/j.1600-051x.2001.280109.x.

[27] N. Alharbi, S. Alharbi, V.M.J.I. Cuijpers, R.B. Osman, D. Wismeijer, Three-dimensional evaluation of marginal and internal fit of 3D-printed interim restorations fabricated on different finish line designs, J. Prosthodont. Res. 62 (2018) 218–226, https://doi.org/10.1016/j.jpor.2017.09.002.

[28] C. Abad-Coronel, J. Villacís Manosalvas, C. Palacio Sarmiento, J. Esquivel, I. Loi, G. Pradíes, Clinical outcomes of the biologically oriented preparation technique (BOPT) in fixed dental prostheses: a systematic review, J. Prosthetic Dent. (2022), https://doi.org/10.1016/j.prosdent.2022.07.010. S0022391322004887.

[29] C. Monaco, M. Caldari, R. Scotti, AIOP Clinical Research Group, Clinical evaluation of 1,132 zirconia-based single crowns: a retrospective cohort study from the AIOP clinical research group, Int. J. Prosthodont. 26 (2013) 435–442, https://doi.org/10.11607/ijp.3099.

[30] C.E. Poggio, R. Dosoli, C. Ercoli, A retrospective analysis of 102 zirconia single crowns with knife-edge margins, J. Prosthetic Dent. 107 (2012) 316–321, https://doi.org/10.1016/S0022-3913(12)60083-3.

[31] B. Serra-Pastor, N. Bustamante-Hernández, A. Fons-Font, M.F. Solá-Ruíz, M. Revilla-León, R. Agustín-Panadero, Periodontal outcomes of anterior fixed partial dentures on teeth treated with the biologically oriented preparation technique: a 6-year prospective clinical trial, J. Prosthet. Dent. (2021), https://doi.org/10.1016/j.prosdent.2021.07.009. S0022-3913(21)00398-X.

[32] B. Serra-Pastor, I. Loi, A. Fons-Font, M.F. Solá-Ruíz, R. Agustín-Panadero, Periodontal and prosthetic outcomes on teeth prepared with biologically oriented preparation technique: a 4-year follow-up prospective clinical study, J. Prosthodont. Res. 63 (2019) 415–420, https://doi.org/10.1016/j.jpor.2019.03.006.

[33] G. Paniz, J. Nart, L. Gobbato, F. Mazzocco, E. Stellini, G. De Simone, E. Bressan, Clinical periodontal response to anterior all-ceramic crowns with either chamfer or feather-edge subgingival tooth preparations: six-month results and patient perception, Int. J. Periodontics Restorative Dent. 37 (2017) 61–68, https://doi.org/10.11607/prd.2765.

[34] R. Agustín-Panadero, B. Serra-Pastor, I. Loi, M.J. Suárez, J. Pelaez, F. Solá-Ruíz, Clinical behavior of posterior fixed partial dentures with a biologically oriented preparation technique: a 5-year randomized controlled clinical trial, J. Prosthetic Dent. 125 (2021) 870–876, https://doi.org/10.1016/j.prosdent.2020.03.031.

[35] J. Pelaez, P.G. Cogolludo, B. Serrano, J.F.L. Serrano, M.J. Suarez, A four-year prospective clinical evaluation of zirconia and metal-ceramic posterior fixed dental prostheses, Int. J. Prosthodont. 25 (2012) 451–458.

[36] J. Schmitt, M. Wichmann, S. Holst, S. Reich, Restoring severely compromised anterior teeth with zirconia crowns and feather-edged margin preparations: a 3-year follow-up of a prospective clinical trial, Int. J. Prosthodont. 23 (2010) 107–109.

[37] M.H. Nicolaisen, G. Bahrami, L. Schropp, F. Isidor, Comparison of metal-ceramic and all-ceramic three-unit posterior fixed dental prostheses: a 3-year randomized clinical trial, Int. J. Prosthodont. 29 (2016) 259–264, https://doi.org/10.11607/ijp.4504.

[38] V. Srimaneepong, A. Heboyan, M.S. Zafar, Z. Khurshid, A. Marya, G.V.O. Fernandes, D. Rokaya, Fixed prosthetic restorations and periodontal health: a narrative review, J. Funct. Biomater. 13 (2022) 15, https://doi.org/10.3390/jfb13010015.

[39] M.A. Alarcón-Sánchez, A. Heboyan, G.V.D.O. Fernandes, N. Castro-Alarcón, N. S. Romero-Castro, Potential impact of prosthetic biomaterials on the periodontium: a comprehensive review, Molecules. 28 (2023) 1075, https://doi.org/10.3390/molecules28031075.

[40] J. Valderhaug, J.E. Ellingsen, A. Jokstad, Oral hygiene, periodontal conditions and carious lesions in patients treated with dental bridges. A 15-year clinical and radiographic follow-up study, J. Clin. Periodontol. 20 (1993) 482–489, https://doi.org/10.1111/j.1600-051x.1993.tb00395.x.

[41] M. Vojdani, A. Safari, M. Mohaghegh, S. Pardis, F. Mahdavi, The effect of porcelain firing and type of finish line on the marginal fit of zirconia copings, J. Dent. (Shiraz) 16 (2015) 113–120.

[42] K. Torabi, M. Vojdani, R. Giti, M. Taghva, S. Pardis, The effect of various veneering techniques on the marginal fit of zirconia copings, J. Adv. Prosthodont. 7 (2015) 233–239, https://doi.org/10.4047/jap.2015.7.3.233.

[43] S. Shihabi, B.R. Chrcanovic, Clinical outcomes of tooth-supported monolithic zirconia vs. porcelain-veneered zirconia fixed dental prosthesis, with an additional focus on the cement type: a systematic review and meta-analysis, Clin. Oral Investig. 27 (2023) 5755–5769, https://doi.org/10.1007/s00784-023-05219-4.

[44] F. Beuer, D. Edelhoff, W. Gernet, M. Naumann, Effect of preparation angles on the precision of zirconia crown copings fabricated by CAD/CAM system, Dent. Mater. J. 27 (2008) 814–820, https://doi.org/10.4012/dmj.27.814.

[45] B. Carlini, D. Cecchin, G.D. da S. Pereira, L.A.M.S. Paulillo, Influence of remaining coronal structure and finish line on the fracture strength of roots restored with metallic posts, Braz. Oral Res. 25 (2011) 345–350, https://doi.org/10.1590/s1806-83242011000400011.