Implant-Supported Extra-Orally Cemented Monolithic Zirconia Crowns: A Prospective Controlled Clinical Study up to 18 Months in Function

Keywords

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ABSTRACT

This study evaluated the clinical performance of implant supported, extra-orally cemented, monolithic zirconia crowns after a follow-up to 18 months. Thirty-one patients with 50 posterior dental implants were consecutively selected for this study. A total of 50 crowns were cemented onto titanium abutments extra-orally and then screwed to the implants with the required torque intra-orally. The patients were followed at 12 months and 18 months after placement of restorations. During the follow-up period, all restorations were evaluated according to following technical parameters: implant failure, crown fracture, screw loosening, loss of retention due to decementation, fracture of antagonist tooth or restoration. Data were analyzed using Kaplan Meier method. One implant and its corresponding crown was lost during the follow-up period, yielding a 18 months survival rate of 98%. During the study, 2 complication events were observed, including one screw loosening and one veneering porcelain chipping in an antagonist bilayered zirconia restoration. The overall success rate of the observed prosthesis was 96%. According to the results of this study, the extra-orally cemented, monolithic zirconia crowns resulted in a favorable short-term outcome for posterior implant supported restorations within this short observation time.

INTRODUCTION

The use of osseointegrated dental implants for rehabilitation of single tooth loss is well documented.[1-4] Among the implant-supported restorations, porcelain fused to metal (PFM) restorations have been regarded as the gold standard.[5]

During the last 2 decades, as an alternative to PFM restorations, zirconia has also been used for implant-supported fixed dental prostheses (FDPs) due to its superior optical and physical properties.[6-9] Unfortunately, cohesive fracture of veneering porcelain have been reported to be the most common complication related to implant supported zirconia-based FDPs.[10-12] In order to overcome this clinical complication, monolithic zirconia design without veneering porcelain has been introduced.[9,13] With regard to low light transmission of zirconia and lack of veneering porcelain, compromised aesthetic outcome was reported, related to monolithic zirconia FDPs.[13]

The manufacturing route of implant-supported monolithic zirconia FDPs is based on computer-assisted design/computer-assisted manufacturing (CAD/CAM) technology utilizing monolithic blocks.[14,15] The retention of implant-supported FDPs can be either achieved using a cement or through screw retention onto the implant abutments. In case of a complication, screw retention is considered superior to cement retention in terms of retrievability.[16,17] Keith *et al.*, reported better marginal adaptation for screw-retained restorations in their *in vitro* study where fracture loads of screw-retained and cement retained zirconia-based implant supported molar restorations were compared.[18] On the other hand, due to relatively complicated fabrication techniques for screw-retained restorations and unfavourable position of screw access holes that may compromise occlusion and aesthetics, cement-retained restorations are recommended.[19]

Beside their easier laboratory procedures and lower fabrication costs, the risk of excess cement accumulation in peri-implant area and difficulty in retrievability are the main disadvantages associated with cement-retained restorations.[17] Wilson reported signs of peri-implantitis in 81% of clinical cases in their clinical study where excess dental cement was present.[20]

A method known as extra-oral cementation was developed to overcome soft tissue responses as a consequence of excess cement.[21] This technique utilizes a stock abutment and a laboratory fabricated crown that is cemented extra-orally on the model, where excess cement can be trimmed off easily. In this technique, possible apical migration of cement due to hydrostatic forces can be eliminated and post-cementation polishing of the abutment-crown interface can be achieved prior to final placement of the crown.

Regarding restoration of edentulism with implant-supported monolithic zirconia crowns (MZCs), studies are limited to case series of full-arch monolithic zirconia restorations.[22,23] To the authors' best knowledge, no clinical follow-up studies have evaluated the clinical results of extra-orally cemented implant supported MZCs yet. This clinical pilot study evaluated the performance of implant-supported MZCs after 18 months of follow-up with a particular focus on technical complications.

MATERIALS AND METHOD

PARTICIPANT SELECTION

The study protocol was approved by Istanbul Medipol University research ethics committee with protocol number: 10840098-604.01.01-E.14175. The patients who had received dental implants in the posterior maxilla or mandible for rehabilitation of single tooth edentulism with implant-supported crowns between December 2017 and April 2019 at the School of Dentistry, Istanbul Medipol University were screened. The inclusion criteria were: willingness to signed consent form, age of 18 years or above, peri-implant tissues free of infection and biologic complications.

PROSTHETIC PROCEDURES

A total of 31 patients (15 males and 16 females) aged between 28 and 67 with 50 posterior dental implants were enrolled in this study. The diameters of the implants were 4.1 mm and 4.5 mm. One experienced clinician performed all prosthodontic procedures (U.A.). The brands, manufacturers and composition of the main materials used in this study are listed in Table 1.

After confirmation of successful osseointegration, implant level impressions of bone level implants were made with polyether (Impregum Penta H Duosoft, 3M, St Paul, USA) using closed-tray impression technique. Prefabricated, non-angled titanium stock abutments were selected and abutment margins were reshaped at 1 mm subgingival. All laboratory procedures were conducted at a dental laboratory authorized by the manufacturers` of the materials and CAD/CAM systems. The working casts with implant abutments were scanned in an optical scanner (7Series, Dental Wings, Montréal QC, Canada). Monolithic zirconia crowns with occlusal abutment screw access holes were designed and milled from partially sintered yttria stabilized zirconia blocks (Wieland Zenostar T, Ivoclar Vivadent AG, NY, USA), and sintered according to the manufacturer's recommendations. After removal of the healing abutment, the titanium abutment was screwed onto the implant intraorally and proximal and occlusal contacts of the MZCs were controlled. Adjustments were made where needed. After patient's approval, the crown was removed, titanium abutment was unscrewed, rinsed, dried and attached to the implant analog on the model *(Figure 1A*). The screw hole of the abutment was filled with a piece of cotton. Inner surface of the MZCs were lined with polycarboxylate cement and seated on the abutment *(Figure 1B*). Cement setting was allowed for an adequate time and the excess cement projecting through the occlusal access hole was removed with an explorer. The cotton piece in the access hole was removed and the titanium abutment-MZC assembly was unscrewed. The presence of excess cement at crown-abutment margin area was checked and cleaned with an explorer. The titanium abutment and the cemented MZC *(Figure 1C*). assembly was screwed onto the implant intraorally and torqued under 35 N with a manual torque wrench *(Figure 1D*). The screw-access holes were closed with Polytetrafluoroethylene (PTFE) band, restored with resin composite (Filtec Z250, 3M ESPE, St. Paul, USA) and photo-polymerized (Elipar DeepCure-S LED Curing Light, 3M, St Paul, USA)

CLINICAL EVALUATION

The presence of bruxism, the nature of antagonist tooth and/or restoration and the location of implant were recorded at the delivery appointment of MZCs. The presence of bruxism

Table 1. Brands, types, chemical compositions and manufacturers of the main materials used in this study.

Brand	Type	Composition	Manufacturer
Adhesor™ Carbofine	Zinc Polycarboxylate Cement	Powder: Zinc oxide, Magnesium oxide, Aluminum oxide, Boric acid Liquid: Acrylic acid, Maleic anhydride, Distilled water	Spofa Dental, Praque, CZ
BEGO Semados® RSX	Cylindrical Implant	Titanium Grade 4	Bego, Bremen, Germany
PS TiA	Abutment	Titanium Grade 5 (Titanium alloy Ti-6Al-4V)	Bego, Bremen, Germany
Wieland Zenostar MT	Monolithic zirconia	Zirconium dioxide (ZrO_2 + HfO_2 + Y_2O_3) > 99.0 %, Yttrium oxide (Y_2O_3) > 4.5 – ≤ 6.0 % Hafnium oxide (HfO_2) ≤ 5.0 %, Aluminum oxide (Al_2O_3) + Other oxides ≤ 1.0 %	Ivoclarvivadent, NY, USA
Filtek Z250	Microhybrid methacrylatebased composite	Matrix: Bis-GMA, Bis-EMA, UDMA, TEGDMA Filler: Zirconia, Silica (0.01 - 3.5 µm), 78 wt%, 60 vol%	3M ESPE, St. Paul, MN, USA

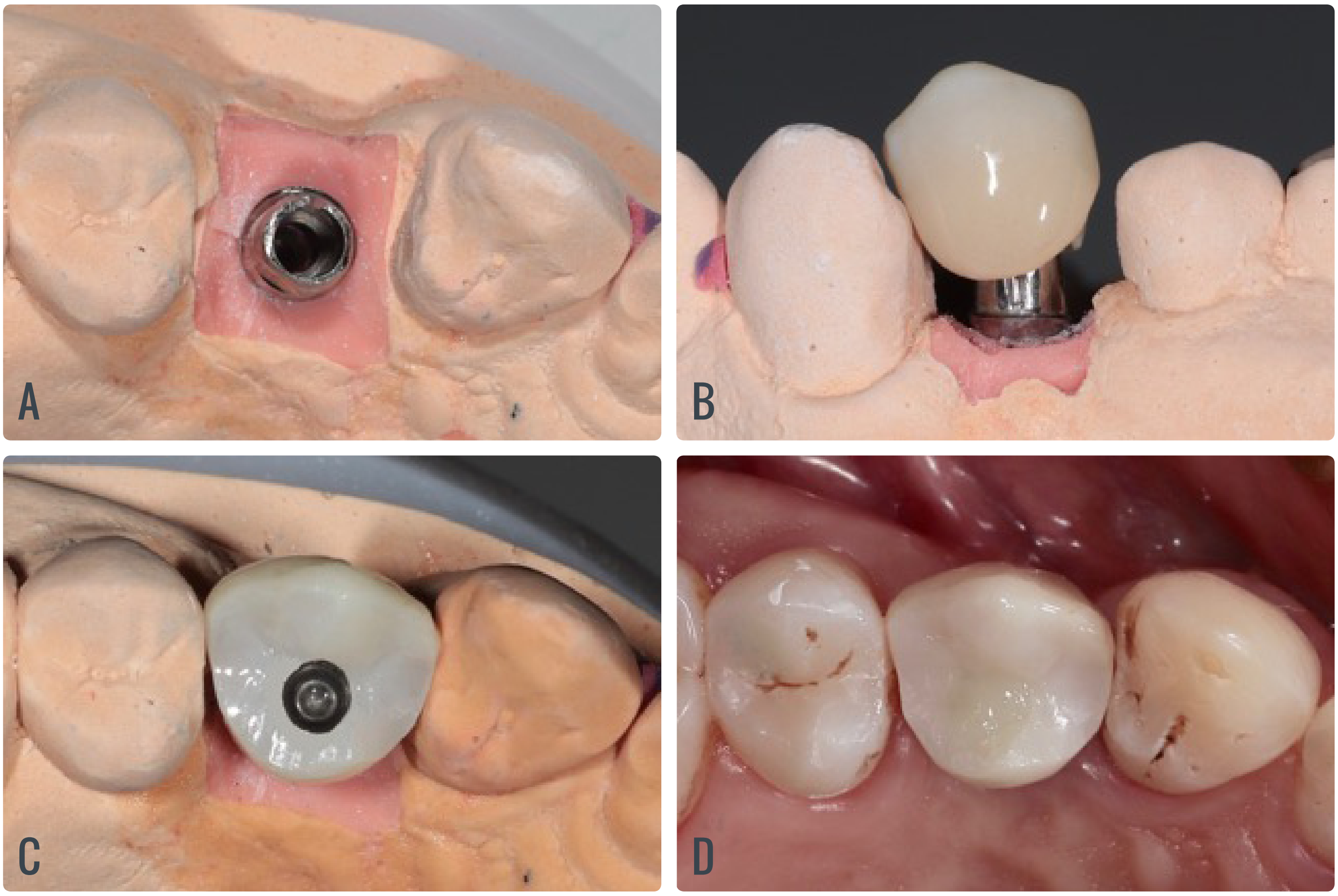

Figure 1A-D: Representative photos of A) abutment on the plaster model, B) extra-orally cemented monolithic zirconia crown, C) crown screwed on the abutment, D) monolithic zirconia crown placed on the maxillary right 1st premolar implant in situ.

was evaluated through clinical examination and self-reporting.[22] The patients were recorded as bruxist according to two criteria: 1) reporting teeth grinding during the night or day and 2) the presence of at least one clinical sign among the following: abnormal attrition wearing facets on teeth, transitory pain or fatigue on wake up, felt in the jaw muscles, temporal headaches on wake up, or jaw locking on waking related to teeth grinding during sleep.[22]

The follow-up visits were performed at 12 and 18 months after placement of the MZCs. During the follow-up period, the following technical parameters were assessed by the same examiner: implant failure, MZC fracture, abutment screw loosening, loss of retention due to crown de-cementation, and opposing tooth or restoration fracture. A failed prosthesis was described as a failure if the prosthesis needed to be remade.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS 21.0 software for Windows (SPSS Inc., Chicago, IL, USA). The restorations were grouped according to the variables of gender, bruxism, implant position and antagonist and the survival rate was calculated using Kaplan-Meier survival analysis. The significance in differences between survival curves was determined with the log-rank test. *P* values less than 0.05 were considered to be statistically significant in all tests.

RESULTS

No drop-out was experienced up to final recall *(Table 2)*. Of the 31 patients, 5 of them presented signs of bruxism where 2 of them had dentitions with severe attrition. Mean observation time was 8.32±4.54. The overall survival rate was 96% *(Figure 2A)*.

One maxillary molar, in one male patient with bruxism and severe attrition, MZC was lost due to loss of osseointegration 11 months after definitive crown insertion, yielding to a cumulative implant and crown survival rate of 98%.

No significant differences were found in failures related to gender (p=0.331), implant position (p=0.177), antagonist tooth complications (p=0.37) and bruxism (p=0.546) (Kaplan-Meier, log-rank test) *(Figures 2B-E)*.

During the study period, veneering porcelain chipping occurred in one mandibular bilayered zirconia opposing to a maxillary molar MZC after 6 months of clinical service. The chipping was limited in size and could be polished.

Screw loosening occurred in one MZC, 7 months after crown insertion. This case, the abutment screw was retightened without any additional complications. De-cementation has not been observed in any of the crowns *(Table 3)*.

Table 2. Distribution of monolithic zirconia crowns and implants in the maxilla and mandible regarding gender, implant position, antagonist tooth or restoration type and bruxism.

Main groups	Subgroups	Number
Gender	Male	15
	Female	16
	Total	31
Implant position	Max molar	8
	Max premolar	26
	Mand molar	8
	Mand premolar	8
Antagonist	Natural tooth	37
	PFM crown	8
	Bilayered zirconia crown	5
Bruxism	With	5
	Without	26
	Total	31

DISCUSSION

Based on the results of this follow-up study reporting on survival and complication rates of implant-supported, extra-orally cemented MZCs, it can be stated that survival at the short-term follow up of 18 months was comparatively high.

The survival of the restorations was evaluated according to the parameters of bruxism, gender, implant position and antagonist restoration or tooth with an overall prosthesis survival rate of 98%. However, one implant and its corresponding crown was lost 1 month after occlusal loading in a bruxing patient. Its antagonist was a PFM crown without any signs of damage. This failure may be attributed to higher occlusal loading due to the presence of bruxism which could not be directly related to the crown material itself. In the present study 10 out of 11 MZCs in five bruxing patients had survived which may be considered as a high survival rate in accordance with a previous study.[24] In their prospective study, Koenig *et al.*, reported the two year results of posterior tooth and implant supported monolithic zirconia restorations in patients with clinical signs of bruxism cemented on titanium bases.[24] The failure of those monolithic screw retained restorations was attributed to high occlusal stress and high stiffness of zirconia which did not allow for occlusal stress absorption, as this stress could be transferred to the implant, the tooth, or its antagonist.[25,26]

Regarding the implant position, the difference between the survival of the maxillary and mandibular restorations was not statistically significant. This finding does not corroborate with the study of Mangano *et al.*, where tooth-supported maxillary MZCs had a significantly lower survival rate than the MZCs.[27] In this study, the majority of the crowns were positioned in the mandible and the number of complications in mandible was greater

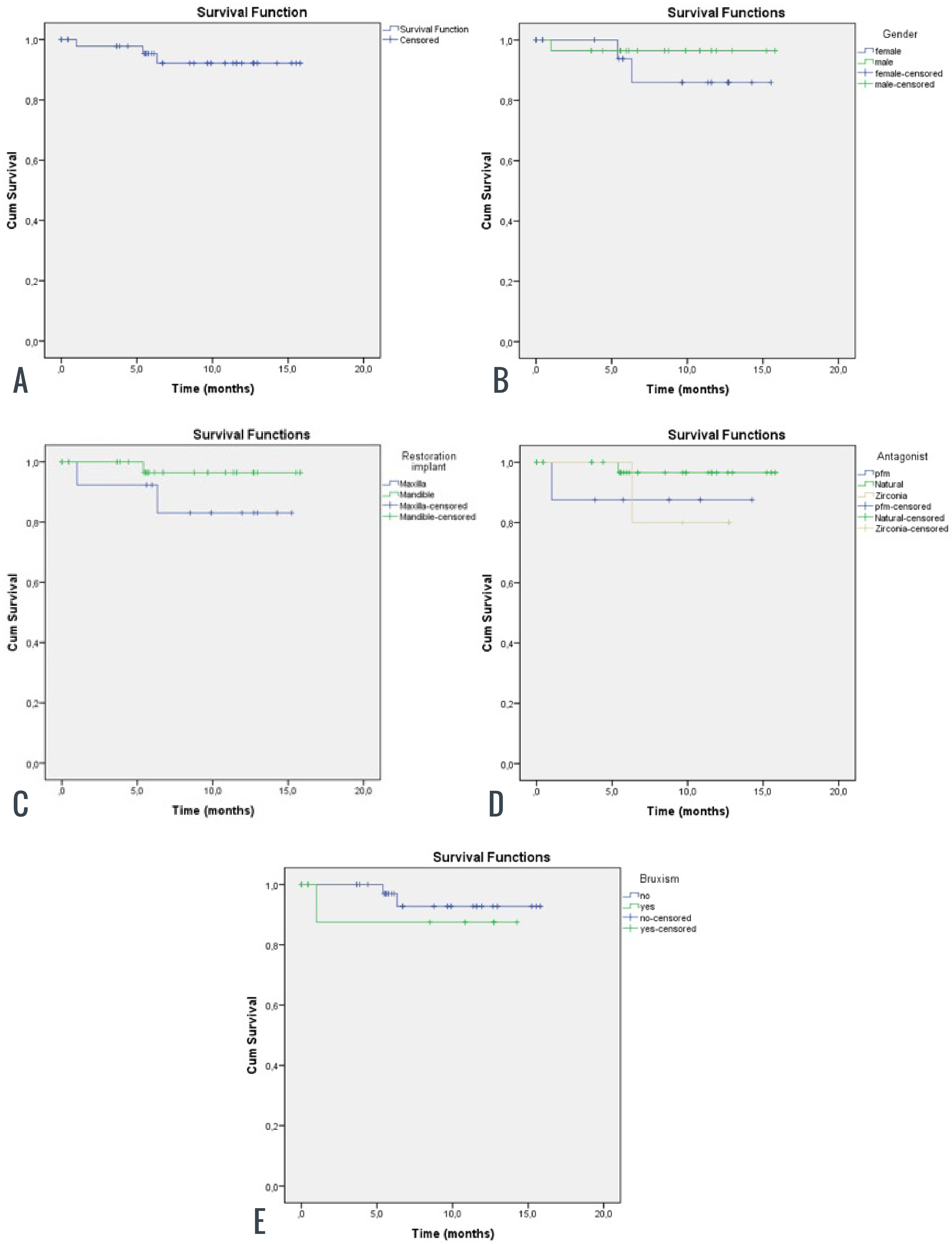

Figure 2A-E: The survival function curves of monolithic zirconia crowns regarding A) overall survival, B) gender, C) implant position, D) antagonist tooth or restoration type and E) bruxism.

Table 3. Distribution of failures and complications affecting the implant-supported monolithic zirconia crowns occurred during the follow-up period of 18 months.

	Failures	Survival Rate %	Complication	Success Rate %
Gender				
Male	1/28	96%	0/27	100%
Female	0/22	100%	1/22 Screw loosening 1/22 Bilayered zirconia chipping	96%
Bruxism				
Yes	1/11	91%	0/10	100%
No	0/39	100%	1/39 Screw loosening 1/39 Bilayered zirconia chipping	97%
Implant Position				
Maxilla	1/16	94%	0/15	94%
Mandible	0/34	100%	1/34 Screw loosening 1/34 Bilayered zirconia chipping	97%
Antagonist				
PFM	0/8	100%	0/8	100%
Natural	0/37	100%	1/37 Screw loosening	97%
Zirconia	0/5	100%	1/5 Bilayered zirconia chipping	80%

than in maxilla. The different results in this study may be due to uneven distribution of restorations in the maxilla and mandible.

Screw loosening observed in one of the mandibular MZCs and abutment was retightened since there was not any sign of de-cementation or structural impairment associated with the crown restoration. Veneering chipping was observed in one tooth-supported, bilayered antagonist mandibular zirconia crown after seven months of clinical service. Since she was not a bruxist, occlusal overloading could not be expected. However, according to a laboratory study, 50% of the veneered zirconia specimens developed cracks in enamel antagonists, while it was 100% in monolithic zirconia groups.[28] Antagonist complication may relate to stiffness of monolithic zirconia.[25,28] On the contrary, Kontonasaki *et al.*, reported that monolithic zirconia ceramics present acceptable abrasiveness to their antagonist materials *in vitro*, while preserving their own surface roughness at satisfactory levels.[29] There is still need for more research investigating the risk of opposing tooth or restoration fracture against monolithic or bilayered zirconia FDPs. Veneering porcelain fracture up to 38% for screw-retained zirconia-based restorations was reported in a clinical study, comparing the complication rates of PFM and zirconia-based restorations.[30] In previous studies, high survival rates have been reported related to functionally loaded implant supported monolithic zirconia restorations.[6-9] In this study, monolithic zirconia was preferred as a restorative material in order to eliminate veneering porcelain fracture incidence in bilayered zirconia restorations. Zirconia and its grinding effect in the opposing teeth however still remains unclear.[24,31] Grinding in zirconia could propagate phase transformation, which may have compromised the mechanical properties of zirconia.[24] In order to reduce abrasive effects of monolithic zirconia, every attempt should be made to carefully polish the external surfaces since this could be a potential limitation of the monolithic ceramics.

Extra-oral cementation can be performed on crowns with an occlusal access hole either fabricated on stock or CAD/CAM abutments.[32] Utilizing extra-oral cementation enables proper cement removal and thus, creates an ideally contoured emergence profile, a smooth abutment-crown connection that can be placed subgingivally.[21,32,33] Occlusal screw access hole may act as a vent hole which will allow cement escape and prevent apical cement entrapment.[32] On the other hand, screw access hole may be considered as a weakening factor for the restoration. In an *in vitro* study where effect of screw access holes on the fracture resistance of 3 types of ceramic implant supported crowns was evaluated, monolithic zirconia crowns with screw access holes presented the highest fatigue failure but the difference between monolithic zirconia, monolithic lithium disilicate, or veneered zirconia ceramic crowns was not statistically significant.[34] In this study, no catastrophic fractures were observed in the crowns, yielding a 100% survival rate implying that the fracture strength of MZC with occlusal screw access hole design was high enough to sustain normal occlusal loading.

During follow up period, no loss of retention due to de-cementation has been observed in any of the MZCs. Until now, the ideal type of cement has not been identified and guidelines for implant supported crown cementation are also lacking.[33,35] Clinicians should balance different considerations when selecting the appropriate cement type. Cements with high retention values (i.e. resin-based cements) minimize the risk of de-cementation but are difficult to remove. In this study, polycarboxylate cement provided satisfactory retention and by using the presented extra-oral cementation technique, authors were able to clean the cement remnants at the margin area thoroughly before delivery. The effect of polycarboxylate cement to the load bearing capacity of MZCs in this study cannot be particularly evaluated since monolithic zirconia itself has a high fracture resistance. On the other hand, Zeswitz *et al*., compared the fracture resistance of conventionally cemented and adhesively luted posterior MZCs and lithium disilicate crowns and reported that MZCs have higher fracture resistance independent from type of fixation.[36]

On periodic recalls, patients presented healthy periodontal status with no signs of inflammation which was in accordance with previously reported healthier soft tissue surrounding screw retained implant supported crowns.[17,20] In terms of lower cost and being familiar to the fabrication procedures, for a clinician, using a stock abutment having a minimum 5 mm abutment height, acting as a tube in tube principle, the axial walls and the intaglio surface of the crown will create adequate contact area for proper cement retention.[19,35] In addition, crown retention will be provided by abutment screw directly from the fixture body as well as creating restoratively directed gingival contours.[18]

One limitation of this study was that the small sample size of 31 patients with 50 MZCs, and a short-term follow-up period of 18 months. Being the only follow up study reporting the clinical outcomes of implant supported, extra-orally cemented MZCs, authors were not able to compare the results of their study with similar other studies. Nevertheless, several complications were encountered in this short follow-up term, indicating that this solution is not problem-free. However, compared to conventional methods, extraoral cementation of FDPs help decrease biological complications related to cement excess removal.[21] Longer follow-up of the same cohort is planned for at least up to 5 years in order to gain more insight regarding the viability of this method versus conventional ones.

CONCLUSIONS

From this study, the following could be concluded:

1. Extra-orally cemented monolithic zirconia crowns supported by posterior dental implants demonstrated an overall survival rate of 96% up to 18 months of clinical function.
2. Experienced technical complications were chipping of the antagonist bilayered zirconia restoration, abutment screw loosening and only one implant lost along with its crown.

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DISCLOSURE

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