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CLINICAL RESEARCH

Long-term outcome of anterior cantilever zirconia ceramic resin-bonded fixed dental prostheses: Influence of the pontic location

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ABSTRACT

Statement of problem. Scientific data on the long-term clinical performance of cantilever zirconia resin-bonded fixed dental prostheses (RBFDPs) replacing missing incisors are lacking.

Purpose. The purpose of this clinical study was to evaluate the survival, retention, and success rates of cantilever zirconia ceramic RBFDPs replacing missing maxillary and mandibular incisors.

Material and methods. A total of 258 patients had been provided with 328 cantilever zirconia RBFDPs to replace missing incisors in the period 2001 to 2022. Tooth preparation was minimal, limited to the enamel, and consisted of a veneer design. All restorations had been adhesively bonded, and the patients were periodically followed up. The Kaplan-Meier test was applied to assess survival, retention, and success rates. The Log-Rank test was used to compare the aforementioned rates among 3 groups (Group C: maxillary central incisor RBFDPs; Group L: maxillary lateral incisor RBFDPs; and Group M: mandibular central and lateral RBFDPs).

Results. Seventeen patients could not be evaluated because of loss of contact (dropout rate 6.6%). A total of 310 cantilever zirconia RBFDPs inserted in 241 patients were followed for a mean period of 85 ±55 months. A 15-year survival rate of 97.3% (confidence interval [CI]: 95.7%–98.9%) was calculated using the Kaplan-Meier method. Over the observation time, 17 RBFDPs debonded, resulting in a retention rate of 82.3% (CI: 77.2%–87.4%), of which 16 were adhesively rebonded with no further complications. Pontic location did not statistically affect the survival or retention rates (P>.05) but did significantly affect the success rate (P=.021).

Conclusions. Zirconia ceramic cantilever RBFDPs provided a minimally invasive treatment option for replacing missing maxillary and mandibular incisors with excellent clinical outcomes. (J Prosthet Dent 2025;133:1017-1023)

Minimally invasive restorations are the treatment of choice in contemporary dentistry to treat functional and esthetic dental problems while preserving sound tooth structure and improving long-term durability.[1–17] The concept was facilitated by developments in the field of dental ceramics, adhesive bonding, and computer-aided design and computer-aided manufacturing (CAD-CAM) dentistry.[18–21]

Missing anterior teeth associated with congenital factors,[3] trauma,[22,23] dental caries, periodontitis, orthodontic treatment, or a combination[3] represent an esthetic and functional problem that requires prompt and appropriate treatment. Resin-bonded fixed dental prostheses (RBFDPs) provide a minimally invasive restorative treatment option with excellent clinical outcomes.[3,5,24] Their first use dates back to the early 1970s,[25,26] and electrolytically etched metal RBFDPs were introduced in the 1980s.[27] The relatively high rate of unilateral debonding of 2-retainer RBFDPs has been attributed to the different movements of the 2 abutments.[28,29] Ceramic RBFDPs, introduced in the 1990s, were initially from glass-infiltrated alumina ceramic and subsequently from densely sintered zirconia ceramic, providing high flexural strength and good esthetics.[29–32] Improved performance and improved survival rates were reported when the cantilever single-retainer design was introduced instead of the 2-retainer design.[32–34]

Cantilever RBFDPs replacing missing incisors represent a treatment option with many advantages, especially their

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Clinical Implications

Cantilever zirconia ceramic RBFDPs are a valid minimally invasive treatment option for replacing missing maxillary and mandibular incisors, especially for young patients for whom conventional fixed dental prostheses are too invasive and implants are contraindicated.

minimal invasiveness. The preparation is conservative and limited to the enamel in the form of a veneer on only 1 abutment tooth, preserving healthy tooth structure and improving durability.[35–38] The procedure is reversible and carries no risk of pulpal irritation,[39–41] and anesthesia is not required. RBFDPs have been reported to be cost-effective with a low risk of caries.[42] Ceramic RBFDPs are especially suitable for young patients with missing anterior teeth for whom implants are contraindicated[43] and where conventional fixed dental prostheses (FDPs) might compromise the vitality of the abutment teeth.[3,41] Moreover, soft tissues at the pontic sites of RBFDPs have been reported to remain stable up to 10 years.[44]

A long-term clinical study reported an 18-year survival rate of 81.8% for RBFDPs made from glass-infiltrated alumina ceramic replacing missing teeth in the anterior region, with fracture of the alumina framework being the most observed complication.[24] A promising 10-year survival rate of 98.2% was recorded for zirconia RBFDPs replacing missing incisors.[3]

Studies and meta-analyses have been published on the long-term clinical performance of other available treatment options, including fixed dental prostheses and implant-supported single crowns,[45–47] but only short- or medium-term data on relatively small patient cohorts have been published regarding the clinical performance of zirconia RBFDPs.[3,48–52] A few clinical studies evaluated the long-term performance of RBFDPs made of nickel chromium alloy[53] and of glass-infiltrated alumina ceramic,[24] but long-term data on zirconia RBFDPs are lacking. Therefore, the aim of this study was to evaluate the survival, retention, and success rates of cantilever zirconia RBFDPs replacing missing maxillary and mandibular incisors with a follow-up of up to 19-years and to evaluate whether the survival, retention, and success rates of maxillary lateral incisor, maxillary central incisor, and mandibular incisor RBFDPs differ. The null hypothesis was that no difference in the survival, retention and success rates would be found between the different groups.

MATERIAL AND METHODS

This study was approved by the ethics committee of the Christian-Albrechts University at Kiel. Participants signed an informed consent before enrollment. In total, 258 patients had been provided with 328 cantilever zirconia RBFDPs between 2001 and 2022 to replace missing incisors. Patients were eligible for treatment on the basis of the following inclusion criteria[54]: good oral hygiene; no active periodontitis; abutment teeth with no caries or only a small direct restoration, allowing a minimum of 30 mm^2 bonding surface to sound enamel; appropriate occlusion allowing for a minimum retainer wing thickness of 0.7 mm in the area of the bonding surface; width of edentulous space corresponding to the width of the missing tooth; adequate intermaxillary space to allow for a proximal connector with a minimum height of 3 mm; appropriate or correctable soft tissue conditions to allow for an ovate pontic design; and satisfactory or correctable esthetics. Signs of parafunctional habits were not a contra-indication, but care was taken to avoid initial guidance on the pontic during dynamic occlusion and to ensure that the abutment tooth and the other teeth provided occlusal guidance for the first 2 to 3 mm of dynamic excursion movement.

A waxing of the missing tooth and the planned retainer was fabricated for most patients. The waxing was transferred intraorally using a silicone index and interim resin (Luxatemp; DMG) and was adjusted according to any necessary modifications before minimal preparation in the form of an oral veneer limited to the enamel. The finish line in the proximal area stopped short of the proximal contact, which was marked according to the intraoral trial. A fine shoulder was prepared 2- to 3-mm cervically to the incisal edge. A fine cervical chamfer, a proximal box, and a pinhole on the cingulum were prepared.[54] All sharp edges were smoothed and rounded.

No interim restoration was provided after preparation. However, patients were provided with an interim occlusal device to replace the missing teeth and prevent tooth migration or displacement. The teeth were scanned (TRIOS 3 WIRED or TRIOS 4 Wireless; 3Shape A/S), or a conventional impression was made using polyether impression material (Permadyne Penta H Permadyne Garant 2:1; 3M) with a double-mix technique and a custom tray and cast with die stone. Using CAD-CAM technology, the restorations were milled from presintered high-strength 3 mol% yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP) zirconia ceramic blocks with a flexural strength of 1100 to 1200 MPa and approximately 98% tetragonal phase[55,56] and densely sintered using a conventional sintering procedure reaching 1500 °C. The zirconia framework was labially veneered with feldspathic ceramic (Fig. 1A). The dimensions for the proximal connector were at least 3 mm (vertically) and 2 mm (horizontally), and the minimum thickness of the retainer wing was 0.7 mm. An optimal proximal contact was designed between the pontic and

Figure 1. Labially veneered 3Y-TZP zirconia resin-bonded fixed dental prostheses. A, Prosthesis. B, Occlusal view. C, Frontal view.

the adjacent natural teeth. Occlusal guidance on the pontic during dynamic excursion was avoided.[54] During the clinical evaluation appointment, all aspects were examined and corrected when needed.

The restorations were bonded under dental dam isolation. The zirconia bonding surfaces were airborne-particle abraded with 50-µm alumina particles at 0.25 MPa until 2009 and at 0.1 MPa thereafter, followed by 3 minutes of ultrasonic cleaning in 99% isopropanol. The prepared enamel was etched with 37% phosphoric acid (Total Etch; Ivoclar) for 30 seconds, rinsed with water, and dried with water and oil-free spray. RBFDPs were adhesively bonded using 1 of 3 luting resin systems: a phosphate-monomer-containing resin without primer (Panavia 21 TC; Kuraray Noritake), a dual-polymerizing luting resin (Panavia V5; Kuraray Noritake) with a primer for zirconia intaglio surfaces (Ceramic Primer Plus; Kuraray Noritake) and a primer for tooth substrate (Tooth Primer; Kuraray Noritake), or a dual-polymerizing luting resin (Multilink-Automix; Ivoclar AG) with a phosphoric acid acrylate primer for zirconia intaglio surfaces (Metal/Zirconia Primer; Ivoclar AG) and a primer for enamel (AB Primer; Ivoclar AG). Figure 1B, C shows a representative cantilever zirconia RBFDP replacing a maxillary lateral incisor. Patients with a history of orthodontic therapy were provided with a maxillary occlusal device to prevent changes in position because of abutment movement.

The participants were recalled yearly to examine the restorations. The following criteria in particular were checked: caries, plaque deposition, periodontitis, demineralization, abutment mobility, abutment vitality, abutment hypersensitivity, pain, parafunctional activities, and chipping of the veneering ceramic. RBFDPs were categorized into 3 groups, maxillary RBFDPS were differentiated between replaced central and lateral incisors because of the significant differences in size, and mandibular RBFDPs were grouped together as the width of the pontics was similar: Group C: RBFDPs replacing a maxillary central incisor, Group L: replacing a maxillary lateral incisor, and Group M: replacing mandibular central and lateral incisors.

The data were revised, coded, tabulated, and evaluated with a statistical software program (IBM SPSS Statistics, v20.0 for Windows; IBM Corp). To ensure the independence of observations, only 1 restoration was randomly selected using a coin toss for statistical analysis for participants with more than 1 restoration. The Kaplan-Meier test was then applied to assess the survival, retention, and success rates. Survival was defined as restorations remaining functionally intact and in place over the follow-up period with or without complications. Retention was defined as restorations remaining functionally intact without becoming debonded over the follow-up period. Success was defined as restorations remaining functionally intact and without any complications requiring intervention over the follow-up period. The Log-Rank test was used to compare the previously mentioned rates among the 3 groups (α=.05).

RESULTS

Seventeen patients could not be evaluated due to loss of contact. A total of 310 cantilever single-retainer ceramic RBFDPs inserted in 241 patients were observed for a mean ±standard deviation period of 85 ±55 months (range 12 to 228 months). Twenty-six of the inserted restorations were splinted at the midline by connecting the retainer wings to maintain the closure of a midline diastema, of which 19 were replacing both lateral incisors and 7 were replacing 1 lateral incisor. The distribution of replaced teeth is shown in Table 1. The age of the patients when the restorations were inserted ranged from 7 to 82 years old, with a mean age of 27 ±18 years. Female patients accounted for 60.6% of the patients, and 39.4% were male patients. The distribution of

Table 1. Frequency of distribution of replaced teeth

Pontic Location	Maxilla	Percentage (%)
Maxillary central incisors	44	14.2
Maxillary lateral incisors	183	59
Both maxillary lateral incisors with one splinted restoration	19	6.2
Mandibular central incisors	44	14.2
Mandibular lateral incisors	18	5.8
Maxillary diastema closure	1	0.3
Mandibular diastema closure	1	0.3
Total	310	100

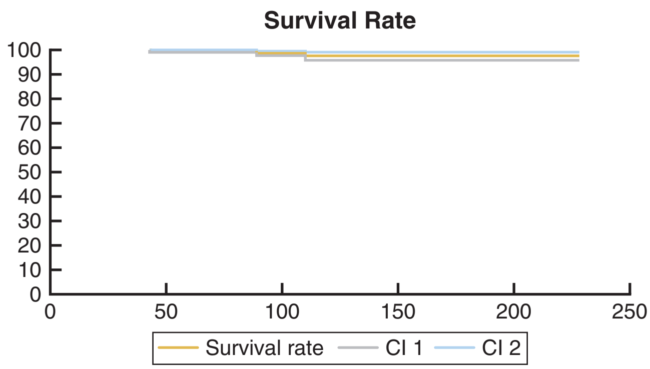

Figure 2. Percentage survival rate with confidence intervals (lower bound: CI 1, upper bound CI 2).

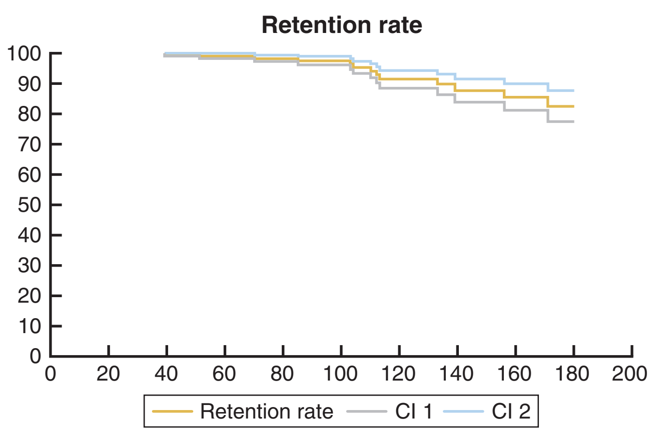

Figure 3. Percentage retention rate with confidence intervals (lower bound: CI 1, upper bound CI 2).

the cause of missing teeth was as follows: 61.8% congenital, 15.4% trauma, and 22.8% other reasons.

Within the observation time only 4 restorations were lost, corresponding to a survival rate of 97.3% (confidence interval [CI]: 95.7% –to 98.9%) after 15 years according to the Kaplan-Meier analysis (Fig. 2). The survival rates for groups C, L, and M were 90.9%, 97.7%, and 100%, respectively, with no statistical difference (*P*=.060). The Kaplan-Meier analysis revealed a 5-, 10-, and 15-year cumulative probability of survival of 99.4%, 97.3% und 97.3% respectively. With 17 debonded RBFDPS, the retention rate after 15 years was 82.3% (CI: 77.2%–87.4%) (Fig. 3). The retention rate among the groups was 78.9%, 84.1%, and 89.9% for groups C, L, and M, respectively with no significant difference (*P*=.128). For group L, the retention rates for splinted restorations; RBFDPs replacing 1 or 2 lateral incisors with 1 splinted restoration, and nonsplinted restorations; single-retainer cantilever restorations replacing 1 lateral incisor, were 62.5% and 91.3% respectively. Splinting as a factor had a statistically negative effect on the retention rate (*P*=.011). When complications that necessitated intervention were considered as a criterion, the estimated success rate over 15 years was 66.2% (CI: 59.9–72.5%) (Fig. 4). The success rates for groups C, L, and M were 37%, 70.5%, and 79.5% after 15 years, respectively. A statistical difference was detected (*P*=.021), with group C showing significantly lower success rates compared with groups L and M. The splinting factor had no statistical significance on the success rate (*P*=.190). The distribution of recorded complications categorized as necessitating intervention and not requiring intervention is shown in Table 2. The cause of missing teeth did not statistically influence the survival rate, retention rate, or the success rate (*P*>.05).

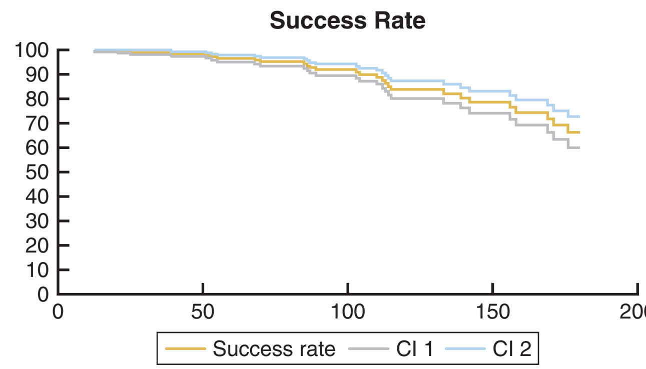

Figure 4. Percentage success rate with confidence intervals (lower bound: CI 1, upper bound CI 2).

DISCUSSION

The use of a RBFDP in the anterior region necessitates a partial preparation for a ceramic veneer that requires the removal of approximately 5% of sound tooth structure compared with the removal of approximately 70% of

Table 2. Frequency of detected complications

Complications Necessitating Intervention	Number of Incidents	Percent (%)	Complications not Necessitating Intervention	Number of Incidents	Percentage (%)
Debonding	17	47	Minimal tooth mobility	9	38
Caries	3	8	Recession	1	4
Chipping	7	20	Minimal change in position	10	42
Periodontitis	9	25	Microcrack	1	4
Total	**36**	**100**	Demineralization	1	4
			Hypersensitivity	2	8
			Total	**24**	**100**

tooth structure and a minimum of 2 abutments, that is required for their conventional complete coverage counterparts in the anterior region.[7] The amount and nature of the remaining tooth structure is essential for the survival of the tooth and the restoration.[35] A correlation between the decrease in the mechanical resistance of the abutment tooth and its restoration and the aggressive nature of the conducted preparation has been reported.[8–10] Catastrophic tooth and restoration failures occur with extensively prepared teeth, whereas such failures are almost not existent with minimally invasive preparations.[11–13] Maximum preservation of the enamel is also essential for the success of ceramic restorations and the adhesive bonding technique.[14,15] The negative influence of adhesive bonding to dentin has been well documented in the literature.[16,17,36,37] At given loads, higher stresses arise for the adhesively bonded ceramics as the elasticity modulus of the underlying tooth structure decreases; this is the case for dentin (16 GPa) compared with enamel (94 GPa) as the underlying structure.[6,38] Another advantage of minimally invasive preparations and restorations is that the risk of devitalization is significantly reduced.[11,39–41] All these factors provide evidence of the benefits of minimally invasive RBFDPs in the anterior region. However, long-term clinical data on a large patient cohort have been lacking. Therefore, the current study was undertaken.

The null hypothesis that no difference would be found in the survival, retention, and success rates among the different groups was partially rejected, as no difference was found in the survival and retention rates among the groups. However, the success rate was affected by the pontic location. Zirconia cantilever single-retainer RBFDPs in the anterior region showed a highly successful clinical outcome with a survival rate of 97.3% after 15 years of clinical service. The survival rates for the 3 groups were statistically similar, which might be explained by the low number of removed restorations. Of the 4 lost restorations, 2 were lost due to traumatic incidents, 48 and 110 months after insertion, both in the same patient. The other 2 were removed because the patients requested complete oral rehabilitation, with 1 replaced by an implant and a single crown and the other by a conventional FDP. The removals took place 43 and 89 months after insertion, respectively.

A long-term clinical evaluation of 211 cantilever RBFDPs reported a survival rate of 90% over a mean service life of 9.4 years,[53] which is lower than that found in the current study and might be explained by different inclusion criteria, different preparation design, different materials (nickel-chromium alloy versus zirconia ceramic), and the inclusion of both anterior and posterior RBFDPs in the study. Another reason might be that of 28 debonded restorations in the study, only 18 were adhesively rebonded unlike in the present study, where 16 of the 17 debonded restorations were successfully adhesively rebonded, resulting in a higher overall survival rate. A medium-term retrospective clinical study on zirconia RBFDPs replacing missing anterior teeth in 10 patients reported a survival rate of 100% over 10 years of clinical service,[51] which is consistent with the results of the present study despite the difference in the follow-up time and number of patients. Another study investigating 24 zirconia-based RBFDPs replacing missing anterior teeth concluded a survival rate of 100% after 36 months.[48] This result is also consistent with the results of the current study. A short-term study on RBFDPs reported a survival rate of 82.7% after 3 years of service, although the authors did not differentiate between the removed and the debonded restorations.[52] The high debonding rate may have been associated with the fact that the bonding surfaces of the retainers were not airborne-particle abraded with alumina particles but primed with Monobond-S, a silane-containing primer not suitable for use on zirconia surfaces that require pretreatment with a phosphate monomer primer or bonding with a phosphate monomer-containing adhesive system.

A meta-analysis reported an estimated 15-year survival rate of 75% for the standard crown-retained FDPs when failure was defined as the removal of the FDP.[45] Another meta-analysis calculated a 15-years overall survival rate of 74 ±2% for conventional FDPs.[46] These survival rates are considerably lower than those in the current study, which can be explained by the much more invasive preparation with weakening of the abutment teeth and associated risks for the pulp. The estimated 15-year cumulative survival rate for implant-supported single crowns replacing missing anterior teeth is 93 ±6%.[47] The survival rate of RBFDPs in the current study surpasses the estimated 15-year survival rate of conventional FDPs and that of implant-supported single crowns.

When debonding was considered a failure, the retention rate was 82.3% due to 17 recorded debonding incidents, of which 7 were a result of traumatic incidents, 6 with an unidentified reason, and 4 as a result of the debonding of a splinted restoration, of which 2 were unilateral debondings. Sixteen of these restorations were adhesively rebonded with no further complications. The 4 debonded splinted restorations were separated into 2 single-retainer RBFDPs and adhesively rebonded without showing further problems.

The fact that 41.2% of the debondings were due to traumatic accidents could be explained by the frequency of traumatic injuries in the anterior region, the prevalence of which ranges from 6%[22] to 59%,[23] with maxillary central incisors being the most affected teeth. Other reasons for debonding include contamination during the adhesive bonding,[4] failure due to adhesive failure between the luting resin and the tooth or between the luting resin and the restorative material, or cohesive failure within the luting resin.[50] For group L, splinting as a factor influenced the retention rate, with splinted restorations showing a significantly lower retention rate when compared with the nonsplinted restorations. This finding might be explained by the differential movements of the abutment teeth leading to shear force on the retainer's wing and subsequently to debonding.[50]

Klink et al[48] reported a retention rate of 95.5% after 36 months of service, which was lower than the 100% retention rate in the current study at 36 months of clinical use (Fig. 3). In another study, 28 of 211 restorations debonded, resulting in a retention rate of 86.7% over a mean service life of 9.4 years,[53] which was lower than the 10-year retention rate of 98.8% estimated for the current study. Different inclusion criteria, preparation design and materials, and the inclusion of anterior and posterior RBFDPs in the study might explain the differences between the studies.

The success rate in this study was 66.2% over 180 months of clinical service. The most common complication requiring intervention was debonding. The most common complication not needing an intervention was a minimal change in tooth position, with all affected patients admitting to not wearing the occlusal device provided to prevent abutment migration, especially in patients who had previously undergone orthodontic treatment. Group C showed a significantly lower success rate in comparison with groups C and M. Traumatic incidents, which more frequently affect maxillary central incisors and with a prevalence that ranges from 6%[22] to 59%,[23] can lead to debonding, chipping and other complications and might explain the lower success rate in group C.

Klink et al[48] reported a 76% to 82.4% success rate after 36 months of clinical use. For the same follow-up time, the estimated success rate in the current study was 98.7% (Fig. 4), much higher than that reported previously. Another study with a 10-year follow-up reported no biological failures or technical complications, but the debonding of 2 of 10 restorations resulted in a success rate of 80%, lower than the 96.3% success rate estimated for the current study at 10 years.[51] The lower success rate in the study might be explained by the fact that the bonding surfaces of the retainers were primed with a silane (Clearfil Porcelain Bond) before bonding with a phosphate monomer-containing luting resin system (Panavia 21). The silane might have affected the direct bonding of the phosphate monomer to the zirconia. The success rate of 211 cantilever RBFDPs made of nickel-chromium alloy over a mean service life of 9.4 years was 84.4%,[53] which is lower than the 10-year success rate estimated in the current study. The same explanation of the differing retention rates between the studies applies here.

Limitations of the present study included the variability in practitioner skills, applied technique, and materials used, as the lack of standardization might have influenced the resulting survival, retention, and success rates. The variability of patient-related factors such as age, oral hygiene, diet, habits, compliance, and their possible influence is another limitation of this study.

CONCLUSIONS

Based on the findings of this clinical study, the following conclusions were drawn:

1. Cantilever RBFDPs made of zirconia ceramic present an excellent treatment option for replacing single incisors, regardless of the reasons for missing teeth.
2. The long-term survival rates presented in this study surpass those of conventional crown-retained FDPs, implant-supported single crowns, and RBFDPs made of other materials.
3. RBFDPs have many advantages over conventional FDPs and implant-supported single crowns, the most important being that they are minimally invasive and reversible. They are also suitable for young patients with congenitally missing teeth for whom other treatment options may jeopardize longevity.

REFERENCES

1. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for posterior teeth. *Int J Periodontics Restorative Dent*. 2002;22:241–249.
2. Yazigi C, Kern M, Chaar MS. Influence of various bonding techniques on the fracture strength of thin CAD/CAM-fabricated occlusal glass-ceramic veneers. *J Mech Behav Biomed Mater*. 2017;75:504–511.
3. Kern M, Passia N, Sasse M, Yazigi C. Ten-year outcome of zirconia ceramic cantilever resin-bonded fixed dental prostheses and the influence of the reasons for missing incisors. *J Dent*. 2017;65:51–55.
4. Yazigi C, Elsayed A, Kern M. Secure and precise insertion of minimally invasive resin-bonded fixed dental prostheses after ridge augmentation by means of a positioning splint. *J Esthet Restor Dent*. 2021;33:415–421.
5. Yazigi C, Kern M. Clinical evaluation of zirconia cantilevered single-retainer resin-bonded fixed dental prostheses replacing missing canines and posterior teeth. *J Dent*. 2022;116:103907.
6. Yazigi C, Schneider H, Chaar MS, Ruger C, Haak R, Kern M. Effects of artificial aging and progression of cracks on thin occlusal veneers using SD-OCT. *J Mech Behav Biomed Mater*. 2018;88:231–237.
7. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for anterior teeth. *J Prosthet Dent*. 2002;87:503–509.
8. Guess PC, Schultheis S, Wolkewitz M, Zhang Y, Strub JR. Influence of preparation design and ceramic thicknesses on fracture resistance and failure modes of premolar partial coverage restorations. *J Prosthet Dent*. 2013;110:264–273.
9. Mondelli J, Steagall L, Ishikiriama A, de Lima Navarro MF, Soares FB. Fracture strength of human teeth with cavity preparations. *J Prosthet Dent*. 1980;43:419–422.
10. St-Georges AJ, Sturdevant JR, Swift Jr. EJ, Thompson JY. Fracture resistance of prepared teeth restored with bonded inlay restorations. *J Prosthet Dent*. 2003;89:551–557.

11. Guess PC, Selz CF, Steinhart YN, Stampf S, Strub JR. Prospective clinical split-mouth study of pressed and CAD/CAM all-ceramic partial-coverage restorations: 7-Year results. *Int J Prosthodont*. 2013;26:21–25.
12. Beier US, Kapferer I, Dumfahrt H. Clinical long-term evaluation and failure characteristics of 1,335 all-ceramic restorations. *Int J Prosthodont*. 2012;25:70–78.
13. Stokes AN, Hood JAA. Impact fracture characteristics of intact and crowned human central incisors. *J Oral Rehabil*. 1993;20:89–95.
14. Krämer N, Lohbauer U, Frankenberger R. Adhesive luting of indirect restorations. *Am J Dent*. 2000;13:60D–76D.
15. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. *J Dent*. 2000;28:163–177.
16. Burke FJ. Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: A literature review. *J Esthet Restor Dent*. 2012;24:257–265.
17. Clausen JO, Abou Tara M, Kern M. Dynamic fatigue and fracture resistance of non-retentive all-ceramic full-coverage molar restorations. Influence of ceramic material and preparation design. *Dent Mater*. 2010;26:533–538.
18. Bosch G, Ender A, Mehl A. Non- and minimally invasive full-mouth rehabilitation of patients with loss of vertical dimension of occlusion using CAD/CAM: An innovative concept demonstrated with a case report. *Int J Comput Dent*. 2015;18:273–286.
19. Magne P, Magne M, Belser UC. Adhesive restorations, centric relation, and the Dahl principle: Minimally invasive approaches to localized anterior tooth erosion. *Eur J Esthet Dent*. 2007;2:260–273.
20. Schlichting LH, Resende TH, Reis KR, Magne P. Simplified treatment of severe dental erosion with ultrathin CAD-CAM composite occlusal veneers and anterior bilaminar veneers. *J Prosthet Dent*. 2016;116:474–482.
21. Magne P, Hanna J, Magne M. The case for moderate "guided prep" indirect porcelain veneers in the anterior dentition. The pendulum of porcelain veneer preparations: from almost no-prep to over-prep to no-prep. *Eur J Esthet Dent*. 2013;8:376–388.
22. Burton J, Pryke L, Rob M, Lawson JS. Traumatized anterior teeth amongst high school students in northern Sydney. *Aust Dent J*. 1985;30:346–348.
23. Marcenes W, Zabot NE, Traebert J. Socio-economic correlates of traumatic injuries to the permanent incisors in schoolchildren aged 12 years in Blumenau, Brazil. *Dent Traumatol*. 2001;17:222–226.
24. Kern M. Fifteen-year survival of anterior all-ceramic cantilever resin-bonded fixed dental prostheses. *J Dent*. 2017;56:133–135.
25. Rochette AL. Attachment of a splint to enamel of lower anterior teeth. *J Prosthet Dent*. 1973;30:418–423.
26. Howe DF, Denehy GE. Anterior fixed partial dentures utilizing the acid-etch technique and a cast metal framework. *J Prosthet Dent*. 1977;37:28–31.
27. Livaditis GJ, Thompson VP. Etched castings: an improved retentive mechanism for resin-bonded retainers. *J Prosthet Dent*. 1982;47:52–58.
28. Pjetursson BE, Tan WC, Tan K, Bragger U, Zwahlen M, Lang NP. A systematic review of the survival and complication rates of resin-bonded bridges after an observation period of at least 5 years. *Clin Oral Implants Res*. 2008;19:131–141.
29. Kern M, Knode H, Strub JR. The all-porcelain, resin-bonded bridge. *Quintessence Int*. 1991;22:257–262.
30. Kern M, Strub JR. Bonding to alumina ceramic in restorative dentistry: Clinical results over up to 5 years. *J Dent*. 1998;26:245–249.
31. Kern M. Clinical long-term survival of two-retainer and single-retainer all-ceramic resin-bonded fixed partial dentures. *Quintessence Int*. 2005;36:141–147.
32. Kern M, Gläser R. Cantilevered all-ceramic, resin-bonded fixed partial dentures: A new treatment modality. *J Esthet Dent*. 1997;9:255–264.
33. Kern M, Sasse M. Ten-year survival of anterior all-ceramic resin-bonded fixed dental prostheses. *J Adhes Dent*. 2011;13:407–410.
34. Botelho MG, Chan AW, Leung NC, Lam WY. Long-term evaluation of cantilevered versus fixed-fixed resin-bonded fixed partial dentures for missing maxillary incisors. *J Dent*. 2016;45:59–66.
35. Nagasiri R, Chitmongkolsuk S. Long-term survival of endodontically treated molars without crown coverage: A retrospective cohort study. *J Prosthet Dent*. 2005;93:164–170.
36. Dumfahrt H, Schaffer H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: Part II–Clinical results. *Int J Prosthodont*. 2000;13:9–18.
37. Peumans M, De Munck J, Fieuws S, Lambrechts P, Vanherle G, Van Meerbeek B. A prospective ten-year clinical trial of porcelain veneers. *J Adhes Dent*. 2004;6:65–76.
38. Kelly JR. Clinically relevant approach to failure testing of all-ceramic restorations. *J Prosthet Dent*. 1999;81:652–661.
39. Edelhoff D, Liebermann A, Beuer F, Stimmelmayr M, Guth JF. Minimally invasive treatment options in fixed prosthodontics. *Quintessence Int*. 2016;47:207–216.
40. van Dijken JW, Hasselrot L. A prospective 15-year evaluation of extensive dentin-enamel-bonded pressed ceramic coverages. *Dent Mater*. 2010;26:929–939.
41. Cheung GS, Lai SC, Ng RP. Fate of vital pulps beneath a metal-ceramic crown or a bridge retainer. *Int Endod J*. 2005;38:521–530.
42. Sasse M, Kern M. All-ceramic resin-bonded fixed dental prostheses: Treatment planning, clinical procedures, and outcome. *Quintessence Int*. 2014;45:291–297.
43. Kern M. Single-retainer resin-bonded fixed dental prostheses as an alternative to orthodontic space closure (and to single-tooth implants). *Quintessence Int*. 2018;49:789–798.
44. Türp L, Schlothauer T, Yazigi C, Kern M. Soft tissue changes at the pontic sites of cantilever zirconia ceramic resin-bonded fixed dental prostheses in the esthetic zone: A clinical observational study. *J Esthet Restor Dent* 2024.
45. Scurria MS, Bader JD, Shugars DA. Meta-analysis of fixed partial denture survival: Prostheses and abutments. *J Prosthet Dent*. 1998;79:459–464.
46. Creugers NH, Kayser AF, van 't Hof MA. A meta-analysis of durability data on conventional fixed bridges. *Community Dent Oral Epidemiol*. 1994;22:448–452.
47. Walton TR. An up-to-15-year comparison of the survival and complication burden of three-unit tooth-supported fixed dental prostheses and implant-supported single crowns. *Int J Oral Maxillofac Implants*. 2015;30:851–861.
48. Klink A, Hüttig F. Zirconia-based anterior resin-bonded single-retainer cantilever fixed dental prostheses: A 15- to 61-month follow-up. *Int J Prosthodont*. 2016;29:284–286.
49. Sailer I, Hämmerle CH. Zirconia ceramic single-retainer resin-bonded fixed dental prostheses (RBFDPs) after 4 years of clinical service: A retrospective clinical and volumetric study. *Int J Periodontics Restorative Dent*. 2014;34:333–343.
50. Sasse M, Kern M. Survival of anterior cantilevered all-ceramic resin-bonded fixed dental prostheses made from zirconia ceramic. *J Dent*. 2014;42:660–663.
51. Naenni N, Michelotti G, Lee WZ, Sailer I, Hämmerle CH, Thoma DS. Resin-bonded fixed dental prostheses with zirconia ceramic single retainers show high survival rates and minimal tissue changes after a mean of 10 years of service. *Int J Prosthodont*. 2020;33:503–512.
52. Shahdad S, Cattell MJ, Cano-Ruiz J, Gamble E, Gamboa A. Clinical evaluation of all ceramic zirconia framework resin bonded bridges. *Eur J Prosthodont Restor Dent*. 2018;26:203–211.
53. Botelho MG, Ma X, Cheung GJ, Law RK, Tai MT, Lam WY. Long-term clinical evaluation of 211 two-unit cantilevered resin-bonded fixed partial dentures. *J Dent*. 2014;42:778–784.
54. Kern M. RBFDPs. Resin-Bonded Fixed Dental Prostheses - Minimally Invasive – Esthetic – Reliable. 1st ed. Berlin: Quintessence,; 2017.
55. Lim CH, Vardhaman S, Reddy N, Zhang Y. Composition, processing, and properties of biphasic zirconia bioceramics: Relationship to competing strength and optical properties. *Ceram Int*. 2022;48:17095–17103.
56. Sulaiman TA. Materials in digital dentistry-A review. *J Esthet Restor Dent*. 2020;32:171–181.

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