Received: 26 March 2021 | Revised: 7 December 2021 | Accepted: 10 January 2022

DOI: 10.1111/ipd.12954

INTERNATIONAL JOURNAL OF PAEDIATRIC DENTISTRY WILEY

ORIGINAL ARTICLE

Comparative evaluation of the fracture resistance of newly developed prefabricated fibreglass crowns and zirconium crowns

Zülfikar Zahit Çiftçi[1] | **İpek Şahin**[2] | **Hüseyin Karayılmaz**[1]

[1]Department of Paediatric Dentistry, Faculty of Dentistry, Akdeniz University, Antalya, Turkey

[2]Paediatric Dentist, Antalya, Turkey

Correspondence
Hüseyin Karayilmaz, Akdeniz Üniversitesi, Diş Hekimliği Fakültesi, Pedodonti Anabilim Dalı, Konyaaltı, Antalya\Türkiye.
Email: dthkarayilmaz@yahoo.com

Funding information
Scientific Research Projects Coordination Unit of Akdeniz University, Grant/Award Number: TSA-2019-5091

Abstract

Background: Prefabricated fibreglass crowns (PFCs) require less tooth structure reduction than prefabricated zirconium crowns (PZCs) for restoring primary molars. Little is known, however, about their mechanical properties.

Aim: To investigate the fatigue survival and fracture resistance of PZCs and PFCs cemented with two different types of luting cement [glass-ionomer cement (GIC) and resin-modified GIC (RMGIC)].

Design: One hundred and twenty extracted human primary molars were randomly divided into subgroups ($n = 15$) according to the crown type (PFCs/PZCs), the luting cement (GIC/RMGIC) and crowns subjected to the chewing simulation test with thermocycling mechanical loading (CSTTML). The surfaces of the teeth were reduced by approximately 2 mm in the PZC group and 1 mm in the PFC group. All the samples were subjected to fracture tests.

Results: None of the samples subjected to CSTTML exhibited signs of surface damage, fracture or premature debonding. The forces required to fracture PFCs were higher than those required for PZCs in all groups ($p = .001$). The highest mean fracture resistance values were obtained from the group of PFCs cemented with GIC that were subjected to the CSTTML (2515.8 N ± 619.2 N).

Conclusions: PFCs presented high fatigue survival and could be used as alternatives to PZCs as they require less tooth structure reduction. Crowns cemented with GIC had a similar fracture resistance value when compared with RMGIC.

KEYWORDS

fracture resistance, prefabricated fibreglass crowns, prefabricated zirconium crowns, primary molars

1 | INTRODUCTION

When restoring primary teeth, many factors, including age, compliance, caries risk level, oral hygiene/plaque control, the type of tooth, cavitation status, moisture control, retention of the restoration, aesthetics, cost and parents' motivation, should be considered.[1–4] Despite the many advances in dentistry, there remain difficulties in obtaining satisfactory results in the restoration of primary teeth with excessive tooth structure loss.[5] In these cases, full-coverage crowns are preferred for the restoration of teeth with extensive, multisurface and subgingival carious lesions, as well

as for the restoration of developmentally defective teeth or endodontically treated teeth in the primary dentition.[4,6,7]

Today, different materials can be used in the full-coverage restoration of primary teeth. Stainless steel crowns (SSCs), the most commonly used material for full coronal restorations in paediatric dentistry, have a number of advantages, including high durability and lifespan, specific retentive attributes, rapid placement times, gingival haemorrhage or moisture applications, and cost-effectiveness.[4,8] Although preveneered SSCs have also been developed as an alternative, these crowns provide poor aesthetics, and at present, patients, parents and paediatric dentists alike tend to prefer more aesthetically pleasing alternatives.[9]

Prefabricated zirconium crowns (PZCs) have been developed as an alternative to SSCs for primary teeth, and their use in paediatric dentistry has increased exponentially, largely due to their aesthetic properties.[9,10] The advantages of PZCs are their aesthetically pleasing appearance, high strength, superior biocompatibility, durability and the lower risk of gingival irritation in primary teeth[9–12]; disadvantages include the need for excessive preparation and the inability to adapt to the margins.[13] Because passive seating of these crowns is recommended during cementation, the luting cement gap between the tooth and the crown becomes wider. Therefore, as seen in the previous study, where the effect of four different types of luting cement on the fracture resistance of PZCs was examined, the luting cement is crucial to the success of the crown.[10,14]

Fibre materials are biocompatible, have high mechanical properties and have long been used in various dental applications. In fact, fibre-reinforced composites are frequently used in a variety of dental applications, not only due to their mechanical properties but also due to their easy manipulation, relative flexibility and high adjustability, as well as their aesthetic properties.[15–17] Although recently introduced prefabricated fibreglass crowns (PFCs) for the treatment of primary teeth have many positive features, few studies on these crowns exist.[18,19]

Chewing involves complex mouth motion, and crowns are subjected to high loading by occlusal contact and flexure in aqueous environments. Bite forces can exceed 433 N in 6- to 11-year-old children,[20] suggesting that paediatric crown systems, including luting cement together with the crown material, should be able to withstand these forces without any distortion.

The aim of this study was to investigate the fatigue survival and fracture resistance of PZCs (NuSmile, Houston, TX, USA) and newly developed PFCs (Figaro Crowns; Figaro Crowns Inc, Woodbury, MN, USA) cemented with two different types of luting cement—glass ionomer cement (GIC) (Fuji I Capsule; GC Corporation, Tokyo, Japan) and resin-modified GIC (RMGIC) (FujiCEM 2; GC Corporation).

Why this paper is important to paediatric dentists

- Prefabricated zirconium crowns (PZCs) can currently be used successfully. Within in vitro study limits, it was found that prefabricated fibreglass crowns (PFCs) have a higher fracture resistance value and could be a potential alternative to PZCs.
- This study provides evidence that both types of glass ionomer–containing luting cement used in the study can be used in the cementation of both PFCs and PZCs.

2 | MATERIALS AND METHODS

Ethics approval for this study was obtained from the Ethics Committee of the Clinical Research of the Medical Faculty of Akdeniz University, Antalya, Turkey (approval date/number 15.10.2019/499). This study was performed on freshly extracted primary molar teeth. Any teeth with dentine caries or insufficient root length for retention in acrylic materials were excluded from the study. All the teeth were obtained by the Faculty of Dentistry of Akdeniz University from subjects in the West Mediterranean region of Turkey after receiving permission from the patients and their parents. This study has followed the CRIS guidelines for in vitro studies as discussed in the 2014 concept note.[21]

A power analysis was performed to estimate the target sample size from the previous study of Kist et al.[12] using the G*Power version 3.1.9.4 software (University of Dusseldorf, Dusseldorf, Germany). A priori power analysis with ANOVA indicated that a sample size of at least 11 samples in each group would provide a statistical power of 95% (effect size = 6.12 and $\alpha = .05$).

The teeth were stored in 10% formalin solution for 2 weeks and were then stored in distilled water at room temperature (23°C ± 1°C) for no more than 8 weeks before being used in the study. A total of 120 extracted primary molar teeth were selected and debrided. All the teeth were embedded in cylindrical polyethylene pipes (3.5 mm in height and 2.5 mm in diameter) using a self-cure acrylic material (Panacryl; Ruby Dent, Istanbul, Turkey) up to 1 mm below the cement–enamel junction in an upright position, and they were randomly divided into two main groups according to the type of prefabricated paediatric crown (PZC and PFC; $n = 60$). To ensure that the sizes

of the teeth were equally distributed between the study groups in the process of dividing into all main and subgroups, care was taken to have an equal number of upper–lower and first–second primary molars in each group. These procedures were performed randomly by one of the authors who had not carried out preparations on the teeth.

PZCs (NuSmile) and PFCs (Figaro Crowns) were selected in accordance with the size of the teeth. All the samples were prepared using a high-speed diamond bur under water cooling by the same researcher. The occlusal and axial surfaces of all the teeth in the PZC group were reduced by approximately 2 mm to achieve a passive fit. The crown to be cemented was never tried on the tooth; try-in crowns were used during fitting in the PZC group only. In the PFC group, the occlusal surface and the axial surfaces were reduced by approximately 1 mm to ensure the snug friction fit noted by the manufacturer. The preparation was completed by giving a feather-end finish line and by rounding all line angles in both groups. Each group was divided into two subgroups according to luting cement (PZC/GIC, PZC/RMGIC, PFC/GIC and PFC/RMGIC; $n = 30$). The crowns were cemented with either GIC or RMGIC, according to the manufacturer's instructions. Blinding was not possible in this study due to the distinctive colour and appearance of the crowns and luting cement. Following cementation, each group was finally divided into two subgroups according to whether or not the sample was subjected to the chewing simulation test with thermocycling mechanical loading (CSTTML) ($n = 15$). The study plan is presented in Figure 1.

2.1 | Chewing simulation and fracture tests

The CSTTML procedures were carried out using a device (Mod Dental; Esetron Smart Robotechnologies, Turkey) that can simulate chewing together with thermocycling. Thermomechanical ageing involved 250 000 thermocycles at between 5 and 55°C and 250 000 cycles of the chewing simulation, which corresponds to 1 year of artificial ageing (maximum force = 50 N).[22] A 5-mm-diameter stainless steel ball with a polished surface was used as the antagonist surface. During the test, the chewing cycle accomplished three movements: (i) downward vertical movement simulating incisal clenching; (ii) L-shaped lateral movement of 1 mm simulating lateral movement; and (iii) upward vertical movement simulating opening.

The fracture tests were performed using a universal testing device (Esetron Smart Robotechnologies, Ankara, Turkey) at a crosshead speed of 0.5 mm per min. All the specimens were subjected to axial loading, and a stainless steel bar with a 5-mm-diameter ball end was mounted in the testing machine. When fracture occurred, the loading value corresponding to the turning point on the curve, recorded in Newtons, was evaluated, as shown in Figures 2 and 3.

2.2 | Statistical analysis

After verifying normality (Kolmogorov–Smirnov test) and the homogeneity of variance (Levene's test), the data were analyzed using three-way ANOVA ($2 \times 2 \times 2$) to determine

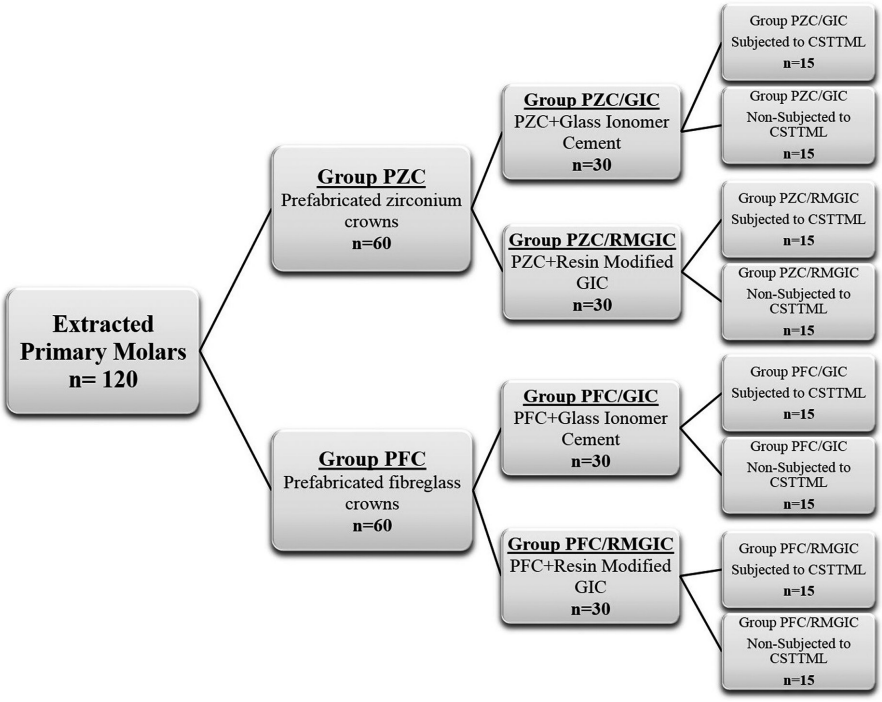


FIGURE 1 FI Charts of the trial. A total of 120 specimens were divided into two main groups and eight subgroups

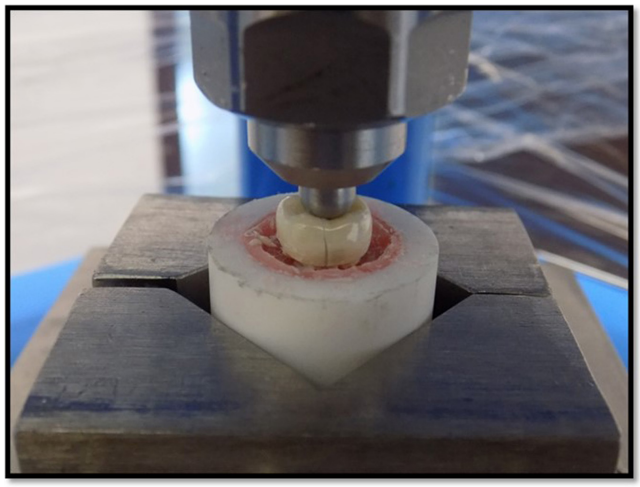


FIGURE 2 View of the prefabricated primary zirconium crowns during the fracture test



FIGURE 3 View of the prefabricated primary fibreglass crowns after the fracture test

any statistical differences among the fracture resistance values. Pairwise comparisons of subgroups within and between groups were conducted using the t-test. Statistical significance was assumed at $p < .05$. All calculations were performed using SPSS 15.0 software (SPSS Inc, Chicago, IL, USA).

3 | RESULTS

The crowns from the groups subjected to the CSTTML were evaluated visually by the same researcher who determined that none exhibited signs of surface damage, fracture or premature debonding, with all crowns found to be 100% successful.

The recorded mean fracture resistance values indicated that the PFC (Figaro Crowns) groups demonstrated higher fracture resistance than the PZC (NuSmile) groups and that this difference was statistically significant ($p = .001$). The highest fracture resistance among the samples was exhibited by the PFC/GIC subjected to the CSTTML group (2515.8 ± 619.2 N), followed by the PFC/RMGIC subjected to the CSTTML group (2285.3 ± 510.2 N), whereas the lowest fracture resistance was exhibited by the PZC/RMGIC non-subjected to the CSTTML group (617.9 ± 162.5 N). Furthermore, the fracture resistance was found to be higher in the groups subjected to the CSTTML except for the PFC/RMGIC non-subjected to the CSTTML group.

Three-way ANOVA (2 × 2 × 2) was conducted to analyse the main effects of crown types, luting materials and crowns subjected/non-subjected to the CSTTML, as well as their interaction effects on the fracture resistance of the crowns.

Although the simple main-effects analysis revealed that crown types [$F(1, 112) = 297.527$, $p = .001$] had a statistically significant effect on the fracture resistance of the crowns, it was found that luting materials [$F(1, 112) = 5.350$, $p = .053$] and crowns subjected or non-subjected to the CSTTML [$F(1, 112) = 3.660$, $p = .059$] did not have a significant effect on fracture resistance.

A statistically significant interaction was detected between crown types and luting materials [$F(1, 112) = 4.245$, $p = .042$]. Yet, the interactions between crown types and crowns subjected/non-subjected to the CSTTML [$F(1, 112) = 1.053$, $p = .307$] and between luting materials and crowns subjected/non-subjected to the CSTTML [$F(1, 112) = 1.406$, $p = .238$] were not significant.

Moreover, the results of the analysis indicate that the three-way interaction between crown types, two different luting materials and crowns subjected/non-subjected to the CSTTML had no significant effect on fracture resistance [$F(1, 112) = 2.075$, $p = .153$] (Table 1).

When PZCs and PFCs were comparatively evaluated within their own groups, no statistically significant difference was found between the subgroups (t-test, $p > .05$). The results are summarised in Table 2 and Figure 4.

4 | DISCUSSION

Although evidence obtained from in vivo studies is more valuable for clinical applications, such studies are limited by difficulties in implementation, ethical compliance and follow-up, as well as the high cost. Therefore, in vitro studies have become more important for testing materials and techniques before clinical application. The results obtained from this type of study are useful to guide the

TABLE 1 Three-way ANOVA (2 × 2 × 2) was conducted to analyse the main effects of crown types, luting materials and crowns subjected/non-subjected to the CSTTML, as well as their interaction effects on fracture resistance

Source of variation	Sum. of squares	*df*	Mean square	*F*	Sig.
Crown types	5.086E7	1	5.086E7	297.527	**.001**
Luting materials	914 644.359	1	914 644.359	5.350	.053
Crowns subjected/non-subjected to the CSTTML	625 704.218	1	625 704.218	3.660	.059
Crown types * Luting mat.	725 782.950	1	725 782.950	4.245	**.042**
Crown types * CSTTML	179 944.281	1	179 944.281	1.053	.307
Luting mat. * CSTTML	240 426.060	1	240 426.060	1.406	.238
Crown types * Luting mat. * CSTTML	354 801.220	1	354 801.220	2.075	.153
Error	1.710E7	112	170 953.917		
Total	3.192E8	120			

Note: Statistically significant values are shown in bold.

TABLE 2 Comparison of fracture resistance values obtained from groups subjected and non-subjected to a chewing simulation test with thermocycling mechanical loading (CSTTML)

				Force require to fracture (N)			
Crown type	**Luting cement**	**Ageing procedure**	***n***	**Mean**	**SD**	**Min**	**Max**
PZC group (NuSmile)	GIC	Subjected to the CSTTML	15	1011.5[a]	259.2	530.2	1273.7
		Non-subjected to the CSTTML	15	930.8[a]	348.6	351.3	1477.2
	RMGIC	Subjected to the CSTTML	15	690.7[a]	131.8	426.7	908
		Non-subjected to the CSTTML	15	617.9[a]	162.5	327.8	851
PFC group (Figaro Crowns)	GIC	Subjected to the CSTTML	15	2515.8[b]	619.2	1758.3	3873.6
		Non-subjected to the CSTTML	15	2070.2[b]	593.7	1356.4	2989.6
	RMGIC	Subjected to the CSTTML	15	2285.3[b]	510.2	1432.2	3184
		Non-subjected to the CSTTML	15	2260.3[b]	366.1	1670.9	2862

Note: Different superscript letters identify groups with statistically significant differences ($p < .001$).

practice protocols for a variety of clinical approaches.[23] The present study was thus planned as an in vitro procedure aimed at comparing the fracture resistance of two different types of aesthetic crown used in primary teeth and at evaluating the effect of luting cement, due to the fact that only a few reports related to PFCs (Figaro Crowns) exist in the literature.[18,19,24]

The luting cement selected for crown cementation plays a significant role in the success of crown restoration, including in terms of establishing retention and marginal integrity. Although some studies have shown that the elastic properties and compressive strength of the luting cement also affect the fracture resistance of zirconia crowns,[14,25] others have indicated that the luting cement has no effect.[26,27] The large cement gap that occurs with PZCs can also be an important factor in this respect. Although researchers have largely recommended resin cement or bioactive cement for the cementation of zirconium crowns,[28,29] it has been shown in both in vivo and in vitro studies that GIC can also be used successfully. In a 36-month follow-up study by Azab et al.,[10] GIC was found to be more successful in terms of retention than bioactive cement. Similarly, at the 36-month follow-up, Mathew et al.[9] observed that GIC-based luting of PZCs was successful. Kist et al.[12] found no difference regarding the fracture load between GIC and BioCem cement in a pilot study, the latter of which was recommended by NuSmile. In this study, RMGIC and GIC were chosen for the cementation of crowns and no statistically significant difference was detected, regardless of the crown material.

A few studies exist that evaluated the fracture load of PZCs for posterior use. Townsend et al.[30] compared the fracture resistance of PZCs for molars from three different manufacturers. In their study, which involved no ageing process, epoxy dies were used instead of primary teeth and the crowns were cemented with GIC. The force required to fracture the EZ-Pedo Crowns (1.091 ± 146.5 N) was significantly higher than that required for NuSmile ZR Zirconia Crowns (691 ± 113.3 N) and Kinder Krowns (576 ± 132.3 N). In another study,[31] which evaluated the fracture resistance of PZCs for the anterior teeth, resin cement was used to lute the crowns and the samples

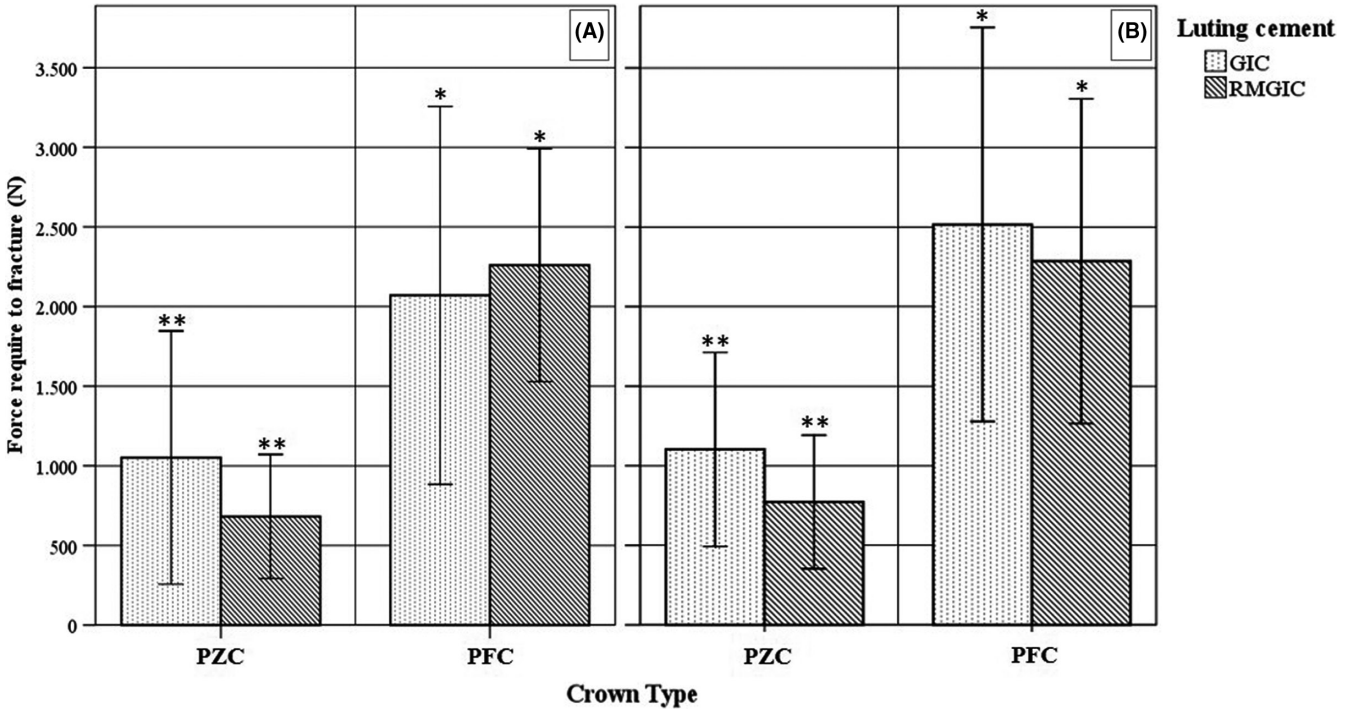


FIGURE 4 Force that causes the crowns to fracture (N), and crowns (A) non-subjected or (B) subjected to the chewing simulation test with thermocycling mechanical loading. The forces required to fracture PFCs were higher than those for PZCs in all groups. The crowns cemented with GIC have a higher fracture resistance value than RMGIC in all groups except for the PFC/non-subjected to the CSTTML group. Luting materials and the CSTTML procedure did not have a significant effect on fracture resistance. Different superscripts (* or **) identify groups with statistically significant differences ($p < .001$). Error bars represent standard deviation. GIC, glass ionomer cement; PFC, prefabricated fibreglass crown; PZC, prefabricated zirconium crown; RMGIC, resin-modified GIC

underwent a CSTTML. The mean force required to fracture PZCs was found to be 937.36 ± 131.69 N for NuSmile ZR Zirconia Crowns and 751.43 ± 02.1 N for Cheng Zirconia Crowns.[31]

Kist et al.[12] measured the highest mean fracture resistance values for PZCs used in these studies, except for Spring EZcrowns, and returned the following results: NuSmile Zirconia Crowns = 1.582 N, Kinder Krowns = 1.570 N and Spring EZcrowns = 893 N. These discrepancies may have been due to methodological differences in terms of, for example, the die material, the shape, type (content) and size of the opposing material, the type of luting cement and the thickness of the cement gap. Cobalt–chrome dies were used by Kist et al.,[12] and it was stated that as this material has higher Young's modulus than dentine, a higher fracture resistance value is likely to be obtained in studies than in a real-world clinical situation.[32]

Results obtained in this study were similar to those obtained in a previous in vitro study using the same methodology (1102.20 ± 304.69 N for GIC and 772.42 ± 209.96 N for RMGIC).[14]

One of the main reasons for using fibre-reinforced composites in dentistry is that it increases fracture resistance, as proven in numerous studies.[17] This study observed that PFCs have a higher fracture resistance value than PZCs. No similar studies on PFCs, however, exist within the dental literature, which means no comparison with previously published data could be carried out. One recently published clinical study compared PFCs with SSCs in terms of 32 primary molar teeth among 10 children, and it was reported that, at a 3-month follow-up, there was no significant difference between the groups. At a 6-month follow-up, PFCs exhibited significant changes from intact crown to either chipped crown or crown with large loss, whereas all SSCs were found to be intact.[19] Nevertheless, further research is needed to examine the wear and fracture resistance properties of PFCs.

The most obvious difference between the groups is related to the amount of preparation, unlike the crown materials used. There have been limited studies conducted on preparation design in relation to the mechanical strength of crowns. In their research investigating the marginal and internal fit of CAD/CAM-fabricated zirconia crowns, Kunii et al. reported that the smaller cement thickness affords mechanical advantages.[33] A study evaluating the effect of cement thickness on failure loads of CAD/CAM crowns found that failure loads decreased with increasing resin cement thickness. The study stated that polymerisation shrinkage can be influential in the failure resistance of crowns, especially

for thicker cement layers.[34] Similarly, it was found that the value of the fracture resistance in PFC groups with lower cement thickness was much higher. When the luting cement used in the study is compared, it is seen that the fracture resistance value of the RMCIS groups is lower. The fact that this difference is more pronounced in PZC groups with a wider cement gap may be related to polymerisation shrinkage. Although PZCs are currently used successfully, perhaps one of the most obvious drawbacks is the need for extensive tooth preparation. On the contrary, PFCs seem to be advantageous in this regard as they require much less preparation. Since a clinical indication for full-coverage crowns is multiple surface caries, however, the remaining tooth structure will greatly affect the preparation design. Teeth with such extensive caries lesions will also have a thicker cement gap in PFC preparation, like PZCs. Therefore, comparison of PZCs and PFCs with the same tooth preparation and PFCs with different tooth preparations in future studies will also contribute to a better understanding of the issue.

A CSTTML was used to comparatively evaluate PFCs and PZCs. All crowns demonstrated a 100% survival rate following the simulation. Contrary to the belief that the fracture resistance of the crowns would decrease due to fatigue resulting from the chewing simulation, the fracture strength of the crowns in both groups, in fact, increased. Kist et al.[12] obtained similar results. The authors exposed different types of paediatric crowns to fracture loading following chewing simulation and observed that the fracture resistance of PZCs, especially that of the Kinder Krowns, had increased. The authors stated that this situation may be related to the phase transformation from the metastable tetragonal state to the stable monoclinic form, depending on the energy applied to the crowns during chewing simulation. Although there was an increase across all groups in the study, the highest increase was obtained with PFCs cemented with GIC. The indication is that this was due to the luting cement used, as was noted in the authors' previous study.

To increase the clinical relevance of these results, the CSTTML was used to simulate the ageing and fatigue of the retention system of crowns in terms of 1 year of clinical use. Although the CSTTML is designed to simulate a complex mouth environment by applying vertical and horizontal forces with sudden temperature changes, it is not entirely sufficient. For example, the saliva content, which is believed to affect the composition and solubility of the luting cement, cannot be imitated. The initial setting reaction and, hence, the properties of the cement may also be different since the cementation performed in a laboratory environment will differ from that performed in an oral environment, given the differences in terms of humidity and temperature. This aspect can thus be regarded as one of the limitations of the investigation, whereas a further limitation relates to the die material used. The fracture resistance of zirconia, as with all ceramics, is dependent on the physical property of the supporting material.[30] Although primary teeth are suitable for clinical conditions, ensuring standardisation is difficult due to the variations between the hydroxyapatite structure and the size and history of the teeth. In addition, different sizes of crowns were selected due to the use of primary teeth and the tooth preparation could not be standardised such that a uniform amount and thickness of luting cement was achieved.

When the authors compared their study results with clinical applications, all the samples showed significantly higher fracture load values than the reported bite forces. It was reported that the maximum mean bite force was between 374.4 and 433 N in 6- to 11-year-old children.[20] On that basis, it can be stated that both types of crown can be used successfully with the luting cement selected in this research.

ACKNOWLEDGEMENT

This study was supported by the Scientific Research Projects Coordination Unit of Akdeniz University (Project No. TSA-2019-5091).

CONFLICT OF INTEREST

All authors certify that they have no affiliations with, or involvement in, any organisation or entity with any financial interests or non-financial interests in the materials discussed in this manuscript.

AUTHOR CONTRIBUTIONS

ZZC and HK conceived the ideas and designed the study; ZZC and İ.Ş. prepared the samples and performed the experiments; HK analysed the data; and ZZÇ. wrote the manuscript with support from HK

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Zülfikar Zahit Çiftçi https://orcid.org/0000-0002-1888-6634
İpek Şahin https://orcid.org/0000-0002-3259-9420
Hüseyin Karayılmaz https://orcid.org/0000-0003-2075-6350

REFERENCES

1. Trachtenberg F, Maserejian NN, Tavares M, Soncini JA, Hayes C. Extent of tooth decay in the mouth and increased need for replacement of dental restorations: the New England Children's Amalgam Trial. *Pediatr Dent*. 2008;30:388-392.

2. Zimmerman JA, Feigal RJ, Till MJ, Hodges JS. Parental attitudes on restorative materials as factors influencing current use in pediatric dentistry. *Pediatr Dent*. 2009;31:63-70.
3. Bucher K, Metz I, Pitchika V, Hickel R, Kuhnisch J. Survival characteristics of composite restorations in primary teeth. *Clin Oral Investig*. 2015;19:1653-1662.
4. Chisini LA, Collares K, Cademartori MG, et al. Restorations in primary teeth: a systematic review on survival and reasons for failures. *Int J Paediatr Dent*. 2018;28:123-139.
5. Santamaria RM, Abudrya MH, Gul G, Mourad MS, Gomez GF, Zandona AGF. How to intervene in the caries process: dentin caries in primary teeth. *Caries Res*. 2020;54:306-323.
6. Attari N, Roberts JF. Restoration of primary teeth with crowns: a systematic review of the literature. *Eur Arch Paediatr Dent*. 2006;1(2):58-62.
7. Toupenay S, Fournier BP, Maniere MC, Ifi-Naulin C, Berdal A, de La Dure-Molla M. Amelogenesis imperfecta: therapeutic strategy from primary to permanent dentition across case reports. *BMC Oral Health*. 2018;18:108.
8. American Academy on Pediatric Dentistry Clinical Affairs Committee-Restorative Dentistry Subcommittee, American Academy on Pediatric Dentistry Council on Clinical Affairs. Guideline on pediatric restorative dentistry. *Pediatr Dent*. 2008;30:163-169.
9. Mathew MG, Roopa KB, Soni AJ, Khan MM, Kauser A. Evaluation of clinical success, parental and child satisfaction of stainless steel crowns and zirconia crowns in primary molars. *J Family Med Prim Care*. 2020;9:1418-1423.
10. Azab MM, Moheb DM, El Shahawy OI, Rashed MA. Influence of luting cement on the clinical outcomes of Zirconia pediatric crowns: a 3-year split-mouth randomized controlled trial. *Int J Paediatr Dent*. 2020;30:314-322.
11. Manicone PF, Rossi Iommetti P, Raffaelli L. An overview of zirconia ceramics: basic properties and clinical applications. *J Dent*. 2007;35:819-826.
12. Kist S, Stawarczyk B, Kollmuss M, Hickel R, Huth KC. Fracture load and chewing simulation of zirconia and stainless-steel crowns for primary molars. *Eur J Oral Sci*. 2019;127:369-375.
13. Clark L, Wells MH, Harris EF, Lou J. Comparison of amount of primary tooth reduction required for anterior and posterior zirconia and stainless steel crowns. *Pediatr Dent*. 2016;38:42-46.
14. Sahin I, Karayilmaz H, Ciftci ZZ, Kirzioglu Z. Fracture resistance of prefabricated primary zirconium crowns cemented with different luting cements. *Pediatr Dent*. 2018;40:443-448.
15. Strassler HE, Serio CL. Esthetic considerations when splinting with fiber-reinforced composites. *Dent Clin North Am*. 2007;51(2):507-524.
16. Alavi S, Mamavi T. Evaluation of load-deflection properties of fiber-reinforced composites and its comparison with stainless steel wires. *Dent Res J*. 2014;11:234-239.
17. Scribante A, Vallittu PK, Ozcan M, Lassila LVJ, Gandini P, Sfondrini MF. Travel beyond Clinical Uses of Fiber Reinforced Composites (FRCs) in Dentistry: a review of past employments, present applications, and future perspectives. *Biomed Res Int*. 2018;2018:1498901.
18. Chakraborty S, Das A, Agarwala P, Zahir A, Lahiri PK, Kundu GK. Esthetic rehabilitation of decayed primary incisors using figaro crowns and strip crowns. *IJDSIR*. 2019;2:490-494.
19. El-Habashy LM, El Meligy OA. Fiberglass crowns versus preformed metal crowns in pulpotomized primary molars: a randomized controlled clinical trial. *Quintessence Int*. 2020;51(10):844-852.
20. Kamegai T, Tatsuki T, Nagano H, et al. A determination of bite force in northern Japanese children. *Eur J Orthod*. 2005;27:53-57.
21. Krithikadatta J, Gopikrishna V, Datta M. CRIS guidelines (Checklist for Reporting In-vitro Studies): a concept note on the need for standardized guidelines for improving quality and transparency in reporting in-vitro studies in experimental dental research. *J Conserv Dent*. 2014;17:301-304.
22. DeLong R, Sakaguchi RL, Douglas WH, Pintado MR. The wear of dental amalgam in an artificial mouth: a clinical correlation. *Dent Mater*. 1985;1:238-242.
23. Bayne SC. Correlation of clinical performance with 'in vitro tests' of restorative dental materials that use polymer-based matrices. *Dent Mater*. 2012;28:52-71.
24. Banerjee A, Ghosh A, Datta P, Zahir S, Kundu G. Esthetic restoration of deciduous anterior teeth using prefabricated zirconia crowns: a case report. *Int J Appl Dent Sci*. 2020;6:113-115.
25. Campos F, Valandro LF, Feitosa SA, et al. Adhesive cementation promotes higher fatigue resistance to zirconia crowns. *Oper Dent*. 2017;42:215-224.
26. Stawarczyk B, Beuer F, Ender A, Roos M, Edelhoff D, Wimmer T. Influence of cementation and cement type on the fracture load testing methodology of anterior crowns made of different materials. *Dent Mater J*. 2013;32:888-895.
27. Nakamura K, Mouhat M, Nergård JM, et al. Effect of cements on fracture resistance of monolithic zirconia crowns. *Acta Biomater Odontol Scand*. 2016;2:12-19.
28. Kramer N, Rudolph H, Garcia-Godoy F, Frankenberger R. Effect of thermo-mechanical loading on marginal quality and wear of primary molar crowns. *Eur Arch Paediatr Dent*. 2012;13:185-190.
29. Stepp P, Morrow BR, Wells M, Tipton DA, Garcia-Godoy F. Microleakage of cements in prefabricated zirconia crowns. *Pediatr Dent*. 2018;40:136-139.
30. Townsend JA, Knoell P, Yu Q, et al. In vitro fracture resistance of three commercially available zirconia crowns for primary molars. *Pediatr Dent*. 2014;36:125-129.
31. Al Shobber MZ, Alkhadra TA. Fracture resistance of different primary anterior esthetic crowns. *Saudi Dent J*. 2017;29:179-184.
32. Kelly JR. Clinically relevant approach to failure testing of all-ceramic restorations. *J Prosthet Dent*. 1999;81:652-661.
33. Kunii J, Hotta Y, Tamaki Y, et al. Effect of sintering on the marginal and internal fit of CAD/CAM-fabricated zirconia frameworks. *Dent Mater J*. 2007;26:820-826.
34. May LG, Kelly JR, Bottino MA, Hill T. Effects of cement thickness and bonding on the failure loads of CAD/CAM ceramic crowns: multi-physics FEA modeling and monotonic testing. *Dent Mater*. 2012;28:e99-e109.

How to cite this article: Çiftçi ZZ, Şahin İ, Karayılmaz H. Comparative evaluation of the fracture resistance of newly developed prefabricated fibreglass crowns and zirconium crowns. *Int J Paediatr Dent*. 2022;32:756–763. doi:10.1111/ipd.12954