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COMPARISON OF FRACTURE RESISTANCE AND MICROLEAKAGE OF TWO TYPES OF PRIMARY MOLAR'S CROWN WITH TWO LUTING CEMENTS: AN IN VITRO STUDY

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ABSTRACT

Objective: This study assessed and compared both the fracture resistance (FR) and microleakage (ML) of esthetic prefabricated zirconia crowns (PZCs) with CAD/CAM-manufactured hybrid ceramic crowns for primary molars, using two different types of luting cements.

Material and Methods: Sixty-four sound or simply carious mandibular second primary molars were divided into two equal groups (n=32) based on crown material fabrication: prefabricated zirconia (NuSmile ZR) for Group 1, and CAD/CAM hybrid ceramic (Grandio disc) for Group 2. Each group was further divided into two subgroups (n=16) by luting cement: conventional glass ionomer (Subgroup A) or self-adhesive resin cement (Subgroup B). After crown cementation and thermal cycling, 8 teeth from each subgroup were used for FR testing, and the remaining 8 for ML testing. Statistical analysis was performed at $p \leq 0.05$.

Results: Regarding FR, the highest mean value (1930.28 N) was recorded for Zr crowns cemented with resin cement, while the lowest value (803.97 N) was measured for CAD/CAM-fabricated hybrid ceramic crowns cemented with glass ionomer cement. For ML, the highest value (4.00 μ) was recorded for both crown systems cemented with glass ionomer cement, while the lowest one (2.00 μ) was found when PZCs were cemented using resin cement.

Conclusions: The luting cement has a significant influence on the ML of crown restorations for primary molar teeth, while the crown material has not. Compared to conventional glass ionomer cement, self-adhesive resin cement has a significant positive impact on both the FR and ML.

KEYWORDS: Primary zirconia, Hybrid ceramic, Glass ionomer cement, Resin cement.

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INTRODUCTION

Dental caries is currently the most frequent chronic disease in the pediatric age group, with a high prevalence in early childhood. Preserving the primary molar teeth with arch integrity and functional efficacy until their scheduled shedding times is considered one of the major aims in pediatric dentistry.[1, 2] In those with high risk caries, full-coverage crowns are suggested for their durability. Furthermore, they have been used for the restoration of negotiated deciduous teeth with developmental imperfections (e.g. hypoplasia/ hypocalcification), traumatic injuries to deciduous teeth affected and also for pulpal therapy (i.e. pulpotomy/ pulpectomy).[3, 4]

Compared to other restorations, full-coverage crowns are more successful for the restoration of tooth with marked degradation; however, cement failure is a leading cause for their clinical failure.[5] The presence of ML in the crown margin permits bacterial penetration into tooth structure leading to recurrent caries, pulpitis, or re-infection of root-treated tooth. One important factor that influences the ML is the type of cement.[5, 6]

Stainless steel crowns have been used over many years for treating primary teeth with marked degradation.[5, 7] However, the need for more esthetic restorations have increased the use of tooth-colored restorations.[8] For the primary teeth in children, esthetic complete-coverage crowns such as pre-veneered SSCs, composite resin strip crowns, and PZCs were developed for their durability and enhanced esthetics.[7, 9]

CAD/CAM system is a new technology for restoring the primary teeth. When the complete -coverage restorations are required in children, CAD/CAM crowns serve as esthetic and conservative alternative as they do not necessitate aggressive tooth preparation as in PZCs.[10] However, there is insufficient information related to the impact of various CAD/CAM materials and luting cements on the FR and ML behaviors of the crowns for primary molars.[7, 11]

The question that still needs to be answered is "whether the crown material and luting cement have a significant influence on both the fracture resistance and ML of crown restorations for primary molar teeth?". As an attempt to answer this controversial question and search for an ideal material that can be used effectively in primary dentition, this in vitro study was performed. This research assessed and compared both the FR and ML of esthetic PZCs with CAD/CAM-manufactured hybrid ceramic crowns for primary molars, using two different types of luting cements. The major null hypothesis tested was that both the crown type and luting cement would not have a significant influence on the FR and ML of crown restorations for primary molars.

MATERIAL AND METHODS

1. Ethical approval:

This study was approved by the Local Research Ethics Committee, Faculty of Dentistry, Mansoura University (no. A0207024PP).

2. Sample size calculation:

Firstly, based on previous studies[12, 13], a power analysis test was conducted to calculate the sample size. Using G power program version 3.1.9.7 based on effect size of 0.42 using 2-tailed test, α error = 0.05 and power = 80.0%, the sample size was 64 in total divided into 2 main groups.

3. Teeth selection:

A total of 64 mandibular second primary molar teeth with sound structure or simple caries were selected. They were freshly extracted with sufficient root length for retention in acrylic resin and homogenous dimensions and morphology. The extraction was based on eruption guidance or ectopic eruption of successors, not based on the study purpose.[7] All teeth were collected from Department of Pediatric Dentistry and Dental Public Health, Faculty of Dentistry, Mansoura University after parents written informed consent and receiving permission from the patients and their parents. At cemento-enamel junction level, the occlusocervical, buccolingual and mesiodistal dimensions with root lengths of teeth were measured with a digital caliper. For achieving the least variation, the average similarity in size and shape was selected while teeth with widely-curved or those with atypical roots were ruled out.

4. Teeth cleaning, disinfection and storage:

All selected teeth were cleaned according to the recommendations by the 1993 Centers for Disease Control and Prevention (CDC, Atlanta, Georgia, US). Dirtiness, carious tissue and defects were removed using high and low speed burs with water spray. The teeth were properly examined under blue light trans-illumination with magnifying lens to assure that the teeth are cracks-free. Then, all selected teeth were autoclaved followed by storage in a container filled with 0.1% thymol solution at room temperature during all testing period.[7, 14]

5. Teeth preparation:

The preparation of all selected natural teeth included reduction of the occlusal surface by 2 mm using a high speed, medium grit, flame-shaped diamond bur (blue coded, MANI INC., Tochigi, Japan) following the natural occlusal contours. Then, the tooth was reduced circumferentially by 20-30% or 0.5-1.25 mm using a round-end, tapered diamond bur (blue coded, MANI INC., Tochigi, Japan). The preparation margin was carefully extended and refined to a feather-edge 1-2 mm above cementoenamle junction.Finally, all prepared surfaces were properly finished and smoothed with fine grit diamond bur to remove any irregularity, bur striations or sharp line/point angles. All the teeth were prepared by the same operator under copious water spray.[15]

6. Teeth grouping:

The prepared teeth were allocated into two equal groups (n = 32) based on the material utilized for crown fabrication; group (1): 32 teeth restored with PZCs (NuSmile ZR, NuSmile Ltd, TX, US), and group (2): 32 teeth restored with CAD/CAM-fabricated hybrid ceramic crowns (Grandio disc BL LT, VOCO GmbH, Cuxhaven, Germany). Each group was subdivided into 2 subgroups (n = 16) based on the material used for crown cementation; subgroup (A): cementation with self-cured glass ionomer cement, and subgroup (B): cementation with self-adhesive resin cement. After crown cementation, from each subgroup, 8 teeth were used for fracture resistance testing and 8 teeth were used for ML testing.

7. Crown fabrication:

For group (1), a PZC (NuSmile ZR, NuSmile Ltd, TX, USA) with appropriate size was selected for each prepared tooth. For group (2), a total of 32 crown restorations were CAD/CAM-constructed from hybrid ceramic material (Grandio disc BL LT, 98.4/15 mm, VOCO GmbH, Cuxhaven, Germany). The CAD/CAM process chain consisted of scanning, designing and milling phases was followed.

7.1. Scanning phase:

After the tooth preparation was successfully finished, proper steam cleaning and complete dryness were applied for all teeth. A highly-sensitive 3D optical scanner (Medit i500, Medit dental, Seoul, Korea) was utilized for tooth scanned. A special software (colLab Scan, v2.0.0.4, Medit dental, Seoul, Korea) was utilized to scan the procedure completion till providing high resolution scan data.

7.2. Designing phase (CAD):

A design software (DentalDB 3.1 Rijeka, exocad GmbH, Darmstadt, Germany) was utilized to design the crown restoration for each scanned tooth. Firstly, the job definition included determination of the tooth, the restoration, and the material. Then, the cement gap thickness, crown path of insertion, and crown morphology were determined until the finished full anatomical crown design was obtained. To standardize the crown morphology of all study teeth, a prefabricated zirconia crown used for group (1) was scanned using a refractory scanning powder (D-SCAN Scanspray, Dentify GmbH, Engen, Germany). This crown scan was used as a master reference model applied for all teeth.

7.3. Milling phase (CAM):

After verifying the virtual design of crown restoration, this finished design was nested using a dental CAM system (iCAM V5 Smart, imes-icore GmbH, Eiterfeld, Germany). A 5-axis wet/dry milling machine (CORiTEC 150i PRO, imes-icore GmbH, Eiterfeld, Germany) was used with the suitable diamond milling tools for both gross milling and fine adjustment. After finishing of the milling process, finishing and high-gloss polishing for the milled unfired crowns were completed using the suitable manufacturer-recommended finishing/polishing tools. Each finished crown was tried-in on the corresponding tooth, cleaned up by gentle steam blasting and finally well-dried.

8. Cementation of crown restorations:

According to teeth grouping, each crown was cemented to its corresponding prepared tooth. Considering both main groups, the crowns of subgroup (A) were cemented using self-cured glass ionomer cement (GC Luting & Lining Cement, light yellow, GC Corporation, Tokyo, Japan) according to the manufacturer's guidelines. The cement was loaded into crown which in turn placed correctly onto its corresponding prepared tooth with slight finger pressure for proper seating. The excess cement was removed using dental cotton pellet followed by finishing and polishing of the margin area.

For crowns of subgroup (B), they were cemented onto corresponding teeth using a dual-cured, syringeable self-adhesive resin cement (han Luting Cement, Han Dae Chemical Co., Chungcbuk-do, Korea) in accordance with manufacturer's instructions. Using a LED light-curing unit (Elipar DeepCure-S, 3M ESPE Dental, MN, USA), initial spot curing of excess cement for 2-3 seconds per margin was performed to allow removal of this excess cement using a probe or a scaler. Light-curing step was completed for up to 40 seconds per margin followed by finishing and polishing. All cemented specimens were stored and preserved at room temperature for 24 hours prior to mounting and testing.[15]

9. Teeth mounting

To facilitate handling of the restored teeth used for fracture resistance testing, roots were embedded vertically along their long axes within acrylic resin blocks. Teeh were separately mounted in a cylindrical plastic ring filled with self-curing acrylic resin material using a 1-arm dental laboratory parallelometer device. For all cleaned selected teeth, a line representing the simulated alveolar bone level was drawn 1 mm below the CEJ level.[7, 16] To represent the alveolar bone surrounding the tooth, a soft mixture of pink, self-curing acrylic resin (Acrostone cold cure denture base material, Acrostone Co., Ltd, Cairo, Egypt) was poured into the ring till the marked line. After complete setting of the acrylic resin material, the block was removed from the ring and the tooth was cleaned, polished and stored in the thymol solution until testing time. All the steps were performed by the same operator.

10. Thermal cycling (Fatigue aging)

Each specimen was subjected to an accelerated artificial aging process using a thermocycler (SD Mechatronik, Feldkirchen-Westerham, Germany). In this study, thermal cycling was performed for 500 cycles altering between 5 ± 1°C and 55 ± 1°C with a dwell time of 30 sec in each water bath and 5 sec of transfer time.[6, 15, 17]

11. Fracture resistance testing:

The selected 8 specimens from each subgroup were subjected to the FR testing using a computercontrolled, dual-column, tabletop universal testing machine (model 3365, Instron Industrial Products, MA, US). The metal loading stylus was attached to the upper movable part of machine while the specimen was secured on the lower fixed part without separating tin foil placed between the occlusal surface of the crown and the loading stylus. The compressive load was axially- and centrally-applied with a 6 mm-diameter, stainless steel, round-end antagonist stylus at a crosshead speed of 1 mm/minute until fracture or failure of the specimen.[12, 18] The maximum load that produced fracture was recorded in newton (N). (Figure 1)

12. Microleakage testing:

The selected unblocked 8 specimens from each subgroup were subjected to ML evaluation test through immersion in 2% methylene blue solution

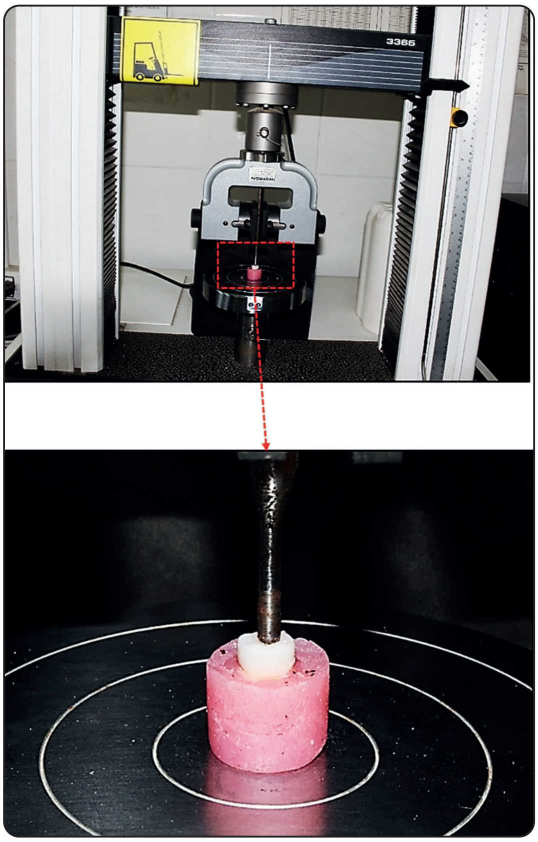

Fig. (1) Fracture resistance testing; the specimen in its place in the universal testing machine with axially- and centrally- applied compressive load.

for 24 h at room temperature.[17, 19] Initially, the root surface underneath the crown margin underwent sealing for 1.0 mm with two layers of nail varnish.[19] After finishing, specimens were washed with distilled water, cleaned of excess methylene blue dye, air-dried and mounted within clear self-curing acrylic resin blocks following the same mounting protocol, but with the acrylic resin level up to the occlusal surface of the crown. Then, they were sectioned buccolingually through the middle with a diamond linear precision saw blade (15LC, BUEHLER, IL, US) mounted in a water-cooled, low-speed (3000 rpm with 19 mm/min feed rate) sectioning machine (IsoMet 5000, BUEHLER, IL, US).[20] After marking the sectioning line on the block, it was fixed firmly in its precise position through a suitable stainless steel holder. (Figure 2)

After the sectioning process completed, the sectioned specimens were assessed using a calibrated stereomicroscope (SZ61TR, Model SZ2-ILST, Olympus Co., Tokyo, Japan) up to 20x magnification to determine the dye penetration level.[15, 20] (Figure 2F) Microleakage values were recorded using the scale given by Tjan et al.[21];

- 0: No ML
- 1: ML to one-third of the axial wall
- 2: ML to two-thirds of the axial wall
- 3: ML along the full length of the axial wall
- 4: ML over the occlusal surface

13. Statistical analysis:

Data underwent analysis by the SPSS software (SPSS Inc., PASW statistics for windows version 26. Chicago: SPSS Inc.). Qualitative data were represented in frequencies and percentages. Quantitative data were represented in means ± SDs for normally distributed data after testing normality by Shapiro-Wilk test. One-way ANOVA test was used to compare > 2 independent groups for normally distributed data with Post hoc Tukey test for pairwise comparison. The significance of the result was set at $p \leq 0.05$ level.

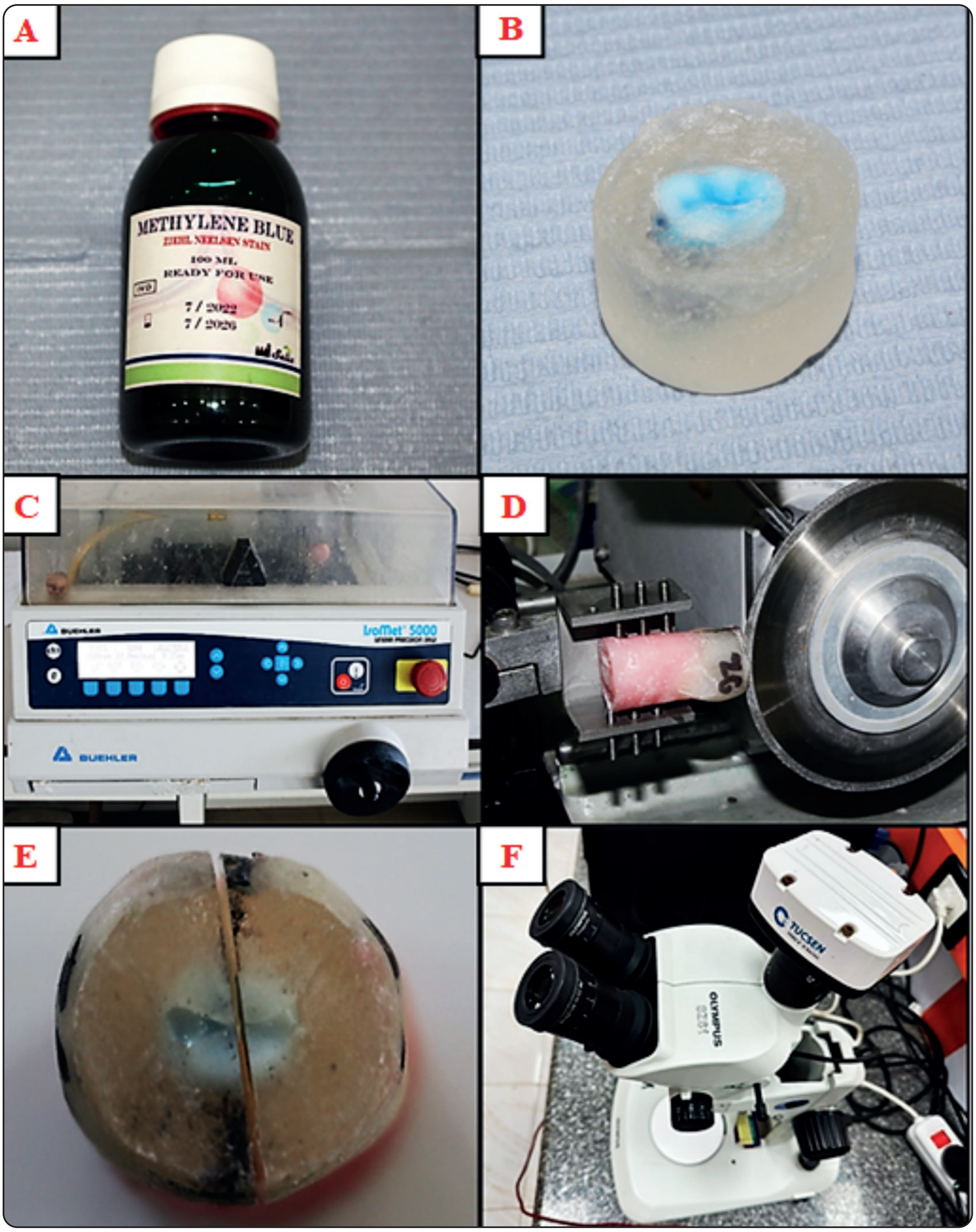

Fig. (2) Microleakage testing; (A) the used methylene blue dye solution, (B) the specimens after dye immersion and mounting into acrylic resin blocks ready for sectioning, (C) the used Isomet 5000 sectioning machine, (D) the specimen in its place before sectioning, (E) the specimen after sectioning, and (F) the used stereomicroscope for microleakage evaluation.

RESULTS

(A) Effect of crown type and luting cement on the FR of crown restorations for primary molars:

The mean failure load values for all groups were as follows: 1029.29 ± 271.56 N for group (1A), 1930.28 ± 560.03 N for group (1B), 803.97 ± 197.89 N for group (2A), and 1489.64 ± 166.07 N for group (2B). The highest mean value of load-to-failure was recorded for PZCs cemented with self-adhesive resin cement, while the lowest mean value was measured for CAD/CAM-fabricated hybrid ceramic crowns cemented with self-cured glass ionomer cement. Results showed a significant difference between tested groups in terms of the mean failure load values (p=0.001). (Table 1) Post hoc Tukey test was used for pairwise comparison of fracture load values among tested groups. Significant differences existed between all groups except between (1A) and (2A) groups (p=0.192). (Table 2)

TABLE (1). Descriptive statistics (Mean ± SD) and One-way ANOVA test (F) for comparison of fracture load values in newton (N) among study groups.

		Fracture Load (Mean ± SD)	Test of significance
Tested groups	**(1A)**	1029.29 ± 271.56[a]	F=17.66 P=0.001*
	(1B)	1930.28 ± 560.03[b]	
	(2A)	803.97 ± 197.89[a]	
	(2B)	1489.64 ± 166.07[c]	

significance at p-value ≤ 0.05. - SD: Standard Deviation. - Group (1A): PZCs cemented with self-cured glass ionomer cement, Group (1B): PZCs cemented with self-adhesive resin cement, Group (2A): CAD/CAM-fabricated hybrid ceramic crowns cemented with self-cured glass ionomer cement, and Group (2B): CAD/CAM-fabricated hybrid ceramic crowns cemented with self-adhesive resin cement. - Mean values (±SD) with same superscripted letters represent non-significant difference and different superscripted letters represent significant one.

Table (2). Post hoc Tukey test for pairwise comparison of fracture load values among tested groups.

(I) group	(II) group	Mean Difference (I-II)	Std. Error	P-value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
(1A)	**(1B)**	-900.98589*	168.47133	0.001*	-1246.0838	-555.8880
	(2A)	225.32458	168.47133	0.192	-119.7733	570.4225
	(2B)	-460.35855*	168.47133	0.011*	-805.4564	-115.2607
(1B)	**(1A)**	900.98589*	168.47133	0.001*	555.8880	1246.0838
	(2A)	1126.31048*	168.47133	0.001*	781.2126	1471.4084
	(2B)	440.62734*	168.47133	0.014*	95.5295	785.7252
(2A)	**(2B)**	-685.68314*	168.47133	0.001*	-1030.7810	-340.5853
	(1A)	-225.32458	168.47133	0.192	-570.4225	119.7733
	(1B)	-1126.31047*	168.47133	0.001*	-1471.4084	-781.2126
(2B)	**(2A)**	685.68314*	168.47133	0.001*	340.5853	1030.7810
	(1A)	460.35855*	168.47133	0.011*	115.2607	805.4564
	(1B)	-440.62734*	168.47133	0.014*	-785.7252	-95.5295

significance at p-value ≤ 0.05. - Group (1A): PZCs cemented with self-cured glass ionomer cement, Group (1B): PZCs cemented with self-adhesive resin cement, Group (2A): CAD/CAM-fabricated hybrid ceramic crowns cemented with self-cured glass ionomer cement, and Group (2B): CAD/CAM-fabricated hybrid ceramic crowns cemented with self-adhesive resin cement.

B) Effect of crown type and luting cement on the ML of crown restorations for primary molars:

It was found that the mean microleakage values for all groups were as following; 4.00 ± 0.00 μ for group (1A), 2.00 ± 0.76 μ for group (1B), 4.00 ± 0.00 μ for group (2A), and 2.25 ± 0.71 μ for group (2B). The highest mean value of microleakage was recorded for both crown systems cemented with self-cured glass ionomer cement, while the lowest mean value was found when PZCs were cemented using self-adhesive resin cement. A significant difference existed between tested groups regarding the mean microleakage values (p=0.001). (Table 3) Post hoc Tukey test was used for pairwise comparison of microleakage values among tested groups. Significant differences existed between all studied groups except between (1A) and (2A) groups (p=1.000) and between (1B) and (2B) groups (p=0.342). (Table 4)

TABLE (3). Descriptive statistics (Mean ± SD) and One-way ANOVA test (F) for comparison of microleakage values in microns (μ) among tested groups.

		Microleakage (Mean ± SD)	Test of significance
Tested groups	**(1A)**	4.00 ± 0.00[a]	F=35.31 P=0.001*
	(1B)	2.00 ± 0.76[b]	
	(2A)	4.00 ± 0.00[a]	
	(2B)	2.25 ± 0.71[b]	

significance at p-value ≤ 0.05. - SD: Standard Deviation. - Group (1A): PZCs cemented with self-cured glass ionomer cement, Group (1B): PZCs cemented with self-adhesive resin cement, Group (2A): CAD/CAM-fabricated hybrid ceramic crowns cemented with self-cured glass ionomer cement, and Group (2B): CAD/CAM-fabricated hybrid ceramic crowns cemented with self-adhesive resin cement. - Mean values (±SD) with same superscripted letters represent non-significant difference and different superscripted letters represent significant one.

TABLE (4). Post hoc Tukey test for pairwise comparison of microleakage values among tested groups.

(I) group	(II) group	Mean Difference (I-II)	Std. Error	P-value	95% Confidence Interval	
					Lower Bound	Upper Bound
(1A)	**(1B)**	2.00000*	0.25877	0.001*	1.4699	2.5301
	(2A)	0.00000	0.25877	1.000	-0.5301	0.5301
	(2B)	1.75000*	0.25877	0.001*	1.2199	2.2801
(1B)	**(1A)**	-2.00000*	0.25877	0.001*	-2.5301	-1.4699
	(2A)	-2.00000*	0.25877	0.001*	-2.5301	-1.4699
	(2B)	-0.25000	0.25877	0.342	-0.7801	0.2801
(2A)	**(2B)**	1.75000*	0.25877	0.001*	1.2199	2.2801
	(1A)	0.00000	0.25877	1.000	-0.5301	0.5301
	(1B)	2.00000*	0.25877	0.001*	1.4699	2.5301
(2B)	**(2A)**	-1.75000*	0.25877	0.001*	-2.2801	-1.2199
	(1A)	-1.75000*	0.25877	0.001*	-2.2801	-1.2199
	(1B)	0.25000	0.25877	0.342	-0.2801	0.7801

significance at p-value ≤ 0.05. - Group (1A): PZCs cemented with self-cured glass ionomer cement, Group (1B): PZCs cemented with self-adhesive resin cement, Group (2A): CAD/CAM-fabricated hybrid ceramic crowns cemented with self-cured glass ionomer cement, and Group (2B): CAD/CAM-fabricated hybrid ceramic crowns cemented with self-adhesive resin cement.

DISCUSSION

Comparative in vitro studies regarding fracture behavior between esthetic prefabricated and custom-made crowns of primary molar teeth as well as ML studies on the most appropriate luting cement for them are lacking. In addition, no complete data exist so far regarding applicability of CAD/CAM-manufactured hybrid ceramic crowns for primary teeth.[11] Hence, this in vitro study assesses and compared both the fracture resistance and microleakage of esthetic PZCs with CAD/CAM-manufactured hybrid ceramic crowns for primary molars, using two different types of luting cements.

Earlier studies utilized different supporting dies such as methacrylate resin, epoxy resin, Cr-Co metal alloy, or natural teeth to evaluate the FR of restorative materials.[7] Yucel and co-workers [22] stated that elastic modulus of supporting die materials influenced the FR of all-ceramic restorations. If supporting dies have higher elastic modulus than dentin, greater load values can be obtained in in vitro studies than in clinical conditions. So, in this study, natural teeth were utilized as supporting dies to obtain relevant fracture load values resembling the clinical conditions. The mandibular primary second molar teeth were selected for this in vitro study as the molar region is the area most often requiring full coverage restorations in the primary dentition.[3]

In our study, to standardize the crown morphology and thickness of all prepared teeth, a prefabricated zirconia crown used for group (1) was scanned. This crown scan was used as a master reference model applied for all teeth. Then, auto-adaptation of this model was made according to each tooth. Townsend et al.[18] found a positive correlation between increased thickness of primary zirconia crowns in the buccal, lingual, mesio-occlusal, and disto-occlusal locations and increased fracture resistance. In light of this finding, one may postulate that increased force required to fracture the crowns is a product of increased crown thickness.

In this study, the oral environment was simulated through subjecting all specimens to artificial thermomechanical aging.[6, 15] In 2015, the latest specifications issued by International Organization for Standardization (ISO/TS11405) recommended that thermal cycling protocol between 5 ± 1°C and 55 ± 1°C with a dwell time of 30 sec in each water bath and 5 sec of transfer time is as an accelerated aging test. This protocol simulate the physiological range of temperatures created in the mouth by hot or cold drinks.[17, 20]

In our study, we assessed the ML by a dye leakage model with methylene blue dye solution for 24 hours at room temperature. Dye penetration technique has been utilized in previous studies demonstrating ML.[17, 19, 20] There is no universally accepted method applied to detect the ML patterns of dental restorations. In other words, it appears that various techniques used for detecting the ML of restorative materials do not yield equivalent results and thus should not be compared.[20]

The major null hypothesis tested was that both the crown type and luting cement would not have a significant influence on both the fracture resistance and microleakage of crown restorations for primary molar teeth. Based on the findings of the fracture resistance test, a significant difference was found between tested groups in terms of the mean failure load values (p=0.001). In other words, a non-significant difference only resulted between the mean fracture load values for both crown systems when cemented with the same self-cured glass ionomer cement. As a result, the luting cement and may be the crown material had a significant influence on the mean fracture load values when primary molar teeth were restored with different cemented crown restorations. Consequently, the minor hypothesis related to the first part of the study regarding the fracture behavior is rejected.

Additionally, the study results demonstrated a significant difference between tested groups regarding the mean microleakage values (p=0.001).

A non-significant difference only resulted between the mean microleakage values when both crown systems were cemented with the same self-cured glass ionomer cement or the same self-adhesive resin cement. This means only the luting cement had a significant influence on the microleakage value when primary molars were restored with PZCs or CAD/CAM-fabricated hybrid ceramic crowns. As a result, the minor hypothesis related to the second part of the study regarding the microleakage behavior is partially accepted.

Esthetic primary crowns represent not also an attempt to meet parents' desire for esthetic restorations but also to meet the dentist's desire for the durability of restorations that can tolerate the occlusal forces on mastication.[23] The highest mean value of load-to-failure was recorded for PZCs cemented with self-adhesive resin cement, while the lowest mean value was measured for CAD/CAM-fabricated hybrid ceramic crowns cemented with self-cured glass ionomer cement.

All studied groups expressed fracture load values significantly surpassed the maximum bite force of pediatric patients previously reported for mandibular primary molar region, supporting their clinical use. Braun and co-workers [24] found that the mean maximum bite force in primary molars was 78 N in children aged 6-8 years and was up to 106 N in those aged 10-12 years. Utilizing a different methodology, Gaviao et al.[25] found the mean bite force of 235.12 N in a sample of 3-6 years old children. Owais and colleagues [26] found that the mean of maximum chewing force was 433 N in late mixed dentition. Even with this increased estimate, the mean force required to cause crown fracture in this study exceeded such values.

Our results may be considered in agreement with the study performed by Bolaca and Erdoğan[7] who evaluated the influence of various CAD/CAM materials on the FR of primary molar crowns. All tested CAD/CAM primary molar crowns including a resin-nano cermic material (Brilliant Crios) showed high fracture load values which exceeded the chewing force. They stated that CAD/CAM primary molar crowns fabricated using such a hybrid ceramic material may be used as a conservative alternative for the complete-coverage restorations of primary molars.

It was stated that the cementation method can influence the FR of CAD/CAM restoration.[27] In present study, the crowns fabricated form both materials showed significantly higher mean values of fracture load when luted with the self-adhesive resin cement than the self-cured glass ionomer cement. This agrees with Weigl et al.[28] study. They found that the fracture strength after 24 hours of the conventionally-cemented monolithic crowns was significantly lower than that of adhesively-bonded crowns.

Our findings could not be expressed in compliance with the results of Beattie et al.[23] who evaluated the FR of NuSmile zirconia crowns cemented with G-Cem resin-based cement for primary mandibular first molars. They found that the mean force required to fracture for this type of primary crowns was 1671 ± 370 N. In our study, the load-to-failure recorded for PZCs cemented with self-adhesive resin cement was 1930.28 ± 560.03 N. This increased fracture resistance may have been due to differences in the study protocol.

Our results are not correlated with Townsend et al.[18] study. They found the force required to fracture NuSmile zirconia crowns cemented with glass ionomer cement was only 691.0 N, while our study revealed that they needed 1029.29 N to fracture. This incompatibility may be due to variation of the study design that they used epoxy dies while we used natural teeth. The fracture resistance of zirconia, as with all ceramics, is dependent on the elastic modulus of the supporting material. The primary dentin has a higher elastic modulus than that of the epoxy die. It was stated that a greater force is required to fracture the crown if a die with a higher modulus of elasticity was used.[18]

Our study revealed a statistically significant difference between both crown materials in terms of the mean failure load values when cemented using self-adhesive resin cement. Prefabricated zirconia crowns recorded a significantly higher fracture load value (1930.28 N) compared to CAD/CAM-fabricated hybrid ceramic crowns (1489.64 N). Such results disagree with that reported by Oğuz et al.[29] They found that prefabricated zirconia crowns had lower load-to-failure value (557.4 N) in comparison with CAD/CAM-fabricated hybrid ceramic crowns (669.6 N) with a statistically non-significant difference.

A possible explanation to differences between our results and other previous studies may have originated from methodological differences. It could be attributed to the differences in the used supporting die material, the type of CAD/CAM block, the test design, the material thickness, and the artificial aging procedures.[7, 18] That's why it is difficult and inappropriate to directly compare the laboratory results of our study with that of earlier studies.

This study showed that the material type significantly affected the FR of primary molar crowns. Fracture load values were higher when prefabricated zirconia crowns were used than in groups restored with CAD/CAM-fabricated hybrid ceramic crowns. This can be attributed to better mechanical properties of the zirconia when compared to other ceramics. Zirconia has high fracture toughness (6.4 MPa $m^{1/2}$) and high flexural strength (>900 MPa).[7] A polycrystalline phase transformation system of zirconia form tetragonal to monoclinic reduces the stress around the initial crack formation and retards its propagation. As a result, zirconia has high mechanical strength enabling it to resist chipping and fracture under function.[7, 29]

The CAD/CAM resin nano-ceramics or the composite resins reinforced with nano-ceramic crystals are materials with superior mechanical properties than conventional restorative composites due to their polymerization at high pressure and temperature.[30] Moreover, compared with ceramics, CAD/CAM resin composites have low elastic modulus making them a preferred material under high occlusal loads.[7, 30]

Grandio material utilized in our trial is a pre-polymerized highly filled (86%) CAD/CAM restorative material based on a nano-ceramic hybrid technology. It has a relatively low elastic modulus (15.5 GPa) close to that of primary dentin (11.59-17.06 GPa) with a coefficient of thermal expansion comparable to dentin.[31, 32] According to Jassim and Majeed,[33] this allows the material to plastically deform to the same extent as the underlying dentin, thus the load is transferred to the underlying dentin and does not accumulate in restorations. Furthermore, CAD/CAM composite materials have low brittleness, high flexibility, and are able to absorb stresses caused by high loads.[7] This might explain the Grandio high fracture load values that are significantly surpassed the maximum bite force previously reported for mandibular primary molar region.

This in vitro research showed that the luting cement had a significant influence on the mean fracture load values when primary molar teeth were restored with different cemented crown restorations. For both tested crown materials, the self-adhesive cementation provided higher fracture load values compared to the traditional glass ionomer cementation technique. This may be attributed to that adhesive cementation permits a close contact between dental substrate, cement, and restoration material so that the occlusal load applied on the restoration is distributed through the tooth, periodontal ligament and alveolar bone.[28]

In our study, the highest mean value of microleakage was recorded for both crown systems cemented with self-cured glass ionomer cement, while the lowest mean value was found when PZCs were cemented using self-adhesive resin cement. This agrees with Gundewar et al.[17] and Iampinitkul et al.[19] studies in which the adhesively-bonded crowns demonstrated the lowest ML, followed in increasing order by the crowns luted with RMGIC while GIC showed the greatest microleakage values. Similarly, Al-Haj Ali and Farah[15] concluded that irrespective of the crown type, the self-adhesive resin cement achieved the least ML which was significantly different from glass ionomer cement.

A statistically non-significant difference only resulted between the mean microleakage values when both crown systems were cemented with the same self-cured glass ionomer cement or the same self-adhesive resin cement. As a result, only the luting cement had a significant influence on the microleakage value when primary molars were restored with PZCs or CAD/CAM-fabricated hybrid ceramic crowns. This is in contrast with Möhn et al.[11] study that the luting gap analysis demonstrated that PZCs had the largest width, while the individually milled hybrid ceramic crowns achieved perfect marginal adaptation. However, they found the adhesive bonding of crowns was associated with superior marginal seal compared to traditional GICs which is comparable to our results.

In present study, the self-adhesive resin cement was better since it involves enamel bonding that occurs by the micromechanical interlocking of resin to hydroxyapatite crystals and rods of etched enamel. Bonding to dentin is accomplished by resin infiltrating into etched dentin, forming micro-mechanical interlock with semi-demineralized dentin forming hybrid layer or resin inter-diffusion zone. Its improved microleakage behavior might be also as luting agents containing resin filler particles have high modulus of elasticity that reduces the ML and boosts marginal wear resistance.[17]

The glass ionomer cement can create a chemical bond with tooth structure by virtue of its chemical structure (often repeating carboxyl groups). The polyacrylic acid chemically binds with certain cations, calcium or phosphorus in the tooth, forming chemical unit with the cement.[20, 34] However, the glass ionomer shows a maximum linear dye penetration and percentage of ML because the glass ionomer cement easily breakdowns in presence of water before its complete set and also because of its weaker binding affinity to the ceramic intaglio surface of tested crowns.[17]

In addition, further studies are required to provide evidence regarding the practicability of CAD/CAM systems in the first dentition and also to explore marginal quality and the FR of different primary crown materials.

CONCLUSIONS

Considering the conditions and outcomes of our study, the following conclusions were reached:

1. arding fracture resistance, PZCs cemented with self-adhesive resin cement has the best behavior, while CAD/CAM-fabricated hybrid ceramic crowns cemented with conventional glass ionomer cement has the worst.
2. All studied groups expressed fracture load values significantly surpassed the maximum masticatory force of pediatric patients previously reported for primary molar region, supporting their clinical use.
3. The luting cement has a significant influence on the microleakage of crown restorations for primary molar teeth, while the crown material has not.
4. Compared to conventional glass ionomer cement, self-adhesive resin cement has a significant positive impact on both the fracture resistance and microleakage of crown restorations for primary molar teeth.

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