ID Design Press, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2019 Dec 15; 7(23):4094-4100.
https://doi.org/10.3889/oamjms.2019.864
eISSN: 1857-9655
Dental Science

ID Design Press

In Vitro Comparative Analysis of Fracture Resistance of Lithium Disilicate Endocrown and Prefabricated Zirconium Crown in Pulpotomized Primary Molars

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Citation: El Makawi Y, Khattab N. In Vitro Comparative Analysis of Fracture Resistance of Lithium Disilicate Endocrown and Prefabricated Zirconium Crown in Pulpotomized Primary Molars. Open Access Maced J Med Sci. 2019 Dec 15; 7(23):4094-4100. https://doi.org/10.3889/oamjms.2019.864

Keywords: Primary; molars; endocrown; zirconia; crown

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Received: 11-Oct-2019; **Revised:** 08-Nov-2019; **Accepted:** 09-Nov-2019; **Online first:** 13-Dec-2019

Funding: This research did not receive any financial support

Competing Interests: The authors have declared that no competing interests exist

Abstract

AIM: This study aimed to evaluate the effect of lithium disilicate endocrowns compared to prefabricated zirconia crown used for restoring pulpotomized primary molars, on their Fracture Resistance and to compare the loads to failure these different ceramic restorations with previously reported posterior occlusal forces.

METHODS: Twenty mandibular left second primary molars were randomly distributed into two groups (n = 10 in each group) the zirconia Crown (Nusmile zr.) Group (G1) and the lithium disilicate (IPS e.max Press) Endocrown Group (G2). In all groups pulpotomy procedure was done before preparation then each sample was prepared based on their allocated restoration, both zirconia crown (Nusmile zr.) and endocrown (IPS e.max Press) were cemented by dual-cure resin cement. All samples were loaded to failure using a universal testing machine (Instron, USA), and the compressive force was applied. The data were analysed using one-way (ANOVA) and Tukey's post hoc significance difference tests. Differences were considered significant at ($p < 0.05$).

RESULTS: Group zirconia crown (G1) showed significantly higher fracture strength than Group (G2) lithium disilicate endocrown ($p < 0.05$).

CONCLUSION: The zirconia crown showed higher fracture resistance than lithium disilicate endocrown. However, both tested zirconia crown and lithium disilicate endocrown withstood the application of axial occlusal forces greater than the reference values for posterior occlusal loads.

Introduction

Early Childhood Caries (ECC) is a continuous public health problem. Impoverished babies, preschool children, disregarding their race, ethnicity, or culture, are at extremely high risk [1]. ECC and severe ECC are considered the most common cause of partial or complete loss of coronal tooth structure in the primary dentition. Posterior teeth are continuously focused on attention as they are vital, particularly in the mastication and development of occlusion [2].

Primary molars with infected coronal pulps due to caries usually require pulpotomy [3]. Pulpotomized primary molar teeth are clinically similar in characteristics to endodontically treated teeth (ETT) which are more susceptible to fracture, mainly due to the increased weakness of the remaining tooth substance following the pathological process of pulp treatment. So, on restoring devitalised teeth, the restorative dental material used should be able to replace the lost tooth structure, and aid in enhancing the mechanical and functional properties, esthetics and coronal seal [4], [5].

Stainless steel crowns "SSC" has been the most widely used type of restoration following pulpotomy in primary molars for over forty years [6], as it protects the weakened cavity walls and prevents marginal microleakage providing the required coronal seal [7]. Nowadays, more esthetically pleasing restorations are required to satisfy both the patients and their guardians [8]. Esthetic full coverage restorations, Zirconia Crowns, which are polycrystalline ceramic without glass component material has high compressive strength, high fracture resistance, corrosion resistance, durability and biocompatibility offer an aesthetically pleasing option with acceptable mechanical properties [9], [10]. Their main disadvantages are their high overall cost, the necessity to remove more tooth structure during tooth preparation, and the high wear to enamel in the opposing teeth [11].

The development of the adhesive philosophy in dentistry and the high bonding performances achieved by modern adhesive systems [12] have gradually changed the concept that each Endodontically Treated Tooth (ETT) should receive a full-coverage restoration, and many classical indications for a full-coverage restoration have become nowadays questioned [13].

Based on Minimally invasive dentistry preservation of a healthy set of natural teeth for each patient should be the objective of every dentist. The goal is the preservation of natural tooth structure [14]. A different protocol is used nowadays in restoring ETT based on the principles of the minimally invasive dentistry, aiming for the conservation of sound tissues. With the aid of adhesive techniques, sufficient retention is ensured without the need for aggressive added features of macro retention to the tooth. Consequently, restoration of ETT follows in many cases the same principles as the restoration of vital teeth [12].

Endocrowns were described in 1999 by Pissis [15] as "adhesive endodontic crowns". These crowns are anchored to the internal portion of the pulp chamber and the cavity margins, such that macro mechanical retention is provided by the friction between its surface and the pulpal walls, and micromechanical retention is obtained using an adhesive cement [15].

Endocrowns are especially indicated in cases of molars with short, dilacerated, obliterated or fragile roots and in cases showing excessive loss of coronal dental tissue and limited interocclusal space, in which there is no adequate thickness available for a restoration with a ceramic covering on an underlining (metal or zirconia) substructures most of which are circumstances that pediatric dentists face when restoring pulpotomized primary molars [16].

These restorative procedures of Endocrown were made possible by the development of etchable acid ceramics (such as leucite and lithium disilicate-based ceramics), dentinal adhesives, and resin types of cement, and consequently, ensure the stability of the piece in the preparation. Pressed or machined ceramics, particularly those reinforced with lithium disilicate, appear to be the best option. The lithium disilicate ceramic used to make the restorations has high mechanical strength and provides restorations with an esthetic appearance very comparable to that of tooth enamel [17].

There is an abundance of reviews discussing the application of lithium disilicate endocrowns in restoring permanent ETT but was scarce regarding the utilisation of endocrowns in restoring pulpotomized primary molars as an upshot of this new restorative proposal. This laboratory study has been carried out to evaluate the effect of lithium disilicate endocrowns compared to prefabricated primary zirconia crown used for restoring pulpotomized primary molars, on their fracture resistance and compare the loads to failure these different ceramic restorations with previously reported posterior occlusal forces.

Material and Methods

The study was approved by the Research Ethics Committee of Minia University, Faculty of Dentistry with reference no. (186) of the year 2016.

Teeth selection

Thirty left mandibular second primary molars were collected, recently extracted for purposes other than this experiment (e.g. exfoliation time), based on similarity in Buccolingual (BL) and Mesiodistal (MD) dimensions using a digital calibre allowing for a maximum of 10% difference from the standard deviation. Twenty teeth then were selected according to the following inclusion criteria: the presence of enamel on the crown margins, having at least three of its axial walls intact with a minimum of 1 mm of remaining sound tooth structure, at least one-third of the root was still intact, with the intact floor. After that, they were disinfected with 10% thymol and stored in distilled water at room temperature until usage.

Teeth mounting

The selected teeth were individually fixed with self-cure acrylic resin (Acrostone, Egypt) in a specially designed “Teflon” mould leaving the CEJ 2 mm above and parallel to the acrylic resin to approximate the height of healthy alveolar bone.

Classification of the samples

Teeth were numbered from 1 to 20 and randomly distributed into two groups (n=10 for each group) according to the type of restoration and material used as shown:

- Group (G1) pulpotomized primary molars restored with prefabricated zirconia (Nusmile zr.) crown.
- Group (G2) pulpotomized primary molars restored with lithium disilicate (IPS e.max Press) endocrown.

Randomisation & allocation of the samples

All samples were numbered from 1 and ascending to 20 and then were divided by the web site by www.**randomizer**.org into 2 equal groups.

Implementation: All steps of sample selection, randomisation and preparation were assigned by the academic candidate under supervision.

Blinding: assessor blinding.

Pulpotomy procedure for each sample

Pulpotomy procedure was done as follows: the caries was removed with a round steel bur, and all access cavity walls were flared to allow complete exposure of the pulp chamber. Then a thick mix of Zinc-oxide & Eugenol (ZOE) paste was applied to the prepared cavity to seal the orifices. For endocrown group (G2) it was covered with a layer of self-cured glass ionomer cement (GIC) (Riva-self cured) to isolate the Zn-oxide eugenol from the successive resin-based restorations and adhesives, while for prefabricated primary zirconium crown group (G1) the cavity was filled with glass ionomer to the top.

Prefabricated primary zirconium crown "Nusmile zirconia crown" Group (G1)

Suitable crown size can be identified using NuSmile (Houston, TX, USA) Try‑In Crowns and should always be selected on the start of tooth reduction.

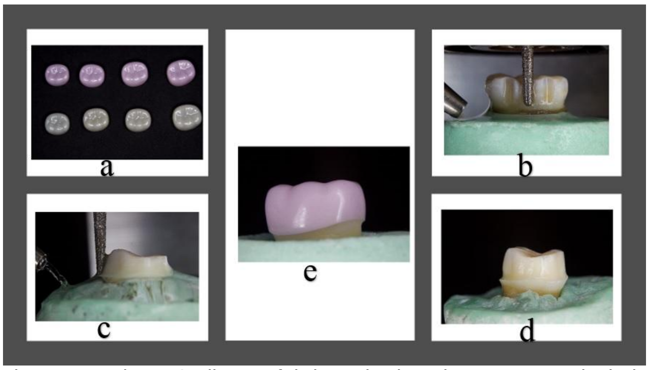

Figure 1: a) NuSmile prefabricated zirconia crown and their counterpart pink try-in crown for lower left 2nd primary molars (Houston, TX, USA), b) depth cuts to determine facial and lingual reduction, c) Showing step of removing of the depth cuts to complete preparation for zirconia crown using a special milling machine mounted with coarse tapered stone, d) after removing all depth cuts leaving an edge all around tooth, e) Showing Try in step: the pink try-in crown is the same size as its tooth-coloured counterpart and was used to accurately determine correct passive fit after smoothing and polishing the anticipated edge to a feather edge

Standardisation for preparation for zirconia crowns depended on the selection of primary molars with minimal differences in size and on using depth cuts, which were needed to determine occlusal, facial, lingual and interproximal reductions about 0.8-1.25 millimetre for (facial-lingual surfaces) and 1.5-2 millimetre for (occlusal). Such procedures were administered with a special milling machine. The anticipated edge from circumferential reduction was stretched out and polished to a feather‑edge allowing for the passive fit of the zirconia crown [18] (Figure 1).

Endocrown (IPS e-max press) Group (G2)

Preparations for endocrowns were made by using a preparation standardisation device a special milling machine incorporated with the conventional-speed straight hand-piece perpendicular to surveyor platform.

Occlusal reduction/ clearance: was achieved by making depth cuts of 1.5mm using tapered stone (TR-12 Dia Bur Mani) then mounting a wheel stone (WR-13 Dia Bur Mani) to reduce occlusal surface. The vertical component was adjusted by allowing only 1.5 mm reduction while the horizontal component was flexible to allow clearance from the whole surface which determines the position of the cervical margin or "cervical sidewalk." or "butt joint" finish line.

***Axial wall preparation**:* the axial walls were flared to a standard degree of divergence by using tapered stone of 8 degrees angle (TR-12 Dia Bur Mani) also while fixing the vertical component such that the stone nearly touches the Glass Ionomer base, while the horizontal component was kept flexible. The step of smoothening and rounding the internal angles of the margins began with the use of the same diamond tip and ended with the polishing of the internal angles with an abrasive rubber tip giving the polished and smoothed preparation (Figure 2).

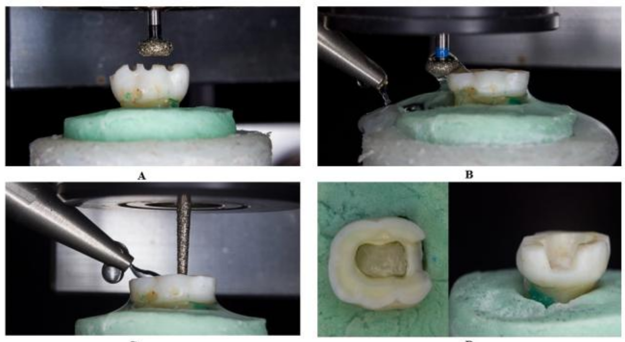

Figure 2: A) showing occlusal depth cuts for occlusal reduction of endocrown preparation, B) showing mounted wheel stone on conventional-speed straight hand-piece attached to the milling machine was reducing occlusal surface with coolant to produce a flat cervical sidewalk, C) showing a mounted tapered stone of 8-degree angle during flaring of axial wall for the axial preparation of endocrown, D) showing final tooth preparation for endocrown restoration with "cervical sidewalk" after smoothening and polishing the walls

Laboratory Phase

The specimens were scanned with a CAD‑CAM scanner, and a wax pattern of the end crowns was milled with a standard occlusal thickness of 1.5 mm. A wax sprue was attached to each wax pattern before investing, producing a mould. The preheating cycle was accomplished at 850°C for one hour; then, the moulds were placed in a furnace for wax elimination and pressed with IPS e.max Press ingot (Ivoclar-Vivadent AG) material at 915°C for 20 min. After that, the endocrown restorations were separated, finished and glazed.

Bonding procedures

For cementation of pediatric prefabricated zirconium crown (Nusmile zirconia crown) self-etch, self-adhesive automix dual-cure resin cement (TOTALCEM-Itena-France) was employed to sit NuSmile zr. Crowns (Figure 3).

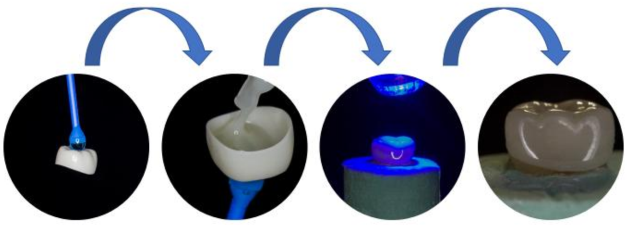

Figure 3: Steps of cementation of Nusmile zirconia crown using TOTALcem dual-cure self-adhesive resin cement

For bonding of IPS e.max Press endocrowns: surface treatment was done as follow Tooth surface enamel was selectively etched by 37% Phosphoric acid (Jade-USA) for 20 sec and rinsed thoroughly by water spray then air-dried.

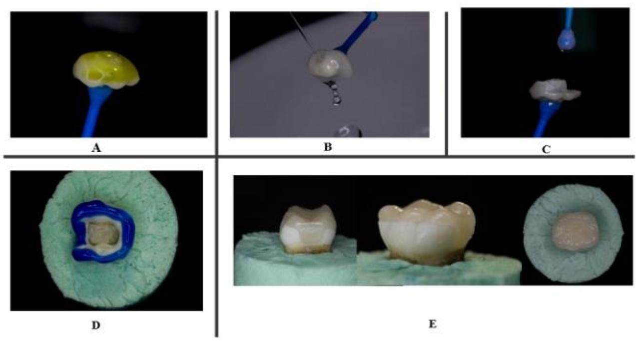

Figure 4: Showing steps of cementation of endocrown A: etching of intaglio of endocrown with 9.5% HF acid for 20 seconds B: rinsed thoroughly for 60 seconds C: Porcelain Silane was then applied by micro brush on the etched intaglio, D: enamel was selectively etched by 37% Phosphoric acid for 20 sec E: Endocrown after cementation with dual-cure resin cement

Endocrown surface, etching of the Intaglio surfaces of the endocrowns was done using porcelain etchant (9.5% HF acid: Bisco USA) for 20 seconds, then rinsed thoroughly for 60 seconds then dried with air. Porcelain Silane (Pentron-USA) was then applied by a micro brush then allowed to dry for 60 seconds. Then the Self-adhesive resin cement (TOTALCEM-Itena–France) was applied using auto mix syringe to the fitting surface of the previous surface-treated endocrowns and the prepared teeth. The applied cement was then lightly thinned with air to avoid its coagulation. The endocrowns were placed on their corresponding preparations by static finger pressure. The bonded endocrowns were exposed to a brief light curing for only 2 seconds. Excess cement was removed with a scaler, and then light-curing was done for 40 seconds for each side, (Figure 4).

Fracture Resistance Test

All samples were individually mounted on a computer-controlled material using a universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a load cell of 5 kN and data were recorded using computer software (Instron® Bluehill Lite Software). Samples were secured to the lower fixed compartment of the testing machine by tightening screws. Fracture test was done by compressive mode of load applied occlusally using a metallic rod with a round tip (3.6 mm diameter) attached to the upper movable compartment of testing machine travelling at cross-head speed of 1mm/min with tin foil sheet in-between to achieve homogenous stress distribution and minimisation of the transmission of local force peaks. The load at failure manifested by an audible crack and confirmed by a sharp drop at the load-deflection curve recorded using computer software (Bluehill Lite Software Instron® Instruments). The load required to fracture was recorded in Newton (N). (Figure 5).

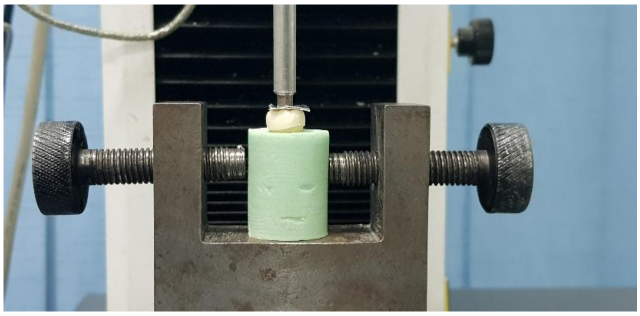

Figure 5: Showing fracture test done by compressive mode of load applied occlusally using a metallic rod with a round tip (3.6 mm diameter) using a universal testing machine

Results

Data were presented as mean, standard deviation (SD), range (Minimum-Maximum) for values. One-way ANOVA followed by Tukey post hoc test was used. Data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. The significance level was set at $p \leq 0.05$ and 95% Confidence interval. Statistical analysis was performed using Graph Pad Instat (Graph Pad, Inc.) software for windows.

Fracture resistance test results measured in Newton (N) as a function of restoration type are summarised in Table 1 and graphically drawn in Figure 6.

Table 1: Comparison of fracture resistance test results (Mean and SD) between both *restoration* groups

Variables		Mean	SD	95% CI		Range	
				Lower	Upper	Mini.	Maxi.
Restoration type	Gr 1	1420.893	308.39	1219.415	1622.372	1145.13	1883.48
	Gr 2	854.427	130.52	769.152	939.701	658.64	1018.91
p value		0.0001*					

*; significant ($p < 0.05$) ns; non-significant ($p>0.05$).

The mean and SD values recorded for ***G1*** were (1420.893 ±308.39 N), while for ***G2,*** the mean and SD values were (854.427±130.52 N).

The difference was statistically significant at p=0.0001.

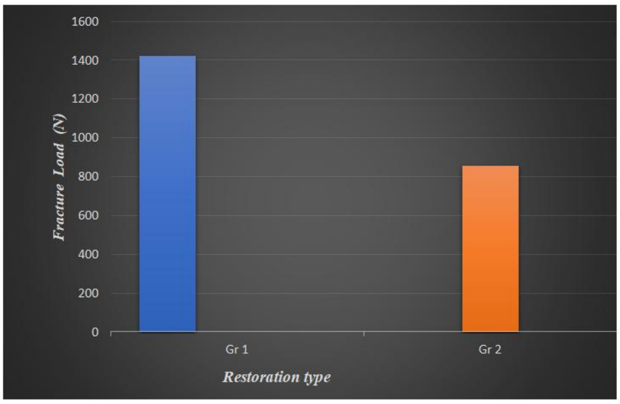

Figure 6: Column chart showing the mean values of fracture resistance for both restoration groups

Discussion

The challenge of restoring pulpotomized primary molars continues to be a problem in Pediatric Dentistry. Stainless steel crowns have been the leading treatment modality and are considered the gold standard for treating pulpotomized primary molars. However, with the evolution of Esthetic dentistry, both pediatric patients and their guardians have been seeking more esthetic options other than stainless steel crowns [19], [20].

Zirconia crowns offer an aesthetically pleasing option, but their complicated manipulation, aggressive full tooth reduction [21], risk of causing tooth wear to the opposing dentition, and their high cost are all drawbacks that limit their usage [22].

More conservative, yet aesthetically pleasing, treatment options have become available, that is due to the increased popularity of adhesive dentistry, which questions the need for aggressive tooth preparations needed for full coverage modalities [23].

The present study was undertaken to evaluate the effect of lithium disilicate endocrowns compared to prefabricated zirconia crown used for restoring pulpotomized primary molars, on their fracture resistance.

In vitro testing was employed because it overcomes many limitations associated with clinical testing such as individual human variation by establishing a controlled environment. These tests provide a guideline about the load-bearing capacity of the different systems on a prosthetic restoration like crowns may provide information that is closer to the clinical situation than testing material properties on standardised samples [24].

Endocrowns were selected for this study because of their conservative approach and fulfilling esthetic demands for patient's and become a frequent treatment modality depending on the remaining tooth structure [25].

Moreover, the data provided regarding the application of Endocrowns as a restoration for pulpotomized primary molars is limited to case reports only.

Previous studies [26] have used artificial abutments as specimens for primary molars for standardisation purposes, on measuring fracture resistance, for better standardisation purposes. However, artificial replicas fail to reproduce the actual force distribution at the inner surface of the crown.

Human teeth were selected for this study to mimic better the clinical situation where the contour of the pulp chamber and root canals, and the ratio between the crown and root would be more accurate than on artificial teeth. The monoblock action of the endocrowns is dependent on the enamel and dentin surface available for bonding, especially that the fracture resistance of the specimens would depend greatly on the surface treatment of not only the restorations but on the tooth surface as well [27] It was compared with prefabricated zirconia crown since it is commonly used by many pediatric dentists.

Previous studies [28], [29] discussed Endocrowns as a restoration for permanent endodontically treated teeth (ETT), and the obtained results had been assumed to apply to primary teeth, but some evidences suggest significant morphological and chemical differences between permanent and primary dentition, such as a less mineralisation and larger tubular diameter of dentinal tubules [30].

Reinforced, acid etchable dental ceramics as lithium disilicate ceramic (IPS e.max Press/Ivoclar Vivadent), have been the materials of choice for the fabrication of endocrowns, because they guarantee the mechanical strength needed to withstand the occlusal forces exerted on the tooth, as well as the bond strength of the restoration to the cavity walls [17].

Teeth were prepared according to clinically established preparation criteria for all-ceramic endocrowns using a special milling machine to ensure standardisation of the preparation [31].

The samples testing was done by applying compressive load using a universal testing machine along the long axis of the endocrown using a load applicator in the form of stainless-steel round tip with a 3.6 mm diameter centred in occlusal surface between the buccal and lingual cusp with tin foil sheet in-between to achieve homogenous stress distribution and minimisation of the transmission of local force peaks, at crosshead speed of 1mm/min until failure.

Compressive loading until failure represented a worst-case scenario. It does not simulate what takes place in the clinical oral environment, in which teeth are subjected to masticatory forces over a long period which may cause fatigue resulting in tooth fracture. However, this test would at least detect differences between different treatment modalities regarding their strength. This method of testing has been widely used in previous studies [32].

It was found that Nusmile zirconia crowns recorded statistically significant higher fracture resistance with mean ± SD values (1420.893 ± 308.39 N) than lithium disilicate endocrowns with mean ± SD values (854.427±130.52 N).

The mean occlusal loads to failure the prefabricated primary zirconia crowns tested in this study were related to those produced by research performed by Vinson and colleagues [33].

The physiologic maximal occlusal force may vary up to (500 N) depending on facial morphology and age [34]. Braun and colleagues measured the maximum bite force in the area of the first primary molar and the first permanent premolar. Linear regression generated values of maximum bite force ranging from 78 N for 6-year-olds to 106 N for 10-year-olds [35]. The results from a study of molar bite force about occlusion, craniofacial dimensions, and head posture in children of age 7-13 years old were Angle Class I: 349.2 (N), Class II: 369.3 N & Class III: 288.3 N [36]. In this study, the mean fracture loads for different tested groups were beyond the mean reported maximum masticatory forces. Therefore, it can be assumed that all the tested specimens could withstand the maximum intraoral posterior masticatory forces.

The mean occlusal loads to failure lithium disilicate endocrown tested in this study were comparable to those produced by a study done by Al-shibri (2017) in which the fracture resistance of endodontically treated maxillary premolars restored with lithium disilicate endocrown was tested [34].

On the contrary, the results of the current study were lower than those reported by Altier [37]; this contradictory finding might be related to the difference in the occlusal thickness of the endocrown, as in this study the minimal occlusal thicknesses were used 1.5 mm to accommodate for minimal interocclusal space in primary molars, and methodology between studies.

In conclusion, within the limitation of this study, the following conclusions were drawn:

- All fracture resistance loads obtained were far beyond the maximum masticatory forces, which can withstand the maximum intraoral masticatory forces in the primary molar region.
- Lithium disilicate endocrown can withstand the maximum intraoral masticatory forces in the primary molar region with a minimum thickness of 1.5mm.
- The forces determined to cause failure with NuSmile zirconia crowns were significantly higher than those cause failure to lithium disilicate endocrowns.

Clinical Relevance and Importance: According to our knowledge, this was the first study in which fracture resistance, of lithium disilicate endocrown, was measured to withstand teeth weakened by access cavity preparation for pulpotomy in primary molars.

Recommendations: In-vivo studies should be conducted to help the clinician predict the clinical performance of lithium disilicate endocrown in pulpotomized primary molars.

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