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Impact of restorative material on fracture behaviors of class II restoration in endodontically treated deciduous molars

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The purpose of this study was to investigate the fracture behavior of endodontically treated (ET) deciduous molar when directly restored with different restorative materials in Class II (MO) cavities in comparison with permanent teeth. MO cavities were prepared with 2.4–2.5 mm and 1.9–2.0 mm in buccolingual width, and mesiodistal width of each cavity walls, respectively, followed by direct restoration with different materials: resin-modified glass ionomer cement (RMGIC), composite resin (CR), and composite resin containing 25% short glass-fiber (SFRC). All specimens were subjected to mechanical loading tests at a speed of 1 mm/min and evaluated fracture resistance and fracture modes. A one-way ANOVA followed by a Tukey multiple comparisons analysis was used. Deciduous-SFRC (3,310.5±396.2 N) were significantly higher fracture resistance than permanent-RMGIC (1,633.8±346.8 N) ($p<0.001$), and permanent-CR (1,400.0±381.3 N) ($p<0.001$). For the direct restoration of MO cavity after endodontic treatment, SFRC demonstrated its promising performance in load-bearing capacity and failure mode, especially in ET deciduous molars.

Keywords: Deciduous molar teeth, Endodontically treated, Fracture load, Fracture behavior, Short fiber-reinforced composite

INTRODUCTION

Endodontically treated teeth (ET) are considered to be at increased risk of fracture due to the loss of the pulp chamber roof, the pericervical dentin or even the marginal ridges[1)], which results in a loss of structural integrity[2)]. When dealing with extensive, multi-surface lesions or severe decay following deciduous molar ET, pediatric clinicians often choose for the use of full-coverage restorations. However, the most common cases of endodontic treatment in pediatric dentistry consist of MO/OD caries with a large amount of remaining tooth structure. Although the direct restorative method is a more convenient option for cases with a large amount of remaining tooth structure after ET, there is no evidence regarding restorative materials or the fracture resistance of Class II cavities, which is MO/OD after ET of deciduous molars.

Since the root resorption of deciduous teeth begins approximately 2 years before the exfoliation phase, no post procedure is performed after root canal filling, and the core is filled with material. The required clinical durability after ET restorations of deciduous molar teeth is much shorter than that of permanent teeth, 7 years at most. Therefore, it is important that the restoration of the remaining dentin of ET deciduous molar teeth serves as structural reinforcement until the replacement period.

In permanent ET teeth, the restorative treatment of choice largely depends on the dimensions of the cavity, namely the number of remaining cavity walls and their thickness[3)]. MOD cavities cause an average 63% loss in relative cuspal stiffness[4)], whereas Class I occlusal cavities cause only 5%–20% loss[5)], and it is often suggested that Class I cavities in permanent ET teeth can be safely restored directly with filling materials[6)].

In recent years, with the advancements of adhesive technique, direct restorations in cavities of permanent ET teeth particulate filled composite resin materials have been attracting attention. A variety of choices are available to the restorative materials, these include resin-modified glass ionomer cements (RMGICs), conventional composite resins (CR), short fiber-reinforced composite resins (SFRC). Among them, SFRC has been recommended to reinforce restored cavities in high stress-bearing areas, including ET permanent posterior teeth[7,8)]. In deciduous ET teeth in core, glass ionomer cements are the first material of choice in ET primary dentition, then comes the flowable CR. Recently, a new type of flowable SFRC has been developed to overcome some weakness or limitations of using CR in large restorations. Flowable SFRC was reported to exhibit improved mechanical properties regarding strength, fracture toughness, fatigue resistance and polymerization shrinkage and to show a more favorable (restorable) type of failure behavior in comparison to CR[9)]. And, in a study

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of fatigue survival using flowable SFRC was reported for the restoration of root canal treated permanent molars, the flowable SFRC restorations showed higher survival rates[10]. In the situation of restoring the remaining tooth structure in ET deciduous molar teeth, the question arises whether the application of SFRC influences the fracture behavior of the restoration. Although there have been various studies on the fracture of ET permanent teeth and the type of post-core restoration, to our knowledge, no definite has yet tested SFRC in cavities after ET deciduous molar teeth restored with direct restoration. It remains uncertain whether SFRC is a suitable option for the direct restoration of MO or OD cavities following ET. The reason for selecting the premolars as the comparison group is that the premolar tooth is successional tooth of the deciduous molars, and because deciduous molars and premolars show similar hardness trends[11,12], the impact of restorative materials on the fracture behavior of premolars may be acceptable for the restoration of deciduous teeth. Therefore, the aim of this study was to investigate the fracture behavior of ET deciduous molar teeth when directly restored with different restorative materials in Class II cavities (MO) compared to ET permanent teeth groups.

The null hypotheses are that (1) there is no difference between deciduous teeth and permanent teeth and (2) there is no difference among materials.

MATERIALS AND METHODS

In total 48 teeth, 24 second deciduous molars extracted for replacement period and 24 premolars extracted for orthodontic or periodontal causes, were collected for the current research according to the following inclusion criteria, no caries or cracks, no prior endodontic procedures, and no coronal restorations. The teeth were kept in distilled water at 4°C to be prepared. The coronal dimensions of the included teeth were standardized as follows: 8.5–9.4 mm in buccolingual width and 9.3–10.2 mm in mesiodistal width for second deciduous molars; and 9.1–10.0 mm in buccolingual width and 7.1–8.0 mm in mesiodistal width for premolars. Both the second deciduous molars and premolars were randomly allocated into 3 groups based on the three different restorative materials (6 test groups; n=8/group). The research protocol of this study, extracted teeth were collected with permission obtained from the Institute of Dentistry, University of Turku, Finland, in accordance with the law No. 101/2001, Section 20, Act on the Medical Use of Human Organs, Tissues and Cells. No personal data of the patients were collected.

Specimen preparation

MO cavities with standardized wall thicknesses and depths were prepared for each deciduous molar by the one trained operator (K.W.) followed by a conventional endodontic treatment, and premolars as well (Fig. 1). Class II (MO) cavities were prepared with 2.4–2.5 mm, 1.9–2.0 mm, and 4.8–5.0 mm in buccolingual width, mesiodistal width of each cavity walls, and depth, respectively. The tooth preparation was performed using a square-end parallel diamond bur (diamond no.835,

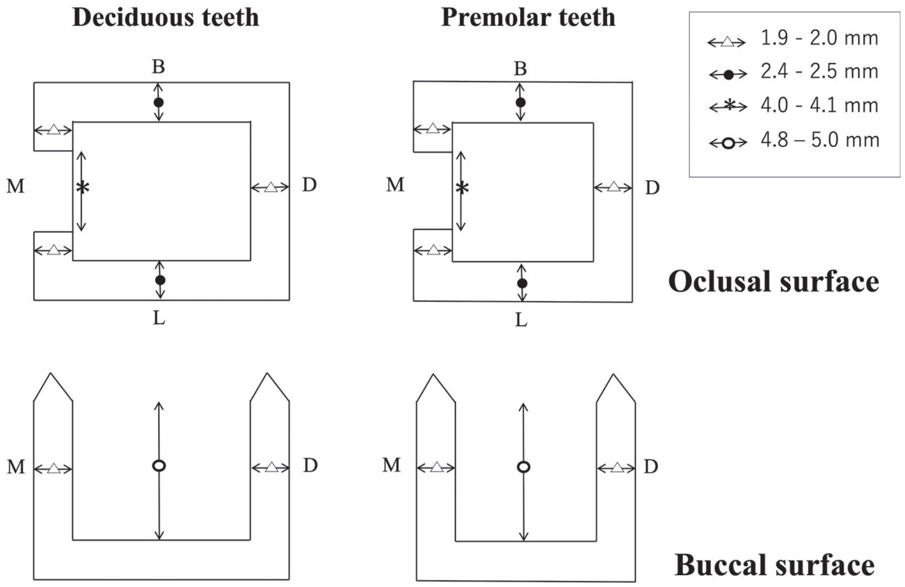

Fig. 1 Schematic cross section of cavity proportions prepared in deciduous molars and premolars subject to mechanical loading testing.
Depth/wall thickness per deciduous and premolar group: B: buccal, L: lingual, M: mesial, D: distal. Deciduous molar and permanent premolar of MO cavities of deciduous molars and permanent premolar with same wall thicknesses and with same depths.

SAR-Machine, Eura, Finland). The size of the occlusal cavity was standardized using a digital caliper (Mitutoyo, Kawasaki, Japan) both in buccolingual and mesiodistal directions. In the endodontic treatment procedure, each included tooth was treated with the concept reported by Molnár *et al.*[10] as follows: after shaping with step-back technique (maximum file size 35–40), the root canals were filled with guttapercha (Gutta percha points, GC, Tokyo, Japan) for premolars[10], while they were filled with Premixed Calcium Hydroxide (Vitapex, Neo Dental Chemical, Tokyo, Japan) for deciduous molars.

Three different restorative materials shown in Table 1 were used for coronal restoration both in the deciduous molar specimens (Groups 1–3) and premolar specimens (Groups 4–6).

During the pretreatment, the enamel was acid-etched selectively with 37% phosphoric acid (Scotchbond Universal etchant, 3M/ESPE, Seefeld, Germany) for 15 s followed by rinsing with water spray for 15 s. Specimens in the groups 2, 3, 5 and 6 received the above-mentioned pretreatment. After air drying the coronal cavity with air, a one-step universal adhesive system (G-Premio Bond, GC Europe, Leuven, Belgium) was applied, according to the manufacturer's instructions using a microbrush-X disposable applicator (Pentron Clinical Technologies, Orange, CA, USA). The adhesive agent was light-cured for 60 s using an Elipar TM S10 curing light (3M/ESPE). In RMGIC groups (groups 1 and 4) was conditioned with polyacrylic acid (Cavity Conditioner, GC Europe) according to the manufacturer's instructions.

Group 1: The core cavities of deciduous molar were restored with RMGIC (Fuji II LC, GC Europe) applied (layer 2 mm) and light-cured according to the respective manufacturers' instructions. The last occlusal layer was light-cured for 60 s, all other layers were cured for 40 s.

Group 2: The core cavities of deciduous molar were restored with flowable composite resin (CR; G-aenial Universal Flo, GC Europe) applied in a horizontal layering technique (approx. 2 mm thick each) according to the anatomy of occlusal. The last occlusal layer was light-cured for 60 s, all other layers were cured for 40 s.

Group 3: The core cavities of deciduous molar were restored with flowable SFRC (everX Flow Dentin Shade, GC Europe) applied in a horizontal layering technique (approx. 2 mm thick each) according to the anatomy of occlusal. The last occlusal layer was light-cured for 60 s, all other layers were cured for 40 s.

Group 4: The core cavities and occlusal layer of the premolar were restored as described by RMGIC in Group 1.

Group 5: The core cavities and occlusal layer of premolar were restored as described CR in Group 2.

Group 6: The core cavities and occlusal layer of premolar were restored as described SFRC in Group 3.

Finally, for all restored specimens were finished with an aluminum oxide polishers (OneGloss PS Midi, Shofu, Kyoto, Japan). Table 2 was shown the details of the groups.

Experimental design

The study evaluated and compared fracture resistance and fracture modes among six groups (presented in "*Specimen preparation*" section) with different restorative materials and tooth types.

Mechanical loading test

After the restorative procedures, the specimens were stored in water for 1 week (at 37°C, 100% humidity) in

Table 1 Three different restorative materials used

Material	Comosition	Manufacturer	Type	Code
GC Fuji II LC CAPSULE	Powder: fluoroaluminosilicate glass Liquid: methacrylic acid ester, polycarboxylic acid, water	GC, Europe	Light-Cured Resin-Reinforced Glass Ionomer	RMGIC
G-aenialTM Universal Flo	Monomer: UDMA, TEGDMA, Bis-MEPP Filler: Silica, Strontium glass	GC, Europe	Flowable Composite resin	CR
everX Flow TM Dentin Shade	Monomer: UDMA, TEGDMA, Bis-EMA Filler: micrometer scale glass fiber, barium glass	GC, Europe	Short Fiber Reinforced Flowable Composite resin	SFRC

Table 2 Pretreatment details for each group

Materials and group	RMGIC		CR		SFRC	
	Deciduous (group 1)	Permanent (group 4)	Deciduous (group 2)	Permanent (group 5)	Deciduous (group 3)	Permanent (group 6)
Pretreatment	polyacrylic acid		37% phosphoric acid		37% phosphoric acid	
Adhesive system	–	–	+	+	+	+

an incubator (BE 600, Memmert, Schwaback, Germany) before the fracture loading test. Specimens were embedded in methacrylate resin (Vertex Self Curing, Vertex Dental, Yeist, the Netherlands) at 1 mm from the CEJ to simulate the bone level. After embedding, all specimens were immediately subjected to a static loading test using a universal loading device (LLOYD LR30KPlus, AMETEK, West Sussex, UK). Each test was performed using a 6mm diameter stainless-steel ball-shaped stylus positioned at the middle of the occlusal surface (Fig. 2). Mechanical loading was at a speed of 1 mm/min[13-15]. The maximum failure load was recorded in newtons (N).

Fracture mode analysis

After mechanical loading testing, the specimens were examined for fracture patterns both visually and under stereomicroscope (Heerbrugg M3Z, Wild-Heerbrugg, Gais, Switzerland) with a 6.5× magnifications to detect the type and location of failure and fracture patterns. According to the methodology reported by Scotti *et al.*, two-examiners performed distinct restorable or non-restorable fractures with an agreement. A restorable fracture is above the CEJ, meaning that the tooth can be restored. While a non-restorable fracture expands below the CEJ and the tooth is likely to be extracted[16].

Statistical analysis

Since the Levene and Shapiro-Wilk tests confirmed equal-variance normality of all data, parametric tests were performed. Two-way analysis of variance (ANOVA) was used to statistically analyze the effects of the two factors (material type and tooth type) on the maximum failure load. In addition, a one-way ANOVA followed by a Tukey multiple comparisons *post hoc* analysis was used to compare the fracture force among all groups. The statistical analyses were performed using a statistical software (IBM SPSS Statistics version 26.0, IBM Japan, Tokyo, Japan). The significance level was set at 5%.

RESULTS

Fracture resistance

The mean values and standard deviation of the fracture resistance for each group and the results of one-way ANOVA followed by a Tukey multiple comparisons are shown in Table 3. The deciduous molars with SFRC restoration (group 3) showed the highest fracture resistance (3,310.5 N±396.2) among all the tested groups. There was no statistically significant difference among three deciduous groups (groups 1–3). Meanwhile, three deciduous groups show higher fracture resistance that each of permanent groups (groups 4–6). Especially, group 3 were significantly higher than group 4 (premolars with RMGIC) ($p<0.001$), group 5 (premolars with CR) ($p<0.001$), and group 6 (premolars with SFRC) ($p=0.001$). Within the permanent groups, group 6 (premolars with SFRC) showed significantly higher fracture resistance (2,264.5±663.0 N) than group 5 (CR: 1,400.0±381.3 N) ($p=0.001$).

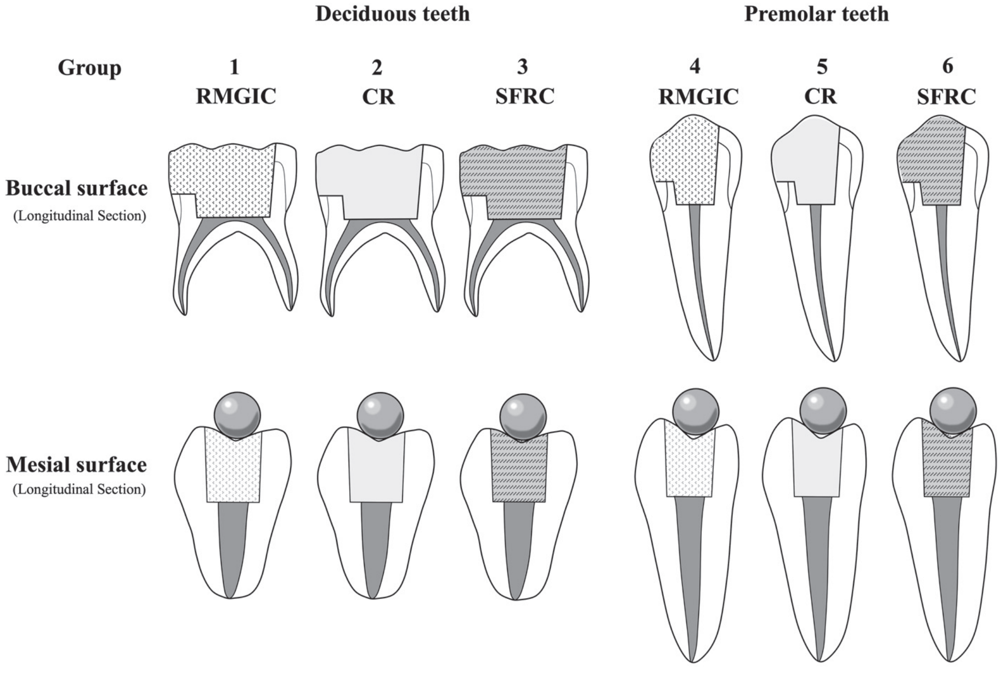

Fig. 2 Schematic figure representing the test groups (Groups 1–6) with different restorative materials (Longitudinal Section).
Gr1–3 are deciduous molar and Gr4–6 are permanent premolar. Gr1: RMGIC; Gr2: CR; Gr3: SFRC; Gr4: RMGIC; Gr5: CR; Gr6: SFRC.

Table 3 The mean values and standard deviation of the fracture resistance for each group

Fracture resistance	RMGIC		CR		SFRC	
	Deciduous (group 1)	Permanent (group 4)	Deciduous (group 2)	Permanent (group 5)	Deciduous (group 3)	Permanent (group 6)
Mean (N)	2,747.9^{abc}	1,633.8^{de}	2,910.4^{afg}	1,400.0^{d}	3,310.5^{bf}	2,264.5^{ceg}
SD	415	346.8	636.2	381.3	396.2	663

The same superscription indicates groups not statistically significantly different.

Table 4 The distribution of fracture modes in all the tested groups

Fracture mode	RMGIC		CR		SFRC	
	Deciduous (group 1)	Permanent (group 4)	Deciduous (group 2)	Permanent (group 5)	Deciduous (group 3)	Permanent (group 6)
Repairable	2 (25%)	1 (12.5%)	2 (25%)	1 (12.5%)	5 (62.5%)	5 (62.5%)
Unrepairable	6 (75%)	7 (87.5%)	6 (75%)	7 (87.5%)	3 (37.5%)	3 (37.5%)

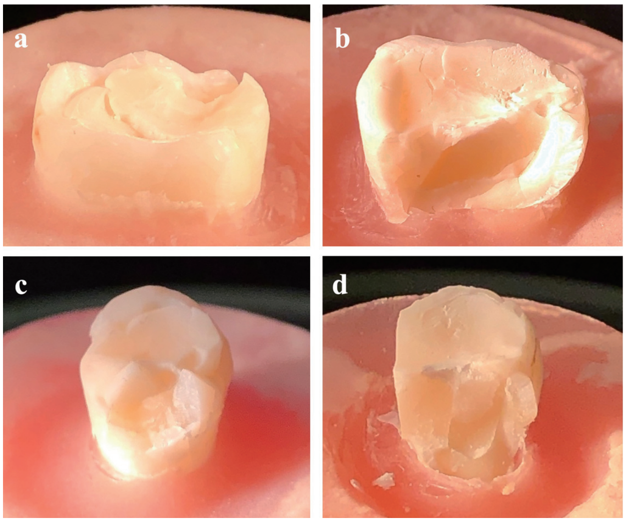

Fig. 3 Photographs of restorable (a and c) and non-restorable (b and d) fracture mode of the tested specimens.
a and b are deciduous teeth, and c and d are permanent premolar teeth.

Fracture mode

The distribution of fracture modes in all the tested groups are shown in Table 4. Regarding fracture modes, the groups restored with SFRC (groups 3 and 6) revealed that restorable fractures were slightly dominant, whereas the groups restored with RMGIC or CR (groups 1, 2, 4, and 5) revealed that unrestorable fractures were dominant. Representative photograph images of restorable and non-restorable fracture modes are showed Figs. 3 and 4.

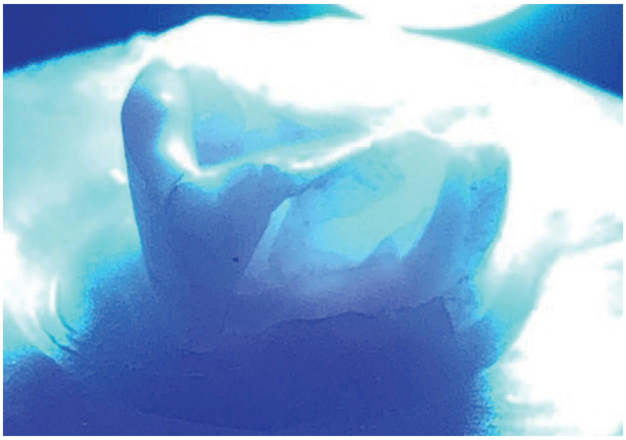

Fig. 4 Photograph showing Elipar TM S10 curing light, an unrestorable fracture going different direction through the restoration (deciduous molar restored with RMGIC).

DISCUSSION

Restoration of endodontically treated deciduous molar teeth should be restored in an optimal way to ensure their survival from 5 to 7 years until the exfoliation phase. The longevity of ET teeth restorations play an important role in treatment outcome and must be considered as a critical step for successful endodontic therapy(17). The reconstruction of the remaining tooth structure of ET teeth would improve their mechanical resistance, prevent unfavorable fractures, and thereby restore anatomy and function(18). In the present study, three restorative materials were used to restore Class II cavities in ET deciduous molars. ET premolars were utilized for comparison. As results, the Class II in ET deciduous molars and ET premolars, the use of short fiber-reinforced flowable composite SFRC as restorative material demonstrated its ability to increase the fracture resistance. It was also demonstrated that fracture resistance was significant higher in deciduous molars than in premolars. Therefore, the null hypotheses were rejected.

In this study, RMGIC and CR restorative materials were selected because, both of them are frequently used after ET in pediatric dental practice, and SFRC that has recently received attention as an improvement in mechanical resistance in studies of permanent teeth. The results of this study showed that, SFRC restorations were higher fracture resistance tendency, although there were no significant differences between the deciduous teeth groups among SFRC, CR, and RMGIC. In the permanent tooth group, SFRC was significantly higher than CR. Composite resins are relatively high brittleness and formation of microcracks in the tooth structure caused by polymerization shrinkage; therefore, they have regarding its application in areas subjected to high stress[19)]. Also, conventional composite and dual-cure core buildup materials used to replace missing coronal part of teeth structures are drawbacks by their significantly lower fracture toughness compared to the toughness of the dentin[9)]. Recent years, to improve their mechanical properties, composite resins are reinforced with micro glass fibers, a fiber-reinforced substructure, whiskers, and particulate ceramic fillers[20-22)]. To our knowledge, SFRC has not been tested in restoring root canal treated deciduous molar teeth before, micrometer-long fibers are used in SFRC in this study. The effectiveness of fiber reinforcement is determined by a variety of factors, including the resin used, fiber weight, orientation, fiber location, aspect ratio, fiber adhesion to the polymer matrix, and fiber impregnation into the resin[8)]. The aspect ratio of a fiber is the length of the fiber relative to its diameter (l/d), and this parameter affects the tensile strength, flexural modulus, and reinforcing performance of the material[23)]. Although the fibers of flowable materials are shorter than the critical fiber length, aspect ratio is 30–94[9)], it is said to be capable of reinforcing the materials and probably to the adhered dental tissues. From our results, Gr3 (deciduous molars SFRC) and Gr6 (premolars SFRC) showed high fracture resistance among the test groups, and this result might be attributed to the characteristics fiber content of the SFRC.

In all cases, the deciduous teeth groups had significantly higher fracture resistance than the permanent teeth groups among each material in this study. The reasons for this were considered to the difference in the number of existing walls, wall thickness, the C-factor (cavity shape), mechanical properties between deciduous and permanent teeth, the volume (size of the cavity) factor, and structural differences in tissues might influence adhesion. Regarding the C-factor, the magnitude of the polymerization stress of a material depends on the cavity configuration and the physical properties of the composite, namely its elastic modulus and polymerization conversion ratio[24)]. It has been reported by Han *et al.* that internal adaptation was inferior in high C-factor cavities compared to low C-factor cavities and that the prevalence of imperfect margins was higher[25)]. In this study, C-factor was unified C-factor 2.0 (MO) when preparing the deciduous and permanent teeth groups. Regarding mechanical properties of nanohardness and elastic modulus, the nanohardness and elastic modulus of first deciduous molar enamel were reported to be 4.88±0.35 GPa and 80.35±7.71 GPa[11)], respectively while premolar enamel was reported to be 4.58±0.23 GPa and 97.5±0.23 GPa[12)]. Thus, the teeth used in this study had similar mechanical properties. Therefore, in the preparation of deciduous and permanent groups, a valid comparison was made by using teeth with similar mechanical properties, and by using the support of the cavity walls thickness and cavity depth, C-factor 2.0 and number of existing walls in this study. However, in the preparation of deciduous and permanent groups, the volume (size of the cavity) was difficult to standardize due to the anatomical characteristics of the teeth. The difference in fracture resistance between permanent and deciduous teeth in this study suggests that although the wall thickness and depth could be standardized during specimen preparation, the deciduous specimens have a larger cavity size and volume of material than the permanent specimens, which the fracture resistance increased as the capacity of the materials to resist the load increased. The significant difference in fracture resistance between deciduous molars and premolars may influence clinical decision-making regarding the choice of restorative materials for each type of tooth. In this study, the significantly higher fracture resistance of the deciduous tooth group than the permanent tooth group, and children have relatively low occlusal forces, material selection for deciduous molars might be more flexible in selecting restorative materials from a wider range of materials to meet the needs of each patient compared to permanent premolar.

The fracture mode analysis in this study showed that CR and RMGIC mainly demonstrated catastrophic unrestorable fractures. However, in the case of the SFRC restorations, more than 62.5% of the specimens withstood in both the deciduous and permanent teeth groups had restorable fractures in the tests. Fracture mode analysis provides a more important role in better understanding the clinical applicability and successful long-term outcomes of directly restoratively treated teeth after endodontic treatment. This analysis reveals which materials mode of fracture affects the tooth and helps in the selection of an appropriate treatment plan and restorative materials. Many studies have concluded that permanent ET molars can be safely restored with direct composite filling when root canals treated in the occlusal cavity[6)]. However, in most cases when fracture occurs in deep cavities restored with only composite filling, dominantly irreparable fractures develop, leaving the tooth unrestorable[3,26)]. On the other hand, it is known that restorations of permanent teeth with SFRC have shown superior fracture resistance with a favorable fracture pattern[26)]. Molnár *et al.* have been reported that fiber-reinforced composites showed stress-distributing and defected away from the bulk of the material and toward the peripheries[10]. Thus, the fact that SFRC were restorable fracture in this study expected that it might have the ability to defected away from the bulk of the material and toward the peripheries. Fráter *et al.* reported that composite or SFRC flow for MO/OD medium sized cavity, and the combination with fiber-containing core and fiber-containing resin for MO/OD ET premolar teeth using fiber post+SFRC flow resulted in less fracture[27]. Since root resorption of deciduous teeth begins before the exfoliation phase, there is no concept of post procedure, and the emphasis is on restorative materials in core. Considering the possibility that a fracture may occur after endodontic treatment, resulting in extraction and placement of space maintainer, the ability to repair a fractured tooth with SFRC, is a benefit because the overall cost is lower and less cost. If the fracture is repairable, multiple alternative options are possible, including restorable fractured restoration or stainless-steel crowns. Early detection and appropriate treatment of restorable fractures can be expected to preserve the tooth and occlusal condition and improve outcomes and long-term outcomes through the permanent tooth replacement period.

Seddik and Derelioglu evaluated the fracture strength of composite endocrowns compared to Class II composite resin restorations in endodontically treated deciduous molars, CR was restored with the same material as our study, and the fracture strength results showed 1,741±379.35 N for endocrowns and 1,126.5±405.39 N for Class II[28]. The composite resin group in our study was much higher at 2,910±636 N. The differences, it might be due to the fact that teeth were subjected to thermal cycling and the thickness of the remaining wall. The occlusal bite forces of 7–13 years old children, were 349.2, 369.3, and 288.3 N for Angle Class I, Class II, and Class III, respectively[29]. Thus, it can be assumed that SFRC, which was able to withstand the ultimate intraoral masticatory forces in the molars tested and had many types of fractures that could be repaired, can successfully repair endodontically treated deciduous molars.

It is important to highlight that the manufacturer's guidelines recommend utilizing flowable SFRC primarily as a bulk base or core foundation, discouraging its usage as a top surface layer. However, numerous laboratory results demonstrating the favorable surface and wear characteristics of flowable SFRC in comparison to many commercial composite resins[30-32].

A limitation of this study is that a static load to fracture test was used instead of applying cyclic loading to determine the maximal fracture resistance. Stresses on teeth and dental restorations are generally low and repetitive, rather than being isolated and impactive. However, according to Taha *et al.* the fracture resistance to static loading is typically much higher than the functional occlusal load, it is a valid method for comparing restorative materials and different cavity designs[2], and since there is a linear relationship between fatigue and static loading, compressive static testing also provides valuable information on fracture behavior and load-bearing capacity[33]. Since deciduous teeth are characterized by natural wear during the permanent tooth replacement period, the wear resistance of the material and its effect on the antagonist wear characteristics of deciduous tooth should be considered[34-37]. The clinical limitations of this study are that SFRC and CR in the deciduous dentition require a dry operative field, cooperative patients, and layering techniques. Further research is needed to better simulate pediatric oral conditions, evaluate performance for cyclic and multiaxial force loads, and determine the potential for clinical success in pediatric dentistry. In addition, future data on the long-term durability and success of teeth treated with SFRCs will be collected to assess their clinical applicability, allowing us to more effectively understand the benefit and potential challenges of SFRCs in endodontic treatment and to provide the best treatment for the patients and their contribution to pediatric growth and development.

Within the limitations of this study, the following can be concluded: (1) for the direct restoration of Class II in ET deciduous molars, the use of short fiber-reinforced composites SFRC demonstrated its promising performance in matter of load-bearing capacity; (2) for the same tested materisals, the significantly higher fracture resistance in the deciduous teeth group than in the permanent teeth group might be attributed to the volume (mass and area of the material) of the specimens; and (3) direct restorations with SFRC revealed that restorable fractures, whereas the other direct restoration groups restored with RMGIC or CR revealed that unrestorable fractures were dominant.

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CONFLICTS OF INTEREST

Pekka K. Vallittu declares that he is a consultant for the Stick Tech Member of GC Company in training, research, and development. The authors declare that they have no conflicts of interest.

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