Comparison of The Fracture Resistance of Endodontically Treated Lower Premolar Teeth Restored with Different Core Build-Up Materials

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Abstract

Recently, conservative approach for restoration of endodontically treated tooth in order to reinforce the tooth structure is being widely accepted due to improvement of reliable bonding systems. However, there are a few studies that evaluated the fracture resistance of endodontically treated lower premolar with ideal access opening restoring different types of bulk-fill resin composites in comparison to the use of other resin-based materials. The objective of this study was to compare the fracture resistance among endodontically treated lower premolars restored with different core build-up materials. Seventy-five human single-rooted mandibular premolar were randomly divided into five groups (n=15): Group I (control group) was sound teeth while Groups II-V were endodontically treated teeth restored with the following resin-based materials after removal of gutta percha 3 mm below the cementoenamel junction (CEJ): Group II, dual-cured composite core build-up material; Group III, nanohybrid resin composite; Group IV, high viscosity bulk-fill resin composite; and Group V, low viscosity bulk-fill resin composite and nanohybrid resin composite. All the specimens were subjected to compressive loading at a 45° angle to the long axis of the tooth until fracture occurred. The data were statistically analyzed using a one-way analysis of variance and Chi square test. The description of the reliability and probability of failure of fracture strength was analyzed by Weibull statistics. Sound tooth had statistically significant difference from the endodontically treated groups ($p<0.05$) while the endodontically treated groups were found no significant differences in fracture resistance values and the Weibull modulus ($p>0.05$). All the five groups exhibited a higher percentage of unfavourable failures than favourable failures. In conclusion, the different types of resin-based materials that restored the endodontically treated lower premolar exhibited similar fracture resistance and failure patterns. Consequently, endodontically treated lower premolars with ideal access openings could be restored using any type of resin-based materials.

Keywords: *Core build-up materials/ Endodontically treated lower premolars/ Fracture resistance/ Resin-based composite*

Received: *Mar 31, 2021*
Revised: *Sep 14, 2021*
Accepted: *Sep 17, 2021*

Introduction

Owing to the loss of tooth structure following endodontic treatment, the endodontically treated tooth commonly receives full coverage restoration (with or without a post) in order to reinforce the tooth structure.[1] However, recently, conservative approaches for restoration of endodontically treated teeth are being widely accepted due to developments in reliable bonding systems. Studies have suggested the use of resin-based restorations to improve fracture resistance and longevity of endodontically treated teeth.[2,3]

Nayyar *et al*.[4] recommended corono-radicular stabilization as a method to improve core retention and preserve the remaining dentin. The corono-radicular reconstruction technique was performed by preparing a space at a 2-4 mm depth from the root canal orifice and slightly removing the undercut of the pulp chamber. The corono-radicular space was filled with amalgam in single-unit cases [4]. Previous studies have suggested that use of an adhesive resin restoration in the corono-radicular technique for endodontically treated teeth exhibits superior fracture resistance.[5-7]Currently, the properties of several dental adhesive resin materials have been improved for use in various types of restorations, including core build-up materials. However, the physical and mechanical properties of core build-up materials depend on the strength, bond to tooth structure, modulus of elasticity, etc.[8,9] Different core build-up materials have been used in root canal-treated teeth in order to improve the fracture resistance to axial and non-

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axial forces. Additionally, there are several resin-based materials, such as conventional resin composite, dual-cured resin composite, and bulk-fill resin composite, which can be selected for restoring root canal-treated teeth.[10-14] The bonded corono-radicular technique is able to strengthen the root canal-treated teeth and minimize dentin removal during root canal preparation for post system support, resulting in strength equivalent to that of natural teeth. Currently, there are no studies that have evaluated the fracture resistance resulting from the use of different types of bulk-fill resin composites in comparison to the use of other resin-based materials in endodontically treated lower premolars with an ideal access opening. Therefore, the objective of this study was to compare the fracture resistance among endodontically treated lower premolars restored with different adhesive resin materials using the corono-radicular retentive technique without the placement of full coverage restoration.

Materials and Methods

Seventy-five sound human single-rooted mandibular premolar teeth that were free from caries, cracks, and restorations, with regular occlusal anatomy and approximately similar crown sizes and root lengths were selected. They were cleaned with an ultrasonic scaler and hand scaling instruments[12] and were stored in a 0.1% thymol solution until the tests. Preliminary radiographs were taken to determine the root canal anatomy. All selected specimen were randomly divided into five groups (n = 15). The teeth in Groups II-V were prepared by means of an endodontic procedure involving the following different types of restorative materials (Table 1).

Table 1 Materials, types, matrix compositions, filler types, content by weight percentage, manufacturer, and LOT number.

Material	Type	Composition	Filler (wt%)	Manufacturer
MultiCore® Flow	Self-cured core build-up composite with light-cured option	- Dimethacrylates - Barium glass fillers, Ba-Al-fluorosilicate glass, Highly dispersed silicon dioxide - Ytterbium trifluoride, - Catalysts, stabilizers and pigments	54.65	Ivoclar, Vivadent, Schaan, Liechtenstein LOT X16305
Filtek™Z350XT	Light-cured composite	- Organic matrix: bis-GMA, UDMA, TEGDMA, and bis-EMA - Inorganic matrix: non-agglomerated 20 nm silica filler, non-agglomerated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler	78.5	3M ESPE, St Paul, Minnesota, USA LOT N929812
SonicFill™2	Light-cured bulk-fill paste composite with sonically activated energy	- Organic matrix: TMSPMA, EBPADMA, bisphenol-A-bis-(2-hydroxy-3-mehacryloxypropyl) ether, TEGDMA - Inorganic matrix: glass, oxide, chemicals, SiO2	81.3	Kerr Corporation, Orange, CA, USA LOT 6772271
SureFil® SDR™*flow*	Light-cured bulk-fill flowable composite	- Organic matrix: Modified UDMA, TEGDMA, EBPDMA - Inorganic matrix: Ba-Al-F-B-Si glass, Sr-F-Si glass	68	Dentsply Caulk LOT1801000416

Abbreviations: Bis-GMA, bisphenol A-glycidyl methacrylate; UDMA, urethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; Bis-EMA, ethoxylated bisphenol-A-dimethacrylate; TMSPMA, 3-(trimethoxysilyl)propyl methacrylate; EBPDMA, ethoxylated bisphenol-A dimethacrylate.

Group I: Fifteen sound teeth that were not subjected to root canal treatment or any restoration process served as the control group.

Group II: Endodontically treated teeth that were restored with a dual-cured core build-up material (MultiCore® Flow, Ivoclar Vivadent, Schaan, Liechtenstein).

Group III: Endodontically treated teeth that were restored with a nanohybrid resin composite (Filtek™Z350 XT Universal Restorative, 3M ESPE, St. Paul, MN, USA).

Group IV: Endodontically treated teeth that were restored with a high viscosity bulk-fill resin composite (SonicFill™2, Kerr, Orange, CA, USA).

Group V: Endodontically treated teeth that were restored with a low viscosity bulk-fill resin composite (SureFil® SDR™*flow,* Dentsply Sirona, DeTrey, Konstanz, Germany) and overlayered with a nanohybrid resin composite (Filtek™Z350 XT Universal Restorative, 3M ESPE, St. Paul, MN, USA)

In Groups II-V, the endodontic access cavities were prepared using a round diamond bur and safe end taper diamond bur (Intensive SA, Montagnola, Switzerland) with a high-speed handpiece (Twin power turbine 4 HK, J Morita, INC.,California, USA).[12] The working length was determined using a size 8-10 K-file (SybronEndo, Kerr, Orange, CA, USA.) at a depth of 1 mm from the root apex, which was set as the initial apical file. All the canals were prepared using rotary canal instruments (ProTaper Next®, Dentsply Sirona, DeTrey, Konstanz, Germany) with files ranging from X1 (17/.04), X2 (25/.06), X3(30/.07) to X4 (40/.06). Between the use of each file during cleaning and shaping, irrigation was performed with 2.5% sodium hypochlorite (M Dent product, Mahidol University, Bangkok, Thailand). Subsequently, the root canal was flushed with 17% ethylenediaminetetraacetic acid (EDTA) (M Dent product, Mahidol University, Bangkok, Thailand) followed by 2.5% sodium hypochlorite.

The canals were dried using paper points (Absorbent Paper points, Dentsply Sirona, DeTrey, Konstanz, Germany) and were obturated using a matched cone gutta percha size 40 with 0.06 taper (Gutta-Percha Point, Dentsply Sirona, DeTrey, Konstanz, Germany) with a root canal sealer (AH Plus®, Dentsply Sirona, DeTrey, Konstanz, Germany) by the lateral condensation technique.[15] Following the cleaning, shaping, and obturation procedures, postoperative radiographs were taken to evaluate the endodontic treatment.[12] All the specimens were filled with a cotton pellet and temporary restoration (Cavit™, 3M ESPE, St. Paul, MN, USA). Subsequently, the specimens were stored in a 100% humidity and 37ºC environment for a week prior to the restoration.

Group I: The control group included fifteen intact teeth without restoration. Groups II-V (root canal-treated teeth), the gutta percha was removed below the CEJ to a depth of 3 mm with a root canal heat carrier. The natural under cuts in the pulp chamber wall were retained in order to assist with core retention.[5] All the prepared teeth were cleaned with normal saline. The access cavity was prepared by etching with 37% phosphoric acid (Scotchbond™ Universal Etchant, 3M ESPE, St. Paul, MN, USA) for 15 s. The specimens were rinsed for 30s with a water/air spray, and they were first dried with paper point and then gently dried air. A dual-cured adhesive (Excite®F DSC, Ivoclar Vivadent, Schaan, Liechtenstein) was applied, and any excess was dispersed into a thin layer with a gentle stream of air. This was followed by light polymerization for 10s using a light-emitting diode (LED) light curing unit (Bluephase®, Ivoclar Vivadent, Schaan, Liechtenstein).[16] The specifics in each of the groups were as follows:

Group II: Specimens were restored directly with the application of dual-cured core build-up material (MultiCore® Flow) into the cavity. Light curing was performed for 20s from the occlusal direction according to the manufacturer's instructions.[17]

Group III: Specimens were restored with a nanohybrid resin composite (Filtek™ Z350 XT Universal Restorative, 3M ESPE, St. Paul, MN, USA) at a thickness increment of 2 mm, followed by LED light curing for 20s from the occlusal direction in each tooth.

Group IV: Specimens were restored with a high viscosity bulk-fill resin composite (SonicFill™2, Kerr, Orange, CA, USA) in bulk increments of 4 mm each, followed by LED light curing for at least 20 s according to the manufacturer's instructions.[18]

Group V: Specimens were restored with a low viscosity bulk-fill composite resin with a maximal increment thickness of 4 mm (SureFil® SDR™*flow*, Dentsply Sirona, DeTrey, Konstanz, Germany) apart from a 2 mm layer at the occlusal surface which was restored with the same resin composite that was used in Group III.[19]

After completing the restorations, all the specimens were polished and finished using a superfine diamond bur. A notch with a diameter of 2 mm was prepared at the centre of the occlusal surface to aid in conducting the strength tests. The specifics of all the groups are presented in Figure 1. To simulate the periodontal ligament, the root surfaces were marked 2 mm below the CEJ and were covered with aluminium foil of approximately 0.2 mm in thickness. Each tooth was embedded in a block of self-cured acrylic resin (Unifast™ Trad, Tokyo, Japan) in a polyvinyl chloride (PVC) plastic cylindrical mould (width, 22 mm; height, 25 mm). The teeth were embedded along their long axis using a dental surveyor.[13,14] After the first sign of polymerization, the teeth were carefully removed manually from the resin blocks. The acrylic resin covered the root up to within 2 mm of the CEJ in order to approximate the support of the alveolar bone in a healthy tooth. In order to simulate the periodontal ligament, the foil was removed from the root surface, and light body addition silicone impression material (Variotime®, Kulzer, Hanau, Germany) was injected into the acrylic resin blocks at the site that was previously occupied by the tooth root and foil; subsequently, the tooth was reinserted into the resin block. A standardized silicone layer that simulated the periodontal ligament was thus created taking into consideration the thickness of the foil.[13] All the teeth were stored in deionized distilled water in an incubator at 37°C and 100% humidity until the tests.[14] All the specimens were mounted in a universal testing machine (model 5566, Instron, Bucks, U.K.) at a 45° angle to the long axis of the tooth. Subsequently, the specimens were subjected to a continuously increasing compressive load at a crosshead speed of 1 mm/min with a 2-mm-diameter round metal indenter as shown in Figure 2. The fracture load of each specimen was measured by recording a sudden drop in load magnitude in Newton (N).[14] The mode of failure was classified as "favourable" if the fracture line occurred above the level of the CEJ and could be restored. When the fracture line extended below the level of the CEJ and could not be restored, it was defined as "unfavourable".[5,10,12,20] Data were analyzed using a statistical software program (SPSS Statistics 18.0, SPSS Inc., Illinois, USA). Data were explored for normality by performing a Kolmogorov-Smirnov Z test and were verified for the homogeneity of variances by a Levene test. A one-way analysis of variance was performed. Subsequently, an intergroup comparison was performed using a Tukey's honestly significant difference multiple comparisons test. Percentages were determined for the mode of failure, and a chi-square test was used for the statistical evaluation (α=0.05). The description of the reliability and probability of the failure corresponding to fracture strength was analyzed using Weibull statistics. The fracture values were analyzed by ranking them in ascending order, calculating the best statistical estimate of fracture probability, and determining the Weibull parameter estimates using the following equation:

$$P_{F(\sigma_c)} = 1\text{-}\exp\,[-(\sigma_c/\sigma_0)]$$

where $P_{F(\sigma_c)}$ is the probability of failure, σ_c is the fracture strength, σ_0 is the characteristic strength ($P_{F(\sigma_c)}$ = 63.2%), and *m* is the Weibull modulus. On plotting ln [ln 1/(1-P_f)] against lnσ, a slope with the value of the Weibull modulus is obtained.

This study was approved by an Ethics committee of Mahidol University (COE.No.MU/DT/PY-IRB 2018/022. 0106) following international guidelines such as Declaration of Helsinki, the Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP) for protection of human subjects and animals in research. The committee provide a certificate of exemption because the human teeth were collected without knowing the patients; therefore, there was no need patient inform consent in this study.

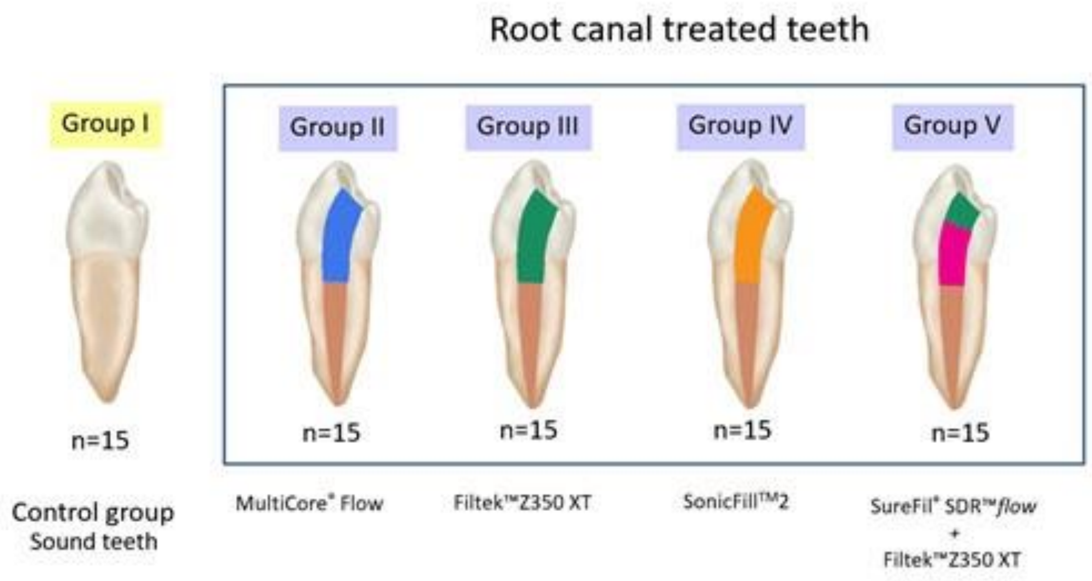

Figure 1 Demonstration in all the test groups; Group I (control group): sound teeth, Groups II-V (experimental groups): endodontically treated teeth restored with different resin-based materials after removing gutta percha 3 mm below the cementoenamel junction.

Figure 2 Simulated occlusal loading using a 2-mm-diameter handpiece along the axio-occlusal line at a 45° angle to the long axis.

Results

Sound teeth (Group I) exhibited the highest fracture resistance (1161.89±115.42 N) and had significantly higher fracture strength when comparing to that of endodontically treated teeth groups (Table 2). Regarding the endodontically treated teeth, low viscosity bulk-fill resin composite capped with nanohybrid resin composite (Group V; SureFil®SDR™*flow* with Filtek™Z350XT, 927.86±175.99 N) and dual-cured core build-up material (Group II; MultiCore® Flow, 922.59±174.96 N) exhibited higher mean values of fracture resistance compared with those of nanohybrid resin composite (Group III; Filtek™Z350 XT, 880.97±146.03 N) and high viscosity bulk-fill resin composite (Group IV; SonicFill™2, 848.98±120.19 N) that showed lower fracture resistance. However, all endodontically treated teeth groups revealed no statistically significant differences in fracture resistance (p>0.05).

For each group, the Weibull analysis yielded two parameters, the characteristic fracture load (6) and Weibull modulus (*m*) (Figure 3 and Table 2). The range of the *m* values was 6.12 to 11.87. Sound teeth exhibited the highest *m* value (11.87) compared with those of endodontically treated teeth groups. Among the restored groups, Groups II, III, and V exhibited similar *m* values in contrast to Group IV that exhibited a higher *m* value (8.55) compared to those of others. The values of the characteristic strength (a specimen fails at 63.2% of the material strength) in the control group and Group V, 1215.97 MPa and 1004.34 MPa respectively, were higher compared to those of the other groups.

Table: 2 The maximum load applied corresponding to the fracture (N) and Weibull parameters that were recorded as the Weibull modulus (*m*) and characteristic strength (6) in each group.

Group	N	Mean	Weibull modulus	Weibull characteristic
I Control	15	1161.89 (115.42)[a]	11.871	1215.97
II MultiCore	15	922.59 (174.96)[b]	6.432	991.90
III FiltekZ350	15	880.97 (146.03)[b]	6.887	942.00
IV SonicFill2	15	848.98 (120.19)[b]	8.546	900.59
V SDR & FiltekZ350	15	927.86 (175.99)[b]	6.125	1004.34

Different superscript letters indicate statistically significant difference

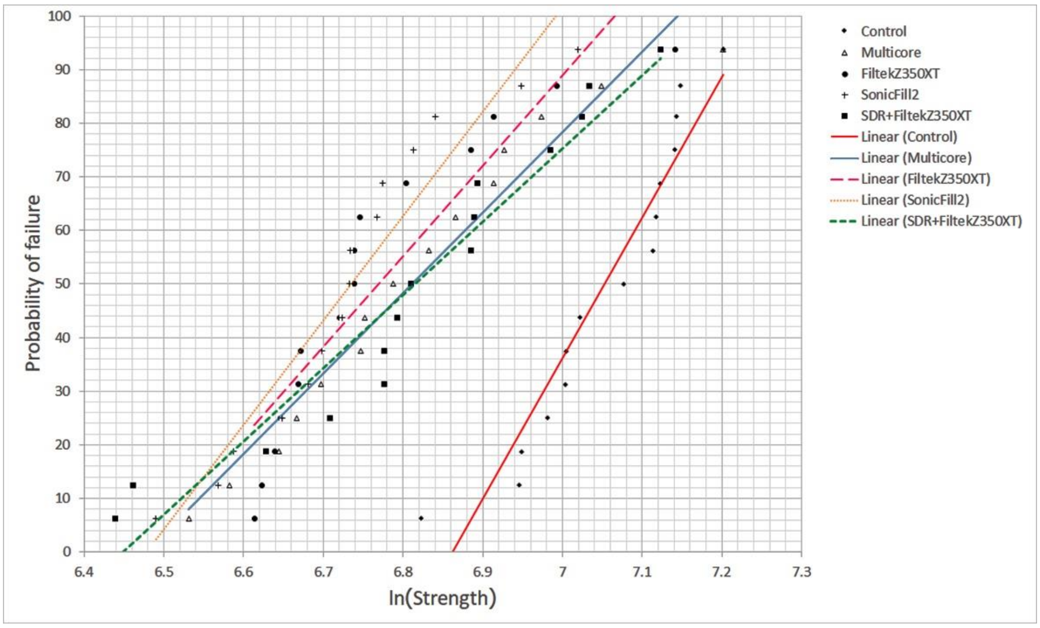

Figure 3 Weibull analysis of fracture loading.

The distribution of the favourable and unfavourable fractures is presented in Table 3. All the groups demonstrated a higher percentage of unfavourable failures compared to that of favourable fractures. Groups I and II, had 11 samples (73.3%) that exhibited unfavourable patterns and 4 samples (26.7%) with favourable patterns. While in Groups III and V, 13 samples (86.7%) exhibited unfavourable failures, and 2 samples (13.3%) exhibited favourable failures. In addition, Group IV had 14 samples (93.3%) with unfavourable patterns and 1 sample (6.7%) with favourable patterns. However, no significant differences were found in the mode of failure among the groups (Figure 4).

Table 3 Failure mode of each group

Failure mode (n = 15)		Group I	Group II	Group III	Group IV	Group V	Total
Favourable	Count	4	4	2	1	2	13
	% within Failure	30.8%	30.8%	15.4%	7.6%	15.4%	100.0%
	% within groups	26.7%	26.7%	13.3%	6.7%	13.3%	17.3%
Unfavourable	Count	11	11	13	14	13	62
	% within Failure	17.7%	17.7%	21.0%	22.6%	21.0%	100.0%
	% within groups	73.3%	73.3%	86.7%	93.3%	86.7%	82.7%

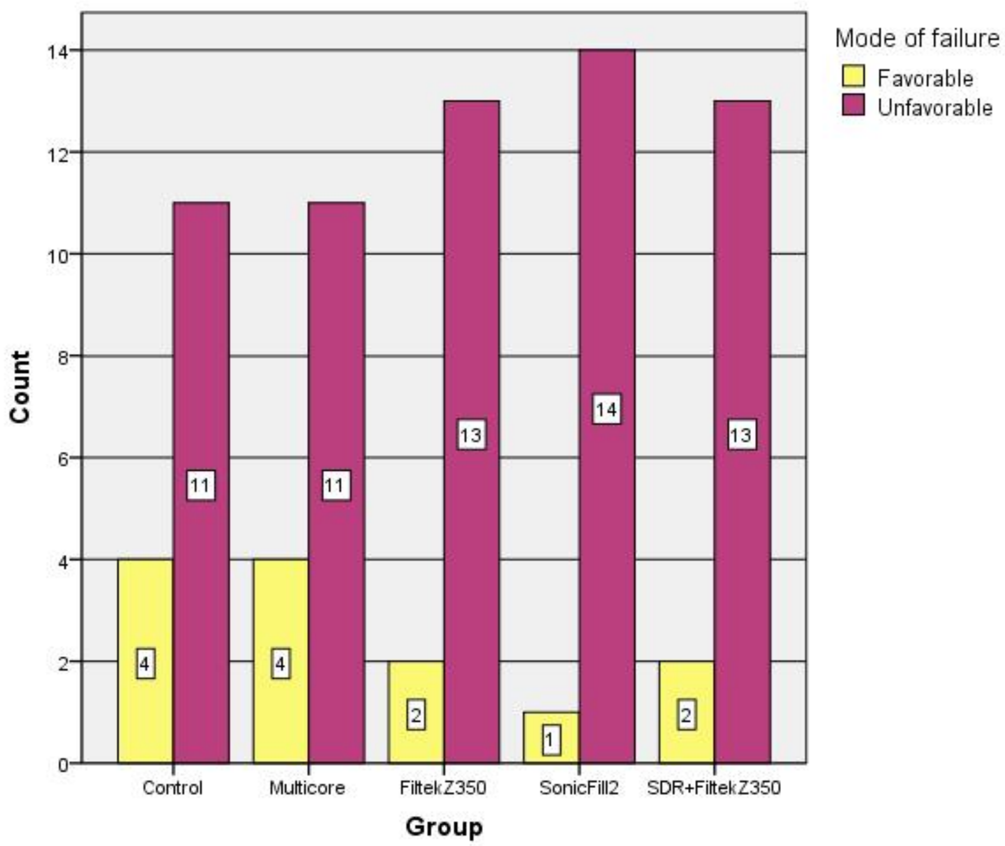

Figure 4 Bar chart representing the mode of failure with the use of different core build-up materials.

Discussion

This study analyzed the fracture resistance of endodontically treated lower premolar teeth restored with the corono-radicular technique using four types of resin-based materials. The results of the current study revealed that there was a significant difference in the fracture resistance of sound teeth compared to that of endodontically treated premolar teeth restored with resin-based materials. Sound teeth (Group I) had the highest fracture resistance mean value owing to the continuity of the dental structure from the intact buccal and palatal cusps, and moreover, the intact mesial and distal marginal ridges strengthened and maintained tooth integrity.[21,22] The Weibull parameters supported these results by demonstrating the highest Weibull modulus in intact teeth, which indicated a higher reliability. In addition, all the restored groups (Groups II-V) exhibited significantly lower fracture strength when compared to that of sound teeth. Early studies demonstrated that the loss of tooth structure reduced the tooth rigidity and structural integrity, which resulted in strength reduction despite intact marginal ridges.[20,23,24] However, all the restored groups could withstand the strength that exceeded the average bite force of the premolar teeth, which was reported as approximately 300 N.[25]

The fracture resistance of endodontically treated lower premolar with ideal access cavity that restored with various materials was not different because there was large amount of the remaining tooth structure. Several studies reported the direct correlation between fracture resistance of endodontically treated tooth and amount of remaining tooth structure.[26,27] Shahrbaf et al. found that endodontically treated maxillary premolar restored with resin composite with the thickness of marginal ridge ranged from 1-2 mm can preserve fracture resistance and their strength were not significant difference from the intact teeth.[28] In addition, the stress will accumulate on the structure with higher elastic modulus and transfer the load with more-intensity to the adjacent structure.[29] Enamel and dentin that had higher elastic modulus than restored materials will absorb higher force than the restored materials. Therefore, the types of materials would have no effect on the fracture strength of endodontically treated premolar that prepared with ideal access cavity.

Based on the Weibull modulus values, the reliability of the teeth was affected in the restored groups that exhibited lower *m* values compared to that of the control group. This result may be due to differences in the access cavities prepared during the endodontic procedure, tooth and root canal morphology, age of the tooth before extraction, unseen microcracks in the tooth structure, and technique sensitivity. However, *m* values were nearly the same in all the restored groups that implied a similar probability of fracture of all groups. The results from the SonicFill™ 2 group, indicated low fracture loading but a high Weibull modulus, highlighted the superior reliability of the material, which was related to the homogeneity of the material delivered through the sonic activated handpiece. Moreover, the *m* values in our study were within the range of 5–15, corresponding to those of resin composite materials.[30-32]

On considering the mode of failure, there was no difference observed in the fracture pattern among the five groups. Almost all the specimens were fractured in unfavourable patterns. Yashwanth et al.[5] evaluated the fractural strength via a load placement at 30^{o} to the long axis and generated the same result as that of this study, which was designed with a load placement at 45^{o} to the long axis.[5] However, compressive loading that applies force parallel to the long axis of the tooth is likely to result in a favourable fracture pattern.[33] This can be explained by the fact that the parafunctional force tends to result in unfavourable fracture patterns while the normal chewing force tends to result in favourable fracture patterns. The unfavourable failure patterns observed in the restored groups in this study might occur as a result of applying force onto one of the inclined cusps and the established tension and compression at the cervical regions, resulting in tooth breakdown as explained by Lee and Eakle.[34]

The limitation of this study was that the experimental method was performed *in vitro,* and it did not simulate the specific intraoral conditions that result in fractures being initiated from fatigue. Future studies taking this issue in consideration are warranted. Additionally, further clinical research is necessary in order to determine the long-term success rate of endodontically treated lower premolar teeth restored with direct resin-bonded materials using corono-radicular technique.

In conclusion, there was significant difference between sound teeth and restored groups; however, no significant difference was found among the restored groups under compressive force. Consequently, endodontically treated lower premolar tooth with an ideal access cavity can be restored by any type of resin-based materials.

Conclusions

Within the limitations of this study, it can be concluded that sound tooth had significantly higher fracture resistance compared with restored endodontically treated lower premolar. Endodontically treated lower premolar with ideal access cavity can be restored using any types of restorative materials.

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การเปรียบเทียบความต้านทานการแตกหักของฟันกรามน้อยล่างที่ได้รับการรักษารากฟันที่บูรณะด้วยวัสดุบัลค์ฟิลล์เรซิน คอมโพสิต กับวัสดุในกลุ่มเรซินชนิดอื่น ๆ

พิริยะ สุภพานิชย์ ศุภศันส์ ทิศทวีรัตน** ฐานวุฒิ คงปรีชา* ปิยพรรณา พุ่มผลึก**

บทคัดย่อ

ปัจจุบันการบูรณะเพื่อสร้างความแข็งแรงให้กับฟันที่ได้รับการรักษารากฟันด้วยวิธีอนุรักษ์ได้รับการยอมรับอย่างกว้างขวาง เนื่องจากมีการพัฒนาระบบสารยึดติดที่น่าเชื่อถือ และมีวัสดุที่นำมาใช้บูรณะฟันอย่างหลากหลาย อย่างไรก็ตามยังไม่มีการศึกษาเกี่ยวกับความต้านทานการแตกหักของฟันกรามน้อยล่างที่ได้รับการรักษารากฟันซึ่งมีช่องเปิดเข้าสู่โพรงเนื้อเยื่อในแบบอุดมคติ ซึ่งบูรณะด้วยวัสดุบัลค์ฟิลล์เรซิน คอมโพสิต เทียบกับวัสดุในกลุ่มเรซินชนิดอื่นๆ ดังนั้นการศึกษานี้จึงมีวัตถุประสงค์เพื่อศึกษาเปรียบเทียบความต้านทานต่อการแต กหักของฟันกรามน้อยล่างที่ได้รับการรักษารากฟันเมื่อบูรณะด้วยวัสดุสร้างแกนฟันชนิดต่างๆ โดยนำฟันกรามน้อยล่างรากเดียวที่มีขนาดใกล้เคียงกันจำนวน 75 ซี่ แบ่งเป็นเป็น 5 กลุ่ม กลุ่มละ 15 ซี่ กลุ่มที่ 1 เป็นฟันปกติ และกลุ่มที่ 2-5 เป็นฟันที่ได้รับการรักษารากฟัน จากนั้นกำจัดกัตตาเปอร์ชาต่ำกว่าเส้นรอยต่อของเคลือบฟันกับเคลือบรากฟันแล้วจึงบูรณะด้วยวัสดุชนิดต่างๆดังนี้ กลุ่ม 2 วัสดุสร้างแกนฟันชนิดบ่มตัวด้วยแสงและปฏิกิริยาเคมี กลุ่ม 3 เรซิน คอมโพสิตชนิดนาโนไฮบริด กลุ่ม 4 บัลค์ฟิลล์เรซินคอมโพสิต ชนิดความหนืดสูง และกลุ่ม 5 บัลค์ฟิลล์เรซินคอมโพสิต ชนิดความหนืดต่ำร่วมกับเรซิน คอมโพสิตชนิดนาโนไฮบริด จากนั้นนำฟันทั้งหมดไปทดสอบแรงกดอัดโดยทำมุม 45 องศากับแนวแกนฟัน ผลการศึกษาพบว่า ฟันปกติ มีค่าความต้านทานการแตกหักต่างจากฟันรักษารากอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) ขณะที่ฟันที่ได้รับการรักษารากฟันแต่ละกลุ่มมีค่าความต้านทานการแตกหักไม่แตกต่างกัน ($p>0.05$) ทั้ง 5 กลุ่มมีรูปแบบการแตกหักต่ำกว่าเส้นรอยต่อของเคลือบฟันและเคลือบรากฟัน จึงสรุปได้ว่าวัสดุในกลุ่มเรซินเมื่อนำมาบูรณะฟันกรามน้อยล่างที่ได้รับการรักษารากฟันที่มีช่องเปิดเข้าสู่โพรงเนื้อเยื่อในแบบอุดมคติ ให้ค่าความต้านทานการแตกหักและรูปแบบการการแตกหักไม่แตกต่างกัน

***คำไขรหัส:** วัสดุสร้างแกนฟัน/ ฟันกรามน้อยล่างที่ได้รับการรักษารากฟัน/ ความต้านทานการแตกหัก/ วัสดุเรซิน คอมโพสิต*

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