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ORIGINAL ARTICLE

Fracture Resistance of Endodontically Treated Maxillary Premolars with Non-carious Cervical Lesions Restored with Different Post Systems

Wing See Fiona LEUNG, Angeline Hui Cheng LEE, Christopher LIU, Mingxin HU, Jeffrey Wen Wei CHANG, Prasanna NEELAKANTAN, Chengfei ZHANG

Division of Endodontics, Restorative Dental Sciences, Faculty of Dentistry, The University of Hong Kong, Hong Kong, China

ABSTRACT

Objective: To test the hypothesis that the (i) presence of non-carious cervical lesions (NCCLs) and (ii) type of post system have no effect on the fracture resistance and pattern in endodontically treated maxillary premolars.

Methods: Human maxillary first premolars (n=60) with two root canals were randomly allocated into four groups (n=15). Buccal wedge-shaped NCCLs were prepared in 45 teeth specimens. Following root canal treatment, the specimens were randomly divided into (i) composite resin core (CRC); (ii) NCCLs + composite resin core (NCCL+CRC); (iii) NCCLs+prefabricated fibre-reinforced composite post + composite resin core (NCCL+PFRC+CRC); (iv) NCCLs+custom fibre posts + composite resin core (NCCL+CFP+CRC). All specimens were subjected to thermocycling (5°C to 55°C/5000 cycles). The compressive load was applied non-axially to the palatal cusp with a universal testing machine at a crosshead speed of 0.5 mm/min at a 30° angle until fracture. Fracture patterns were examined using a loupe magnification (2.5×) under transillumination. Statistical analyses were performed using non-parametric tests and pairwise comparisons of the load-to-fracture among the groups. Chi-square test was used to analyse the fracture patterns (P=0.05).

Results: Fracture resistance of NCCL+PFRC+CRC was significantly higher than NCCL+CRC (P=0.011), while NCCL+CFP+CRC did not show any significant difference when compared to NCCL+CRC (P=0.089). No statistical difference was found between CRC, NCCL+PFRC+CRC and NCCL+CFP+CRC (P=1.000). The frequencies of favourable fracture patterns in descending orders were as follows: CRC (80%), NCCL+CFP+CRC (73%), NCCL+PFRC+CRC (60%), and NCCL+CRC (40%). Chi-square test did not show significant differences in fracture patterns among all groups (P=0.110).

Conclusion: Restoration of the endodontically treated maxillary premolars with NCCLs, with or without post, resulted in similar fracture resistance as their counterparts without NCCLs. Placement of a prefabricated fibre-reinforced composite post exhibited greater fracture resistance to the maxillary premolars with restored NCCLs than those without a post.

Keywords: Composite resin, endodontically-treated teeth, fibre post, fracture resistance, non-carious cervical lesions

HIGHLIGHTS

For the root canal treated maxillary premolars with a non-carious cervical lesion (NCCL):

- Fracture resistance similar to that of the teeth without NCCL could be achieved if properly restored.
- Placing a prefabricated Rely X™ FRC post resulted in a greater fracture resistance than those restored without a post.
- No differences could be detected in the fracture resistance and pattern between the use of prefabricated Rely X™ FRC post and elastic GC everStick® FRC post.

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Address for correspondence:
Chengfei Zhang
Division of Endodontics, Restorative Dental Sciences, Faculty of Dentistry, The University of Hong Kong, Hong Kong, China
E-mail: zhangcf@hku.hk

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INTRODUCTION

Fracture of endodontically treated teeth (ETT) is a common clinical failure that leads to tooth extraction. Vertical root fracture accounts for 13.4% of extracted ETT (1). Recent evidence suggests that fibre-reinforced composite (FRC) posts may strengthen ETT when cemented with an adhesive technique (2) and improve the survival of ETT (3). However, prefabricated FRC posts are usually designed with a predetermined taper, shape and diameter, which rarely conform to the root canal geometry, especially in wide, tapered and oval canals (3, 4), resulting in increased cement thickness, microleakage due to interfacial gap formation, low bond strength, and reduced fracture resistance upon occlusal loading (5, 6). Placement of multiple prefabricated FRC posts and custom-made FRC posts with minimal or no post space preparation might overcome some of these problems to reduce the stress concentration at the post-cement-dentine interfaces, thereby improving the fracture resistance of teeth (4). However, such findings were not supported by a randomised clinical trial with a 5-year follow-up of the ETTs that were restored with full ceramic restorations with an adequate ferrule (7). That trial found no significant differences in root fractures or unrestorable fractures between ETTs treated with the prefabricated and custom-made glass fibre post (7).

NCCLs have been shown to decrease the fracture resistance of ETT by more than 50% (8). Two *in vitro* studies have evaluated the fracture resistance and pattern of endodontically treated maxillary premolars with NCCLs; both equivocally supported the favourable effect of fibre post-retained composite resin in restoring these teeth (8, 9). However, only one of these studies evaluated the impact of NCCLs on the fracture pattern and failure mode in the ETT (9), and none of them tested the effects of different post systems. Contemporary endodontic practice encourages endodontists and dentists to provide a definitive restoration after endodontic treatment as soon as practicable (2). The timely placement of a definitive core, with or without a post, should minimise the chance of secondary contamination and infection of the root canal system (2). Not surprisingly, clinicians who treat a maxillary premolar with a deep NCCL will face the decision of whether post placement is necessary or beneficial to the tooth. Therefore, this study aimed to determine the impact of NCCLs and different post-systems on fracture resistance and patterns in restored endodontically treated maxillary premolars.

MATERIALS AND METHODS

Sample Selection

Ninety intact human maxillary first premolars extracted for orthodontic reasons were stored in 0.9% physiological saline solution at room temperature. Demographic data were recorded, including age, gender, number of roots, and tooth dimensions. The study protocol was reviewed and approved by the Institutional Review Board (UW 20-683). The study was conducted in accordance with the Declaration of Helsinki.

Intact teeth with lengths ranging from 17.5 to 21 mm, mesiodistal (MD) width from 7.5 to 8.5 mm, and buccolingual (BL) width from 4 to 4.5 mm were disinfected with 6% sodium hypochlorite for 3 minutes to remove the organic debris, followed by ultrasonic scaling to remove the hard deposits. Teeth with crack lines were excluded after an inspection under magnification using loupes (HDLTM 2.5 Micro, OrascopticTM, Madison, Wisconsin, USA) and transillumination. Teeth with two canals were included in the experiments regardless of whether they had 1 or 2 separate roots. Root canal configuration was verified by evaluating the radiographs taken in BL and MD views. Teeth with (i) only one or more than two canal(s); (ii) cracks; (iii) open apex; (iv) resorptive lesion; (v) any forms of canal obstruction; and (vi) root canals with a curvature of greater than 10° as evaluated by the Schneider's method (10), were excluded. After careful selection, 60 teeth specimens were included and stored in 0.9% physiological saline at 37°C for no more than 9 months. The specimens were divided into the following experimental groups, as detailed in Table 1:

i. Composite resin core (CRC);

ii. NCCLs + composite resin core (NCCL+CRC);

iii. NCCLs + prefabricated fibre-reinforced composite post + composite resin core (NCCL+PFRC+CRC); and,

iv. NCCLs + custom fibre posts + composite resin core (NCCL+CFP+CRC).

Artificial NCCLs Preparation

Artificial wedge-shaped NCCLs were prepared for the specimens in NCCL+CRC, NCCL+PFRC+CRC and NCCL+CFP+CRC. The cavities were prepared on the buccal cervical aspect using a high-speed handpiece with water coolant and an FG 314 cylindrical diamond (Intensiv SA, Montagnola, Switzerland). The preparation in all specimens was standardised to (i) buccal vertical height of 3 mm; (ii) occlusal wall at 2 mm coronal to the cementoenamel junction (CEJ); (iii) gingival wall at 1 mm cervical to the CEJ; (iv) depth extended to the point of pulpal space exposure (approximately one-third of the BL width at the CEJ level), (v) the apex of the wedge-shaped lesion at the CEJ level; and (vi) the mesiodistal width extending from the mesial to distal line angles.

Root Canal Preparation

The pulp chamber of the specimens was accessed, and the working length was set at 1 mm short of the apical foramen. A crown-down approach was used for coronal preparation with Gates Glidden drills (Mani, Pearson, Japan). Root canal patency was maintained using a new size #10 K-file (Maillefer, Dentsply Sirona, Ballaigues, Switzerland) for each specimen. A glide path was created with a size #15 K-file (Maillefer, Dentsply Sirona, Ballaigues, Switzerland). Root canal preparation was performed using the ProTaper Next® rotary instrument system (Maillefer, Dentsply Sirona, Ballaigues, Switzerland) until the working length was reached. Each canal was prepared up to ProTaper Next® X2 with copious irrigation using 2.5% sodium hypochlorite. After preparation, root canals were rinsed with 6 mL of 17% EDTA, 3 mL of 2.5% sodium hypochlorite, and 3 mL of 0.9% physiological saline. After drying with paper points, canals were obturated to the working length with a ProTaper Next® Conform FitTM Gutta-Percha Point for #X2 and AH Plus® (Maillefer, Dentsply Sirona, Ballaigues, Switzerland) sealer

TABLE 1. Experimental groupings of endodontically treated human permanent maxillary first premolars based on: (i) presence or absence of artificially prepared NCCL; (ii) restoration protocol; (iii) descriptive statistics on the fracture load (N) presented in the median, interquartile range (IQR) and minimum-maximum (min-max); and (iv) descriptive statistics on the fracture pattern - i.e. favourable or unfavourable

Group	n	(i) NCCLs preparation	(ii) Restoration Protocol	(iii) Fracture load			(iv) Fracture pattern			
				Median (N)	IQR (N)	Min–Max (N)	Favourable		Unfavourable	
							n	%	n	%
CRC	15	No	Composite resin	674.66	543.63- 774.72^{ab}	472.29- 993.64	12	80.0	3	20.0
NCCL+CRC	15	Yes	Composite resin	658.23	322.19- 783.13^{b}	144.49- 924.96	6	40.0	9	60.0
NCCL+PFRP+CRC	15	Yes	Prefabricated 3M Rely XTM fiber post+composite resin	859.80	760.31- 1007.87^{a}	527.47- 1199.16	9	60.0	6	40.0
NCCL+CFP+CRC	15	Yes	GC everStick® fibre post+composite resin	799.76	727.26- 935.88^{ab}	518.87- 1292.61	11	73.3	4	26.7

Groups that do not share the same superscript lower-case letter (a and b) indicate a significant difference between groups, i.e. between groups NCCL+CRC and NCCL+PFRP+CRC (P=0.001). n: Number of samples, CRC: Composite resin core, NCCL: Non-carious cervical lesion, PFRP: Prefabricated Rely X Fibre Post system, CFP: Custom fibre post, GC: GC everStick® fiber resin post

using single cone obturation technique. Gutta-percha was removed 1 to 2 mm apical to the canal orifice for the buccal canal. For the palatal canal, System B™ (Analytic Technology, Redmond, Washington, USA) heat plugger was used for removing the gutta-percha to create a post space ranging from 12.5 to 15 mm, leaving 5 to 6 mm of apical root filling. Specimens were stored at 37˚C in a humidified incubator (Forma™ Thermo Scientific™, Twinsburg, Ohio, USA) for 12 hours until the sealer was completely set.

Restorative Procedures

Tooth enamel was selectively etched using 37% phosphoric acid (DiaEtch™; DiaDent®, Chungcheongbuk-do, Korea) for 15 seconds and rinsed with copious water spray for 15 seconds. Self-etching primer (Clearfil™ SE Bond 2 - Primer; Kuraray, Okayama, Japan) was applied for 20 seconds before gentle air-drying for 5 seconds, followed by a thin layer of dentin bonding agent (Clearfil™ SE Bond 2, Kuraray, Okayama, Japan) and light-cured for 10 seconds using a LED curing light unit (C01-C LED Curing Light, Premium Plus™ UK Ltd., Bournemouth Dorset, U.K.). For CRC, a flowable composite (G-aenial™ Universal Flo, GC Corporation, Kasugai, Japan) was placed over the buccal root filling to serve as an orifice seal and light-cured for 40 seconds. The endodontic access cavity was restored with a nanohybrid composite resin (Filtek™ Z250 XT; 3M ESPE, Minneapolis, USA) using the incremental technique in 2 mm increments and 20 seconds of light-curing. For NCCL+CRC, the endodontic access cavity and the artificially prepared NCCLs were restored with composite resin. Flowable composite (G-aenial™ Universal Flo, GC Corporation, Kasugai, Japan) was placed as a buccal orifice seal and to restore the NCCL. The proximal and occlusal surfaces were light-cured separately for 40 seconds. The endodontic access cavity was restored as described in CRC. For NCCL+PFRC+CRC and NCCL+CFP+CRC, the artificially prepared NCCLs were restored with composite resin, while the endodontic access cavity was restored with fibre post-retained composite resin. The working length of post space was determined by applying these two principles: (i) maintaining a minimum crown-to-post length ratio of 1:1 and (ii) leaving a minimum of 5 mm of apical root filling as an apical seal. NCCLs were restored before the endodontic access cavity as described in NCCL+CRC. For NCCL+PFRC+CRC, a prefabricated Rely X™ Fibre Post system drill #1 (3M ESPE, Minneapolis, USA) was used to prepare post space in the palatal canal. Before fibre post cementation, the palatal canal was irrigated with 3 mL of 17% EDTA and 3 mL of 0.9% physiological saline solution, followed by drying with gentle air-blowing and paper points. Once the post length was established, Rely X™ Fibre Post (3M ESPE, Minneapolis, USA) size #1 with a diameter of 1.3 mm was sectioned 2 mm below the occlusal access cavity, cleaned with 70% ethyl alcohol and air-dried. The enamel of the endodontic access cavity was etched using a selective enamel etching technique, as previously described. Rely X™ Unicem (3M ESPE, Minneapolis, USA) was delivered into the post space using an elongated tip based on the manufacturer's instructions.

Resin cement was painted at the apical end of the post before insertion. Once the post was luted, the cement was polymerised from the coronal end of the post with a LED light-curing device (C01-C LED Curing Light, Premium Plus™ UK Ltd)

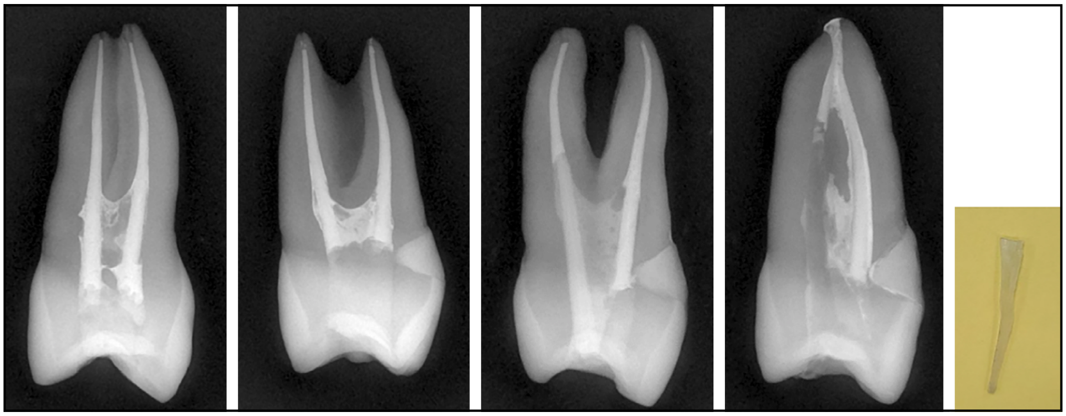

Figure 1. Radiographic images of the experimental specimens from CRC (far left), NCCL+CRC (second from the left), NCCL+PFRP+CRC (second from the right), and NCCL+CFP+CRC (far right), and a clinical picture of a custom-made elastic GC everStick® Post

CRC: Composite resin core, NCCL: Non-carious cervical lesion, PFRP: Prefabricated Rely X Fibre Post system, CFP: Custom fibre post, GC: GC everStick® fiber resin post

for 60 seconds. Composite resin (G-aenial™ Universal Flo, GC Corporation, Kasugai, Japan; Filtek™ Z250 XT, 3M ESPE, Minneapolis, USA) was placed to provide an orifice seal and restore the endodontic access cavity as described for CRC and NCCL+CRC. For NCCL+CFP+CRC, no post space preparation was performed. According to the manufacturer's instruction, one main elastic fibre post of either 0.9 or 1.2 mm in diameter (GC everStick®; GC Europe, Leuven, Belgium) was inserted and adapted to the palatal canal space at the desired length. One or more elastic collateral posts were moulded as apically as possible to obtain an optimal fit at the peri-cervical region up to 2 mm below the occlusal access cavity and then removed with a locking tweezer from the palatal canal as one unit and light-cured for 40 seconds. Posts were repositioned to check for a full depth of insertion. Before cementation, the elastic posts' surface was thoroughly activated using the bonding resin, Stick Resin® (GC Europe, Leuven, Belgium), for 5 minutes under light shielding. Procedures involved in post-cementation and restoration of the endodontic access cavity were performed as described in NCCL+PFRC+CRC.

Excess composite resin was trimmed, and all restorations were finished with a superfine diamond FG 5255 (Intensiv SA, Montagnola, Switzerland) with water coolant. All the prepared specimens were stored in physiological saline solution at 37°C in a humidified incubator (Forma™ Thermo Scientific™, Twinsburg, Ohio, USA) for 48 hours before applying the mechanical compressive loading test. One single operator (FL) performed all the specimen preparations. Examples of the experimental specimens in different groups are shown in Figure 1.

Mechanical Compressive Loading Test

The specimens were subjected to thermocycling between 5° C and 55°C in water that lasted for 54 seconds per cycle with a 20-second dwell time between each temperature change, for 75 hours. To simulate the periodontal ligament, the root surfaces were dipped into molten wax (Doric Toughened Wax®, Schottlander, Herts, UK) up to 2 mm apical to the CEJ, forming a 0.2 to 0.3 mm thick wax layer to act as a spacer (11). The individual specimen was subsequently embedded in a polyvinyl chloride tube filled with self-cure cold acrylic resin, ProBase® (Ivoclar Vivadent Inc., New York, US) up to 2 mm apical to the CEJ and mounted at an angle of 60° from the long axis of the tooth to the horizontal plane using a custom-made angle meter. After the initial polymerisation of the resin, the tooth specimen was removed from the resin cylinder, and the wax was removed from the root surface and cylinder. Silicone-based impression material (3M™ Imprint™ II Light Body, 3M ESPE) was placed in the resin cylinder, followed by remounting the specimen back into the cylinder. Excess impression material was removed with a surgical blade. Samples were kept at room temperature for 24 hours to complete resin polymerisation.

Fracture resistance was determined by a universal testing machine (Instron E3000; Instron, Massachusetts, USA) using a 5 mm diameter stainless steel sphere crosshead. A static compressive load was applied by directing non-axial load at 30° to the long axis of the tooth on the central fossa and buccal incline slope of the palatal cusp at a constant speed of 0.5 mm/min until fracture (Fig. 2). Maximum compressive load required to cause fracture was recorded in Newton (N).

After a fracture, specimens were examined for the failure mode under loupe magnification (HDLTM 2.5 Micro, OrascopticTM) with transillumination. A favourable fracture pattern was defined as one with a repairable tooth fracture that extended coronally or up to less than 1 mm apical to the CEJ. An unfavourable fracture pattern was referred to as a tooth fracture that extended more than 1 mm apical to the CEJ or a split tooth (9).

Statistical Analysis

Statistical analysis was performed using SPSS (IBM® SPSS® Statistic, Version: 25, IBM Corp., Armonk, NY). First, a normality test was performed using the Kolmogorov-Smirnov test, which indicated the data were not normally distributed. Next, the Kruskal-Wallis non-parametric tests were performed to compare the results between the experimental groups and for pairwise comparisons. Finally, Chi-squared analysis was performed to compare the proportion of fracture patterns and to evaluate any association with the demo-

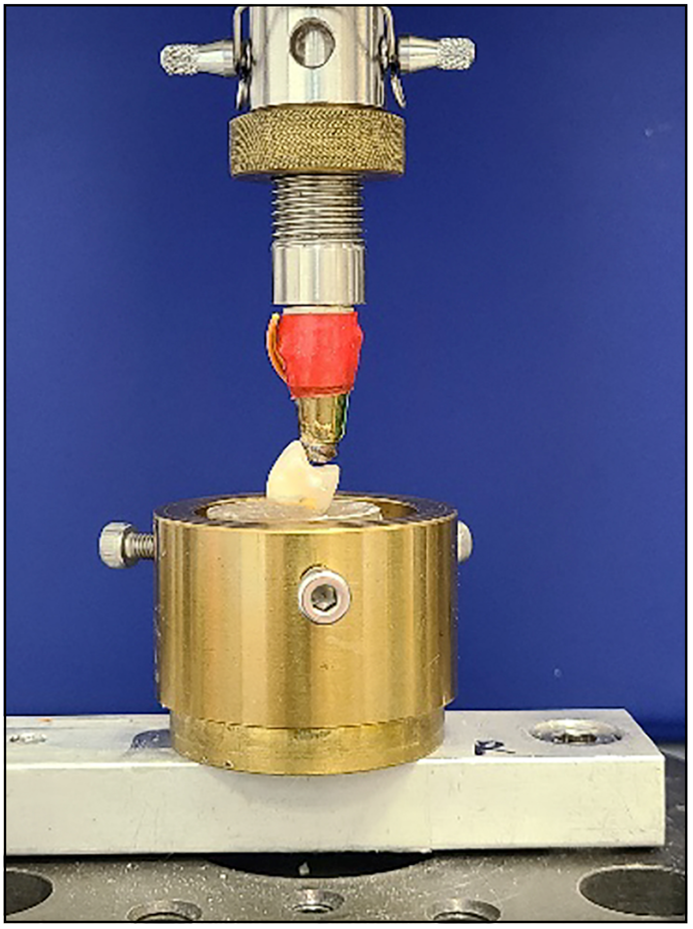

Figure 2. Mechanical compressive loading with a universal testing machine directed at 30° angle to the long axis of the specimen to test for fracture resistance.

graphic and other variables, including age, gender, number of roots, tooth dimensions, and post length. The significance level was set at 5% (P<0.05).

RESULTS

Demographic and Other Variables

No significant difference was found in the age, gender, number of roots, and tooth dimensions, among the groups (P>0.05), as well as in the post length between NCCL+PFRC+CRC and NCCL+CFP+CRC (P>0.05).

Fracture Resistance

Descriptive statistics of the fracture load (N) values are presented in the median, interquartile range (IQR), and minimum-maximum values (Table 1 and Fig. 3). NCCL+CRC had a median fracture load of 658.23 N (IQR 322.19-783.13 N). For fracture resistance, NCCL+PFRC+CRC was significantly higher than NCCL+CRC (P=0.011), while NCCL+CFP+CRC did not show any significant difference compared to NCCL+CRC (P=0.089). Furthermore, no statistical difference was found between CRC, NCCL+PFRC+CRC and NCCL+CFP+CRC (P=1.000).

Fracture Pattern

Frequencies for the unfavourable fracture pattern were: CRC (80%)>NCCL+CFP+CRC (73%)>NCCL+PFRC+CRC (60%)>NCCL+CRC (40%) (Table 1 and Fig. 4). The groups where NCCLs were restored with FRC post-retained composite resin (i.e., NCCL+PFRC+CRC and NCCL+CFP+CRC) resulted in more than 60% of favourable fractures. In comparison, CRC showed the most (80%) favourable fracture among the four groups. However, Chi-square analysis did not reveal significant differences in the fracture pattern between the groups (P=0.110).

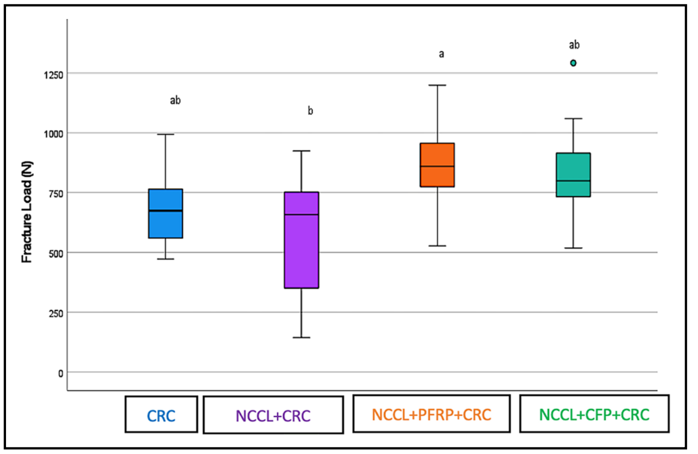

Figure 3. Box chart illustrating the fracture load (N) values of different experimental groups presented as median with Interquartile Range (IQR) and minimum-maximum values

CRC: Composite resin core, NCCL: Non-carious cervical lesion, PFRP: Prefabricated Rely X Fibre Post system, CFP: Custom fibre post

DISCUSSION

NCCLs are common tooth defects with a high prevalence (53 to 72%), and maxillary premolars are the most affected teeth (12, 13). The altered mechanical strength of dentine is a known phenomenon of ageing due to the increased formation of sclerotic dentine (14). At the same time, the loss of structural integrity of a tooth can sometimes be attributed to the reduced thickness of the peri-cervical dentine (15). Standardisation of the dimension of the artificially prepared NCCLs proved to be challenging on extracted human teeth due to morphological variation of the teeth specimens as attested previously, albeit this remains the only method to create a clinically relevant and standardised NCCLs (8, 9, 16). To minimise the structural and dimensional variation in samples selection, this study utilised:

1. Maxillary premolars that were extracted due to orthodontic reasons from patients under 45 years old;

2. Teeth with a narrow dimensional range in MD length and BL width; and

3. Teeth with no greater than 13% of inter-specimen variation in the BL width at the CEJ (9).

There are two distinct morphological features of NCCLs: wedge-shaped and saucer-shaped lesions (17). In maxillary premolars, wedge-shaped lesions are more prevalent on the buccal cervical surface (12), possibly due to the pattern and direction of the occlusal forces upon occlusal loading resulting in the concentration of tensile stress at the deepest part (i.e., apex) of NCCLs (9, 18). Thus, artificial wedge-shaped lesions were created in this study. As mentioned earlier, standardisa-

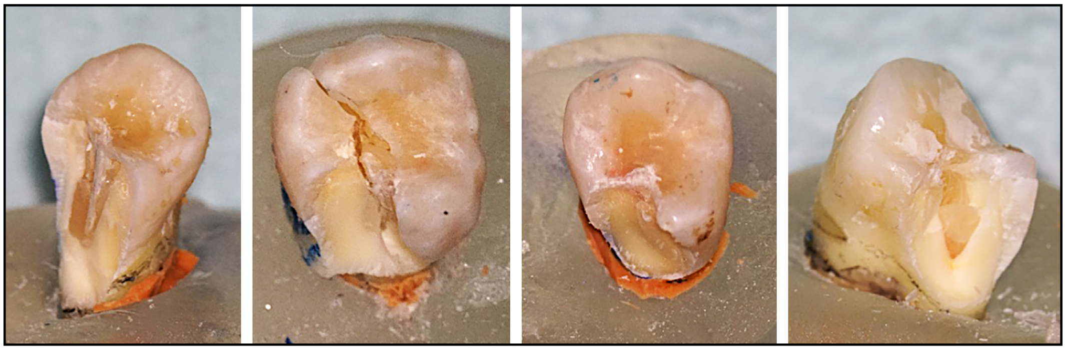

Figure 4. Example of the specimen demonstrating unfavourable (left) and favourable (right) fracture pattern

tion was also applied to the dimension of the artificially prepared NCCLs. The absence of any significant difference among the groups of other variables (including age, gender, and the number of roots) and post length ensured that these variables did not confound the results.

The similarity in the elastic modulus between the FRC post and root dentine (elastic modulus 18 GPa) has been suggested to reduce stress concentration and restore stress distribution closer to that of an intact tooth (19). This study investigated two fibre post systems, Rely X™ Unicem (3M ESPE) and GC everStick® (GC Europe) FRC posts, by cementing posts into the palatal canal of the teeth specimens. Notably, it has been reported that despite a lower fracture resistance of maxillary premolars when the fibre post was inserted into the palatal canal, the mode of failure was more favourable (i.e., restorable fracture) (20). Contrastingly, others found no significant difference in the fracture resistance between teeth with or without posts in the palatal canal or both canals of endodontically treated maxillary premolars with NCCLs (9). Indeed, the current study could have included more groups by evaluating the effect of placing a post in the 'buccal canal' and 'both canals' for more detailed comparisons. However, this study has already provided evidence that the endodontically-treated maxillary premolars with NCCL, when restored with FRC post in the palatal canal (NCCL+PFRC+CRC and NCCL+CFP+CRC), achieved comparable fracture resistance to their counterparts without NCCLs and post (CRC), suggesting the negligible difference that might be observable by adding more experimental groups.

Rely X™ Unicem (3M ESPE), the material used for post cementation in this study, has been shown to have superior bond strength to several other self-adhesive resin cements (21, 22). NCCL was restored with a flowable resin composite (G-aenial™ Universal Flo, GC Corporation). Flowable resin composites typically contain lower filler loading (about 37 to 53 v/v%) and thus exhibit a lower modulus of elasticity and viscosity than their nanohybrid counterparts (23, 24). Additional advantages include better marginal adaptation and less void formation compared to other resin composites (25, 26).

All specimens were subjected to 5000 cycles of thermal stress, representing six months of clinical function, before testing with non-axial compressive static load (27). Non-axial compressive loading simulates the damaging lateral occlusal force to the functional (palatal) cusp upon occlusal loading, and it is the most commonly used loading method for these types of studies (8, 20, 28). Indeed, future studies must also consider the application of both cyclic loading and thermal stresses to simulate better the effect of masticatory function and ageing on the specimens as elegantly described recently (29). Strictly speaking, a single directional loading force applied on the test specimens was not a realistic model to mimic the masticatory function in the mouth. Future studies may improve the experimental model by integrating a multi-directional chewing pattern of varying speed and chewing force of varying magnitude to simulate the physiological chewing pattern and stress over a long period (29). In our study, the storage condition of the tooth specimens before experiments, i.e., at room temperature in saline, might have unknown influences on their mechanical properties and behaviours during experiments (29). Ideally, specimens should have been stored at 37°C degrees under similar humidity to the mouth to reduce potential confounding effects.

The results of this study showed that direct composite resin restoration of endodontically-treated maxillary premolars with NCCLs (NCCL+CRC) could achieve similar fracture resistance as their counterparts without NCCLs (CRC) (Fig. 3). This study also found that different restorative protocols adopted in restoring the endodontically-treated maxillary premolars with NCCLs (NCCL+CRC, NCCL+PFRC+CRC and NCCL+CFP+CRC) resulted in similar fracture resistance as those without NCCLs (CRC) (Table 1). Interestingly, placement of a prefabricated FRC post with Rely X™ Unicem (3M ESPE) (NCCL+PFRC+CRC) showed a significantly higher fracture resistance than those restored without a post (NCCL+CRC). In contrast, elastic GC everStick® FRC post (NCCL+CFP+CRC) did not produce a similar effect. The latter might be explained by the relatively narrow and round palatal canal in the permanent maxillary premolars that could only accommodate one main elastic FRC post, thereby diminishing the need for collateral posts and denying the potential advantage of using an elastic FRC post. In addition, a minimally prepared access cavity might not allow sufficient bulk in the coronal core of the elastic FRC posts necessary to offer optimal mechanical strength. Albeit the lack of statistical significance, the highest proportion of unfavourable fracture patterns was found among the teeth specimens in NCCL+CRC, suggesting the potentially detrimental effects of restoring the endodontically treated maxillary premolars with NCCLs without a post.

While every effort was made to standardise the access cavities in these teeth, absolute standardisation was not possible given inherent variations in the size of teeth, pulp chambers and root canals. Although the variations of tooth structure may be construed as a potential limitation of this study owing to variations in the quality and amount of remaining peri-cervical dentine (30), they may improve the generalisability of the findings in a clinical scenario. Besides, this study did not compare single- versus two-rooted teeth specimens, from which potentially interesting and insightful findings regarding their fracture pattern and behaviour could be studied.

CONCLUSION

For the root canal treated maxillary premolars with a non-carious cervical lesion (NCCL):

Fracture resistance similar to that of the teeth without NCCL could be achieved if properly restored. Placing a prefabricated Rely X™ FRC post resulted in a greater fracture resistance than those restored without a post. No differences could be detected in the fracture resistance and pattern between the use of prefabricated Rely X™ FRC post and elastic GC everStick® FRC post.

Proper restoration of endodontically treated maxillary premolars with NCCLs can potentially restore their fracture strength similar to intact teeth. In addition, the placement of certain prefabricated FRC post systems might further enhance the fracture strength of these teeth.

Disclosures

Conflict of interest: The authors deny any conflict of interest.

Ethics Committee Approval: This study was approved by The Institutional Review Board of the University of Hong Kong / Hospital Authority Hong Kong West Cluster (Date: 25/09/2020, Number: UW 20-683).

Peer-review: Externally peer-reviewed.

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