INTRODUCTION

Post-core system is a frequently used technology for restoring non-vital teeth with substantial loss of the dental crown. Core build-up is one of the most crucial steps during the treatment for rebuilding and supporting the crown, as it serves as a medium of stress distribution. Improving the mechanical performances and reduce polymerization shrinkage is essential for long-term survival.

Conventional packable light-cured resin-based composite (LCRC) materials have appreciable mechanical performances and have been widely used in core build-up. For most LCRC materials, the incremental filling technique is usually employed for severely damaged teeth, since the maximum cure depth is normally reported to be 2.5 mm. In deep cavities as well as spaces between posts and dentin, the procedure can be time-consuming. Also, pores may be generated when filling narrow gaps between the post and residual tooth tissue, reducing the load capacity and leading to structural degradation of the core.

With the expectation of better performance and easier clinical manipulation, a flowable dual-cured resin composites (DCRC) with one conventional packable light-cured resin composite (LCRC) for their application as core build-up material by micro-hardness test, flexural strength test, push-out test, and digital image correlation analysis. The LCRC had a significantly higher micro-hardness (p<0.05) whereas the bond strength demonstrated no difference. The mean values of three materials ranged from 35.16 and 64.82 for the Vickers hardness and from 4.66 MPa to 11.53 MPa for the bond strength. The flexure strength of the three materials was not statistically different from each other. LCRC demonstrated 1.88% of volumetric shrinkage while the two DCRC showed 5.06% and 4.91%, respectively. In general, the DCRC demonstrated a comparable flexural strength and bond strength as the LCRC, however, the significant polymerization shrinkage of DCRC should be emphasized.

Keywords: Core build-up material, Mechanical behavior, Bond strength, Polymerization shrinkage

This study systematically compared the mechanical performances and polymerization shrinkage of two novel dual-cured resin composites (DCRC) with one conventional packable light-cured resin composite (LCRC) for their application as core build-up material by micro-hardness test, flexural strength test, push-out test, and digital image correlation analysis. The LCRC had a significantly higher micro-hardness (p<0.05) whereas the bond strength demonstrated no difference. The mean values of three materials ranged from 35.16 and 64.82 for the Vickers hardness and from 4.66 MPa to 11.53 MPa for the bond strength. The flexure strength of the three materials was not statistically different from each other. LCRC demonstrated 1.88% of volumetric shrinkage while the two DCRC showed 5.06% and 4.91%, respectively. In general, the DCRC demonstrated a comparable flexural strength and bond strength as the LCRC, however, the significant polymerization shrinkage of DCRC should be emphasized.

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Investigation of mechanical performances and polymerization shrinkage of dual-cured resin composites as core build-up material

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determines their degree of bonding. Under the same shrinkage stress, lower bond strength will facilitate debond. Therefore, bond strength is an essential part of evaluating the mechanical performance. However, limited information is available regarding the mechanical behavior of DCRC as a core build-up material.

Therefore, the objective of this study was to evaluate whether the mechanical properties and shrinkage behavior of the DCRC is competitive to the conventional LCRC as core material by measuring the representative parameters and investigating the influence of water storage on LCRC and DCRC. The null hypotheses of this study were that: DCRC and LCRC core-build-up materials have no difference on micro-hardness, bottom/top hardness ratio, flexure strength, bond strength, and polymerization shrinkage.

**MATERIALS AND METHODS**

In the present study, two DCRC: Paracore (PC; Coltene, Altstätten, Switzerland) and Luxacore Z Dual (LC; DMG, Hamburg, Germany) that are widely used in clinical practice and one conventional packable LCRC: Z350XT (ZXT; 3M, St. Paul, MN, USA) was chosen to be investigated. The three materials represent different curing modes and different clinical packing modes. The materials and curing methods used in this study are listed in Table 1.

The photopolymerization was achieved using a LED light-curing unit with a diameter of 1 cm (1,200 mW/cm², 430–480 nm) (Elipar S10, 3M). The distance between the LED light-curing tip and the tested materials was fixed at 1 mm. To unify the influence of background light and sun light on the outcome of this study, the entire experiment was conducted in a dark environment with yellow LED light illumination. Given that chemical curing of DCRC immediately begins after mixing, the filling process was controlled within 20 s. All of the specimens were wet polished under running water sequentially with #320, #600, and #2000 SiC paper (Eaglehead, cw-400-2c, SUISUN, Hongkong SAR, China) and stored in phosphate-buffered saline (PBS; pH 7.4, Gibco, Thermo Fisher Scientific, Waltham, MA, USA) at 37±1°C in a water bath (Thermostatic Water Bath, WT100-3, Miulab, Hangzhou, China) and wrapped with tinfoil until the test began except for polymerization shrinkage. Each test was divided into six groups based on three materials and two immersion time in addition to polymerization shrinkage. The actual operation strictly followed the manufacturers’ instructions.

Table 1  Composition of resin-based materials and bonding agent used in this study

| Product          | Matrix | Fillers               | Filler content (vol%/wt%) | Instructions for use | Curing mode |
|------------------|--------|-----------------------|---------------------------|----------------------|-------------|
| Z350XT, 3M       | Bis-GMA| zirconia, silica      | 63.3%/78.5% zirconia/silica: 0.01–3.5 μm | layer ≤ 2.5 mm: Light curing 20 s | light cure |
| (Code: ZXT)      | UDMA   |                       |                           |                      |             |
|                  | TEGDMA |                       |                           |                      |             |
|                  | Bis-EMA|                       |                           |                      |             |
| Paracore, PC     | Bis-GMA| strontium glass       | 50%/68% 0.1–5.0 μm        | 1) chemical curing intraoral 4 min | dual cure |
| (Code: PC)       | TEGDMA | filler                |                           | 2) layer ≤ 2 mm: light curing 20 s | dual cure |
|                  | TMPTA  | amorphous silica      |                           | layer ≤ 4 mm: light curing 40 s |             |
| Luxacore Z Dual  | Bis-GMA| barium glass          | 50%/70% 0.02–2.4 μm       | 1) chemical curing intraoral 5 min | dual cure |
| (Code: LC)       | UDMA   | pyrogenic silicic acid |                           | 2) layer ≤ 2 mm: light curing 20 s | dual cure |
|                  | DDDMA  | zirconium dioxide     |                           | layer ≤ 4 mm: light curing 40 s |             |
| Scotchbond        | Composition: MDP monomer, Dimethacrylate resins, HEMA, Ethanol, Water, Silane | |
| Universal Adhesive, 3M |        |                      |                           |                      |             |

Bis-GMA: bisphenol A-glycidyl methacrylate; UDMA: urethane dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; Bis-EMA: bisphenol A-diglycidyl methacrylate ethoxylated; TMPTA: trimethylolpropane triacrylate; DDDMA: dodecanediol dimethacrylate; MDP: 10-methacryloyloxydecyl dihydrogen phosphate; HEMA: 2-hydroxyethyl metacrylate.
testing for 24 h, all of the specimens were collected and stored in PBS again until the second measurement began 7 days later.

The ratio of the top and bottom surface was measured and calculated as the hardness ratio according to the following equation:

$$\frac{B}{T} \text{ hardness ratio} = \frac{VHN_{\text{bottom surface}}}{VHN_{\text{top surface}}}$$

(1)

**Flexure strength**

Composite bars were prepared according to ISO 4049:2019. Core materials were filled into a (25±2)×(2.0±0.1)×(2.0±0.1) mm detachable Teflon mold and cured in three sections. Each irradiation overlapped with the prior to ensure that the materials were fully cured. A cover glass (Microscope cover glass, 10212020, Hehy Glass, Jiangsu, China) was placed on the material to produce a flat surface. Specimens with any voids or defects were discarded. A total of 60 specimens were produced for the flexure strength test, 10 for six groups according to three materials and two immersion time. Stainless steel fixtures for three-point bending tests were also prepared following ISO 4049:2019. The apparatus consisted of three parallel stainless-steel rods (2 mm in diameter). Two were placed at the bottom support ends, and one at the middle top surface.

All of the specimens were wet polished sequentially and maintained in PBS at 37±1°C prior to testing in a universal testing machine (ElectroPuls, E3000, Instron, Norwood, MA, USA) in a three-point bending fixture loaded at a crosshead speed of 0.75±0.25 mm/min until fracture. The maximum load at the fracture point was recorded and then the flexure strength was calculated using the following equation:

$$\sigma = \frac{3FL}{2bh^2}$$

(2)

where $F$ is the maximum load in newtons (N), $L$ is the distance between the supports in millimeters, $b$ is the specimen width in millimeters, and $h$ is the specimen height in millimeters.

**Push-out bond strength**

The bond strength of the dentin-resin interface was investigated to evaluate the material bonding performance.

1. Specimen preparation for testing the bond strength of the dentin-resin interface

A total of 30 newly extracted human molar teeth with complete crowns and no caries were selected and stored at 1% thymol solution at room temperature (22°C) for one week, then washed with deionized H2O and stored at 0.5% thymol in a 5°C refrigerator. Crowns were standardized by lathing (Universal lathe, CW61/295F, Nanfang Lathe, Guangzhou, China) and drilling (JCTA, Φ2.0 mm, Riyan Technology, Dongguan, China) cylinders with an inner radius of 1 mm and 3 mm for the outer edge under running water, then cut into 2 mm thick disks using a precision cutting machine (Accutom-50, Struers, Ballerup, Denmark). Next, the dentin disks were cleaned under ultrasound for 15 min, and randomly divided into 6 groups of 5 samples each according to the materials and storage periods.

A thin layer of adhesive (Scotchbond Universal Adhesive, 3M) was applied to the inner circle of the dentin disk, air-dried for 10 s to evenly distribute the adhesive, and illuminated for 20 s. Core materials were filled in the middle of the disk and irradiated for 20 s. Cover glass was used to form a flat top and bottom surface.

2. Push-out test

The final dimensions of the coronal radius and apical radius were measured using digital calipers. The bond strength was tested by a universal testing machine (ElectroPuls, E3000, Instron) with a crosshead speed of 1.00±0.25 mm/min, a 1.2-mm diameter cylindrical metallic plunger, and two parallel mounted braced apparatus (Fig. 1). The specimens were loaded until failure occurred. The specimens with defects and cracks may interfere with the test results, therefore, failures caused by the fracture of materials or dentin were excluded, the maximum load (N) was recorded. The bonding area (mm²) was calculated using the following equation:

$$A = \pi (r_1+r_2)\sqrt{(r_1-r_2)^2+h^2}$$

(3)

where $A$ is the specimen bonding area (mm²), $r_1$ is the coronal radius (mm), $r_2$ is the apical radius, and $h$ is the thickness (mm). The push-out bond strength was then calculated:

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**Fig. 1** Schematic representation of the dentin disk preparation and the push-out test setup.
where $\sigma$ is the bond strength in MPa and $F$ is the maximum load at failure in N.

### 3. Examination of failure surfaces
The tested specimens were air-dried and stored at room temperature until observation. Three samples from each group were randomly collected for surface morphology assessment. The samples were mounted on a metallic stub with conductive tape, coated with gold-palladium, and evaluated under a scanning electron microscope (SEM; Field Emission Scanning Electron Microscope, JSM-6330F, JEOL, Tokyo, Japan) at 800× magnification and an acceleration voltage of 20.0 kV.

#### Polymerization shrinkage
To record and calculate the polymerization shrinkage of the core materials, a previously described digital image system was used (Fig. 2). A charge-coupled device camera (CCD; Blackfly S USB3, BFS-U3-13Y3M-C, FLIR Systems, Wilsonville, OR, USA) together with a 105 mm lens (Sigma, DG Macro HSM, Nikon, Tokyo, Japan) was fixed vertically on a stand with the lens facing down toward the materials. The sample was placed in a $(4\pm0.1)\times(2\pm0.1)\times(2\pm0.1)$ mm Teflon cube applied evenly with Vaseline to minimize adhesion to the core materials. Bulk filling and incremental filling were used. The materials were filled 4 mm at a time and illuminated after 40 s using bulk filling whereas incremental filling was 2 mm by 2 mm with measurements conducted using digital calipers. Each layer was irradiated for 20 s.

Nano-sized black carbon powders (Fluka, CAS: 7440-44-0, Honeywell, NJ, USA) were randomly sprayed on the surface of the composites. A curing light was fixed at a distance of 1 mm from the resin. A metal light shield with a 2×4 mm through-hole was placed to ensure that only the side facing the curing light was irradiated (Fig. 3). Images were taken before and after curing. Shrinkage strain after illumination was investigated. In-plane shrinkage in two directions, longitudinal shrinkage $\varepsilon_{xx}$, and transverse shrinkage $\varepsilon_{yy}$, were calculated with an image correlation software (Davis software, 10.0, LaVision, Goettingen, Germany). Given that a certain strain was also generated between the layers not caused by unconstrained shrinkage, the fluctuation along the $x$-axis was higher and not referenced as a result. The $\varepsilon_{yy}$ was used for plotting and further analysis. Peak values and spatial curves of polymerization shrinkage for each group were exported. Volumetric shrinkage strain $\varepsilon_{volume}$ was determined by $\varepsilon_{volume}=3\varepsilon_{yy}$.

#### Statistical analysis
Shapiro-Wilk test was used to check the normality before statistical analysis. In normal distribution data, one-way ANOVA followed by a Bonferroni post-hoc test was used to analyze the difference among ZXT, PC, and LC over the same storage period whereas the independent-samples $t$ test was used to assess the properties of each material at different storage times (1 day, 7 days) thereinto the micro-hardness value was assessed by paired-$t$ test. Correspondingly, the Kruskal-Wallis test and Mann-Whitney $U$ test were conducted for non-normal distribution data in bond strength and polymerization shrinkage tests. SPSS (IBM SPSS software, 23.0, IBM, Armonk, NY, USA) was used for the statistical analysis and $\alpha$ was 0.05.

#### Ethical approval
All procedures performed in studies involving human participants were in accordance with the ethical standards of our institutional research committee and with the 1964 Helsinki declaration and its later
amendments or comparable ethical standards.

RESULTS

Figure 4 summarizes the results of the mechanical performance measurements. One-way ANOVA followed by a Bonferroni multiple comparison post-hoc test revealed that the ZXT had a significantly higher hardness value among the three materials ($p<0.05$). The micro-hardness of the ZXT at 1 day was $64.82\pm11.99$ while the PC was $41.16\pm4.59$ and the LC was $35.16\pm4.86$. The PC and LC values were similar and there was no statistical difference ($p=0.306$, Fig. 4a). There was no statistical difference in the B/T hardness ratio values among the groups in 1 day ($p=0.135$) and 7 days ($p=0.625$), and the values of the three materials were all close to 1.0 (Fig. 4b).

The flexure strength of the three materials was not statistically different from each other after 1 day and 7 days. However, after 7 days, the independent-samples $t$ test showed a significant decrease from 121.09±15.66 to 97.55±19.38 MPa in the ZXT ($p=0.008$) and from 123.63±22.48 to 101.87±15.95 MPa in the PC ($p=0.022$) as shown in Fig. 4c.

The bond strength of PC and LC were 11.53±4.10 and 10.50±6.13 MPa respectively, but both of the values tended to be close to ZXT (Fig. 4d) after 7 days of storage and there was no statistical difference among the groups in 1 day ($p=0.080$) and 7 days ($p=0.566$). The failure modes within groups were adhesive failure between the core material and dentin. Figure 5 displays the SEM results of representative debonded surfaces. The debonded surfaces and fracture edge of the DCRC are more irregular than ZXT.

Figure 6 shows the in-plane shrinkage strains along the transverse shrinkage $\varepsilon_{yy}$ after 40 s of photocuring. In general, the main shrinkage occurred at the side near the light source. The maximum shrinkage value occurred approximately 0.3–0.7 mm from the illuminated surface of the composite. Figure 6a shows the shrinkage of the bulk filling. The highest $\varepsilon_{yy}$ of the ZXT was approximately 0.63% while PC and LC were 1.69% and 1.64%, respectively. Shrinkage still occurred in the ZXT at depths beyond the curing depth of 2.5 mm. In the layered filling, digital image correlation (DIC) captured the shrinkage process of the first and second illuminations (Fig. 6b). The $\varepsilon_{yy}$ of the layered filling was similar to that of the bulk filling. The peak value and position of the maximum shrinkage were similar. Average volumetric shrinkage was calculated from the peak value and has listed in Fig. 6c. The volume shrinkage of ZXT was about

Fig. 4 The means and standard deviations results of mechanical properties in each group. (a) Micro-hardness, (b) Bottom/top hardness ratio, (c) Flexure strength, (d) Bond strength. (a) 1/15$^\circ$ represents the applied test force (kgf) and 15 was the duration of the test force. The same lowercase letters indicate no statistically significant difference ($p>0.05$) among each material. The same uppercase letters indicate no statistically significant difference ($p>0.05$) between 1 day and 7 days.

Fig. 5 Representative SEM micrographs of different materials after the push-out test. The figures shown were all adhesive failure between the core material and dentin. Dentin is on the left while the composite is on the top right. The dashed line represents the debonding interface. The interface in the square frame shows the DCRC debonded surface is more irregular. (a) ZXT, (b) PC, (c) LC.
1.88%, while the two PC and LC showed 5.06% and 4.91% shrinkage, respectively. The volume shrinkage of PC and LC was remarkably greater than that of ZXT whether using a bulk filling or layered filling.

DISCUSSION

The core plays an important role in supporting the crown and conducting stress to the root in whole post core restorations. The resin core should strongly bond to the residual tooth structure to prevent marginal leakage. Low mechanical strength, poor bonding, or high polymerization shrinkage of core materials may lead to early restoration failure. The present study compared the mechanical performances, and polymerization shrinkage of three commercial resin composites as core materials by testing the micro-hardness, B/T hardness ratio, flexure strength, and shrinkage strain. The results indicate that although the micro-hardness of the DCRC was much lower than that of the ZXT, the other properties, such as the B/T hardness ratio and flexure strength, were close to those of conventional resin composite. The most obvious disadvantage of the DCRC is the large volumetric shrinkage. In the current study, the type of material had an influence on micro-hardness and polymerization shrinkage, therefore the null hypothesis was rejected.

Micro-hardness is widely used to illustrate the efficiency of curing and surface strength. The ZXT had better micro-hardness, even reaching twice that of the other core materials. The ZXT and DCRC had similar matrixes (Bis-GMA), possibly because there was less filler in the flowable material (Table 1). This result was in accordance with previous studies: in a specific resin matrix, the microhardness had a positive correlation with the amount of filler, the microhardness of flowable materials was lower than conventional composites and the amount of filler contributed more than the matrix. After 7 days of storage in PBS, the hardness of LC and PC produced a significant difference. This may be caused by two factors: (1) polymerization by chemical curing continued after photoactivation stopped; (2) when phosphorylated methacrylate with apatite and basic load particles inside the composite reacted with surplus acid groupings from aqueous solution, the hydrophilic properties were superseded by the hydrophobic properties, which tends to limit the deterioration of cured materials. The depth of cure can be evaluated indirectly by measuring the surface hardness. Strong surface microhardness is one of the main requirements of restorations, especially in post-stress-bearing areas. However, with time increase, the matrix will undergo degradation and plasticization reaction, resulting in the softening and roughness of the composite surface and the separation of polymer molecular chains, which will reduce the hardness.
surface hardness of DCRC is lower than ZXT, and low-hardness resin composite materials are more prone to degradation and dissolution. Once degradation occurs on the surface or inorganic fillers precipitate, irregular surface is more likely to cause bacterial adhesion, which is one of the predisposing factors for periodontal disease and material discoloration.  

The hardness at the bottom of the specimen was close to that at the top, demonstrating that the entire specimen was well cured. Compare to the 1-day group, the B/T hardness ratio of DCRC showed no statistical significance in the 7-day group, indicating that although chemical curing compensated for the gradual decrease of light energy density with thickness to some extent, it had little impact on the well-cured materials. Besides, the sample thickness was controlled within the cure depth recommended by the manufacturer to avoid false positives of the material due to insufficient curing.

A strong core with a high flexure strength may reduce the potential for restoration fracture under functional loading. Meanwhile, the strength of the restorative materials might be affected by the moisture oral environment. In this study, it was found that all the 3 materials demonstrated similar flexure strength after 1 day’s PBS immersion, which indicates that the early strength of DCRC is comparable to LCRC. After 7 days’ immersion, the flexure strength of ZXT and PC decreased significantly, the value of LC also showed a decrease, but no significant difference was found, this might be because that the observation period is not long enough. During the PBS storage process, the absorbed aqueous solution expanded into the polymer. Aqueous solution may also be combined with the polymer’s hydroxyl group by breaking the ester bonds. A series of adverse reactions such as filler debonding, mass loss, and decreased mechanical properties result. This result indicates that although the filler composition and content can improve the hardness, the negative effect of hydrolysis on the filler is inevitable. Therefore, the edge sealing of the outer crown (both the temporal and permanent crown) after the core build-up is very important, not only for preventing secondary caries, and permanent crown) after the core build-up is very important, but also for avoiding the negative impact of saliva and ingested liquids on the core materials’ properties.

The adhesion of post-core restoration system mainly includes two interfaces: fiber post-resin composite interface and the dentin-resin composite interface. Compared to fiber post-resin composite interface, the failure between dentin-resin composite interface is more common in clinical practice. Therefore, the emphasis of the current study is dentin-resin composite interface. No significant difference was found among the bond strength of the 3 materials with dentine, in addition, the bonding strength of 1 day and 7 days showed no statistical difference either. This suggested that the material type and short-term PBS storage have little impact on bond strength. Nevertheless, the variation of the bond strength of PC and LC appeared to be greater than that of ZXT, and the mean values of Day 1 and Day 7 showed a trend of decrease. This indicates that DCRC might be more susceptible to moisture.

When the composite resin was in contact with the bonding agent, the tertiary amine in the resin surface layer reacted with the 10-methacryloyloxydecyl dihydrogen phosphate (MDP) in the uncured oxygen inhibition layer on the adhesive and became inactivated. It affected the formation of free radicals, exerted a negative impact on the dentin-resin composite interface, and weaken the bond strength. However, ZXT is reported to be less affected by MDP because the use of LCRC is always accompanied by illumination. The photoinduced free radicals produced much faster in light-cured composites, while the chemical-cured composites prolonged the acid-base reaction competition. This may explain why the bond strength of DCRC showed a downward trend after 7 days, but there was little effect on the LCRC material, ZXT. However, this result did not show a significant difference, which may because the push-out test produced a large standard deviation. Even though, it can be inferred from the trend of the present results that lower acidity of adhesive is not recommended in the use of DCRC, as the acidity of acidic monomers of the adhesive (Scotchbond Universal Adhesive) is reported to be low to pH 2.7.

Dimensional stability is important for core materials to avoid crown failure. During the composite curing process, under the interaction of increased hardness and reduced fluidity and volume, an interior composite reaction is generated that tends to be internal. DIC is a specialized device used to measure the magnitude of shrinkage to track the direction of shrinkage along the longitudinal and transverse axis. Figure 6a shows a distinct decrease in polymerization shrinkage in the ZXT as the distance from the curing light increased. Since the DCRC had a 4 mm curing depth, its shrinkage strain occurred evenly along the y axis and had a moderate downtrend, demonstrating more uniform shrinkage strain and more uniform curing. As shown in Fig. 6b, the first filled layer underwent no apparent polymerization shrinkage during the second illumination. This indicated that the first layer had no obvious polymerization shrinkage during the second illumination. This ratio of monomer and diluent has an effect on polymerization shrinkage. Increasing the amount of filler lowers the concentration of C–C double bonds, further decreasing shrinkage. Overall, the DCRC had a significantly greater shrinkage strain than the LCRC. The previous study indicated that organically modified ceramics such as silica filler can reduce polymerization shrinkage. The materials used in this research all contain silica, but the polymerization shrinkage of PC and LC was still much higher than that of ZXT, indicated that the main factor affecting the polymerization shrinkage is the filler content rather than the filler category. In addition to increasing the packing content, polymerization shrinkage can also be reduced through clinical operations, such as the use of delayed illumination, etc.
of filler and monomer type and was not suitable for restorations, although DCRC are modified based on luting agent, yet they had considerable mechanical properties in the present study. The greatest advantage of using DCRC is reducing procedure time and technical sensitivity. DCRC also have better flowability than conventional packable LCRC. In some clinical cases, conventional LCRC are hard to manipulate in narrow gaps and deep cavities and are thus more likely to cause voids. Consequently, during the clinical process, doctors should make reasonable choices according to the actual situation. DCRC are recommended when there are narrow spaces that are hard to fill whereas both types of core materials can be used when the space is relatively wide. This study only evaluated the performance of DCRC and LCRC in terms of their mechanical properties and polymerization shrinkage. In actual clinical practice, masticatory fatigue and shrinkage stress are also among the main causes of restoration failure. A necessitating a more comprehensive evaluation of core materials, which will be further studied in future experiments.

CONCLUSION

Within the limits of the present study, the dual-cure resin composite core materials demonstrated a comparable flexural strength and bond strength as the packable LCRC. However, the shrinkage strain of the dual-cure resin composite core materials was much higher than that of the light-cured resin composite.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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