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Effect of Temporary Restorative Materials and Cavity Design on the Fracture Resistance of Endodontically Treated Teeth

Mehdi Besharat Far [1], Zahra Sadat Madani [2*], Akam Saeidi [3], Seyedali Seyedmajidi [4], Elham Mahmoudi [4]

1. DDS, Student Research Committee, Babol University of Medical Sciences, Babol, I.R.Iran.
2. Associate Professor, Dental Materials Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, I.R.Iran.
3. Assistant Professor, Oral Health Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, I.R.Iran.
4. Assistant Professor, Dental Materials Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, I.R.Iran.

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ABSTRACT

Introduction: Endodontically treated teeth are highly susceptible to fracture, and the choice of temporary restorative material may influence their Fracture Resistance (FR). This study evaluated the effects of different temporary restorative materials on the FR of endodontically treated teeth with two cavity designs.

Materials & Methods: In this ex vivo study, 108 sound human maxillary premolars were included. Randomly, 12 teeth served as the negative control. The remaining 96 teeth were randomly assigned to mesio-occluso-distal (MOD) or mesio-occlusal (MO) cavity preparations (n=48 per group). Each group was further divided into four subgroups (n=12): unrestored (positive control) or restored with Coltosol F, Cavisol, or NexTemp. FR was measured using a universal testing machine. Data were analyzed using the independent-samples t-test and one-way ANOVA, with statistical significance set at $P<0.05$.

Results: FR was highest in the negative control group, followed by the MO and MOD cavity groups ($P<0.001$). Teeth with MO cavities demonstrated significantly greater FR than those with MOD cavities ($P=0.025$). Within the MO groups, FR did not differ significantly among restorative materials. In contrast, within the MOD groups, Coltosol F yielded significantly higher FR than the unrestored control ($P=0.042$). Compared with the MOD design, the MO design showed significantly greater FR in both the positive control ($P=0.028$) and NexTemp ($P=0.012$) groups.

Conclusion: Among the materials evaluated, Coltosol F improved FR in teeth with MOD cavities and may therefore be considered the preferred temporary restorative material in these cases.

Keywords: Endodontics; Root Canal Therapy; Tooth Fractures; Dental Restoration, Temporary

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* **Corresponding Author:** Zahra Sadat Madani, Department of Endodontics, School of Dentistry, Babol University of Medical Sciences, Babol, Iran.
Tel: +98 1132291408
E-mail: madani_z@yahoo.com

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Introduction

Temporary restorative materials are widely used during endodontic treatment between appointments or after treatment until placement of the definitive restoration. They provide an effective coronal seal, preventing reinfection of the root canal system by saliva and oral microorganisms while preserving intracanal medicaments [1-3].

Endodontically treated teeth are more susceptible to fracture because of dentin dehydration, loss of tooth structure, the effects of irrigating solutions, and stresses generated during instrumentation. Consequently, their Fracture Resistance (FR) is generally lower than that of intact teeth [4-6].

Numerous factors affecting the FR of endodontically treated teeth have been investigated, including rotary instrumentation systems, intracanal medicaments, root canal obturation techniques, permanent coronal restorations, and the type and concentration of irrigating solutions [6-11]. More recently, the influence of temporary restorative materials has also attracted attention [12]. Besides preventing bacterial reinfection, these materials protect structurally weakened teeth from fracture and may remain in place for several weeks until an indirect restoration is fabricated [13, 14]. Therefore, an ideal temporary restorative material should maintain tooth function while providing an adequate seal and allowing proper oral hygiene [15].

The choice of a temporary restorative material depends on factors such as available cavity space, occlusal loading, and the expected duration before definitive restoration [16]. Zinc oxide/calcium sulfate–based materials, including Coltosol F and Cavisol, provide excellent sealing ability, are easy to manipulate, set within 20–30 minutes in the presence of moisture, and withstand masticatory forces after 2–3 hours [15]. Coltosol F has demonstrated effective sealing for up to two weeks, can be removed in bulk, and exhibits hygroscopic expansion of 17%–20% [17, 18].

NexTemp is a light-cured resin-based temporary restorative material that does not require etching or adhesive application and can be placed directly and removed in one piece. According to the manufacturer, it has high elasticity and hardness. In addition, resin-based temporary materials such as NexTemp demonstrate lower water sorption and solubility, as well as superior marginal sealing compared with Cavit, IRM, and glass ionomer materials [19].

The influence of access cavity design on the FR of endodontically treated teeth has recently received increasing attention. Although previous studies have evaluated the effects of mesio-occlusal (MO) and mesio-occluso-distal (MOD) cavity designs, [12] the combined influence of cavity design and temporary restorative material on FR remains unclear. Furthermore, the FR of teeth restored with NexTemp has not yet been investigated. Therefore, this study aimed to evaluate the effect of different temporary restorative materials on the FR of endodontically treated teeth with MO and MOD cavity designs.

Materials & Methods

This ex vivo experimental study was conducted on 108 sound maxillary premolars with similar mesiodistal and buccopalatal dimensions that had been extracted as part of orthodontic

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treatment. The study protocol was approved by the Ethics Committee of Babol University of Medical Sciences (IR.MUBABOL.HRI.REC.1400.066).

The sample size was determined to be 12 teeth per group, based on the results of a previous study [12], assuming a 95% confidence interval and 80% power.

Specimen Preparation

Teeth with fractures or cracks were excluded from the study. Samples were inspected by the researcher under a stereomicroscope to ensure the absence of fractures or cracks. The mean mesiodistal, buccopalatal, and intercuspal dimensions of the collected teeth, measured using a digital caliper, were 7.46 ± 0.61 mm, 8.91 ± 0.75 mm, and 7.32 ± 0.27 mm, respectively.

Twelve teeth were assigned to the negative control group and did not undergo any intervention. The remaining 96 teeth were randomly divided into two equal groups (n=48), and an endodontic access cavity was prepared using a high-speed diamond bur (852G.FG.014; JOTA AG, Rüthi, Switzerland) under water coolant at 1 mm above the cementoenamel junction. All internal margins were beveled and rounded.

Following access cavity preparation, the first group received an MOD cavity and the second group received an MO cavity, both prepared using a direct fissure bur with water cooling.

The teeth in each cavity design group were then randomly assigned to four subgroups (n = 12): a positive control group (no temporary restorative material) and three experimental groups treated with Coltosol F (Coltene/Vigodent, Bonsucesso, RJ, Brazil), Cavisol (Golchai, Tehran, Iran), and NexTemp (Meta Biomed, South Korea). Table 1 presents the characteristics of the three temporary restorative materials used in this study.

Table 1. Characteristics of the three temporary restorative materials used in this study

Material	Manufacturer	Composition
Coltosol F	Coltene/Vigodent, Bonsucesso (RJ), Brazil	Zinc oxide, zinc sulfate monohydrate, calcium sulfate hemihydrate, ethylene-vinyl acetate resin
Cavisol	Golchai Co. Iran	Zinc oxide, Calcium sulfate, Zinc sulfate, Plasticizers, Resins, Pepper-Mint aroma, and Excipients
NexTemp	Meta Biomed, South Korea	Bis-GMA, urethane dimethacrylate, hydroxyethyl methacrylate, silicon dioxide, stabilizer and pigment

Root Canal Instrumentation

A #10 K-file was introduced into the root canal until its tip was visible at the apical foramen. The working length was then determined as 1 mm shorter than this length. The root canals were instrumented with the F2 file from the ProTaper rotary system, following the manufacturer's instructions. During instrumentation, 5% sodium hypochlorite was used for irrigation. After

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instrumentation, the canals were rinsed with saline and dried using paper points [20]. Finally, the root canals were filled with gutta-percha and AH26 sealer (Dentsply Sirona, Konstanz, Germany) using the cold lateral compaction technique [12].

Application of Temporary Restorative Materials

The access cavities were restored with the appropriate temporary restorative material for each assigned group, using a standard Tofflemire matrix band [12]. The temporary restorative materials were applied according to the manufacturers' instructions. Coltosol F and Cavisol were placed in the cavity with a plastic instrument and compacted with a plugger to ensure proper adaptation to the cavity walls. Excess material was removed with a sterile cotton pellet, and the material was gently condensed with a sterile cotton pellet moistened with saline [12].

In the NexTemp group, the material was applied to the cavity and light-cured with a light-emitting diode (LED) curing unit, iLED Plus (Woodpecker Medical Instrument Co., Ltd., Guilin, Guangxi, China), at a light intensity of 1000 mW/cm² for 20 seconds.

Fracture Resistance (FR) Measurement

To simulate the periodontal ligament, the roots were coated with a 0.2–0.3 mm layer of wax. The roots were then vertically mounted in auto-polymerizing acrylic resin inside a plastic cylinder measuring 20 mm in height and 20 mm in diameter. A stainless-steel ball, 6 mm in diameter, was placed on the occlusal surface of the restoration, ensuring contact with the buccal and lingual surfaces of the tooth. A compressive load was applied vertically at a crosshead speed of 1 mm/min using a universal testing machine (Koopa 5T, Sari, Iran) until fracture occurred [12]. The magnitude of the load that caused the first crack was recorded as the FR of the respective tooth.

Statistical Analysis

Data were analyzed using SPSS version 26. The Kolmogorov-Smirnov test confirmed that the data were normally distributed; therefore, independent samples t-tests, ANOVA, and Tukey’s post-hoc test were used to compare the effects of cavity design and temporary restorative material type on the FR of the teeth. A P-value<0.05 was considered statistically significant.

Results

FR of Teeth Based on Cavity Design (MO/MOD)

Table 2 presents the mean FR of endodontically treated teeth with MO and MOD cavity designs, regardless of the type of temporary restorative material, as well as the negative control group (sound teeth).

The results showed that the mean FR of endodontically treated teeth with the MO cavity design was significantly higher than that of teeth with the MOD cavity design (P=0.025).

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Additionally, the mean FR of the negative control group was significantly higher than that of endodontically treated teeth with both MO and MOD cavity designs (both P<0.001).

FR of Teeth Restored with Different Temporary Restorative Materials

Table 3 presents the mean FR of positive control teeth and teeth restored with Coltosol, Cavisol, and NexTemp.

The results showed no significant difference in the FR of teeth restored with different temporary restorative materials in the MO cavity design. However, there was a significant difference in the FR of teeth restored with different temporary restorative materials in the MOD cavity design (P=0.038). Pairwise comparisons using Tukey's test revealed that the mean FR of the Coltosol F group was significantly higher than that of the control group (P=0.042). There was no significant difference among the other groups.

The mean FR of the positive control (P=0.028) and NexTemp (P=0.012) groups was significantly higher with the MO cavity design than with the MOD design. However, the difference between the two cavity designs was not significant for the Coltosol F and Cavisol groups.

Table 2. Mean FR ± Standard Deviation (SD) of endodontically treated teeth (in Newtons) with MO and MOD access cavity designs and the negative control group (sound teeth).

	Groups	N	FR	P value*
Cavity design	**MO**	48	448.13±150.1^{A}	**<0.001**
	MOD	48	375±164.41^{B}	
Sound teeth	**Negative control**	12	624.17±132.97^{C}	

* ANOVA
- Different uppercase letters indicate statistically significant differences between groups

Table 3. Mean FR (in Newtons) of positive control teeth and those restored with Coltosol, Cavisol, and Nextemp.

Groups	N	Cavity design		P value**
		MO	MOD	
Positive control	24	454.17±109.17	310.83±177.43^{A}	**0.028**
Coltosol F	24	448.33±199.9	484.17±184.07^{B}	0.652
Cavisol	24	421.67±162.53	377.5±123.44	0.461
NexTemp	24	468.33±129.32	327.5±122.19	**0.012**
P value*		0.901	**0.038**	

* ANOVA
**Independent samples t-test
- Different uppercase letters indicate statistically significant differences between groups

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Discussion

The results indicated that the mean FR of teeth with the MO cavity design was significantly higher than that of teeth with the MOD cavity design. This finding is consistent with the reports of Nam et al. [21], Alavinejad et al. [22], and Nagasiri et al. [23], who also reported higher FR in MO and DO cavities than in MOD cavities and demonstrated that the loss of two or more cavity walls markedly reduces FR. These studies further emphasized that the amount of remaining tooth structure and the restorative material are major determinants of the survival of endodontically treated molars.

Cavity preparation increases the risk of tooth fracture. Accordingly, the negative control group (sound teeth) showed significantly greater FR than endodontically treated teeth with MO and MOD cavities. Factors such as cavity size, geometry, and occlusal loading contribute to this reduction. Previous studies have shown that MOD cavity preparation may reduce FR by up to 55%, with further reduction following endodontic treatment because of additional loss of tooth structure. [24, 25] Bassir et al., [26] Alavinejad et al., [22] and Soares et al. [27] similarly reported significantly higher FR in sound premolars than in unrestored teeth with MO or MOD cavities.

It has been established that the loss of marginal ridges contributes to a reduction in the FR of teeth [28, 29]. Marginal ridge thickness is directly correlated with FR [30], as intact ridges create a ferrule effect that protects against cuspal fracture, whereas the loss of sound dentin decreases restorative support [26, 31].

The present results indicated that, for the MO cavity design, the FR of endodontically treated teeth restored with different temporary restorative materials did not differ significantly. However, a significant difference was observed in the FR of teeth with the MOD cavity design. This finding underscores the importance of selecting restorative materials based on the cavity configuration, dimensions, and the number of residual cavity walls.

For MOD cavities, Coltosol F produced the highest FR, followed by Cavisol, NexTemp, and the positive control group. Coltosol F showed significantly higher FR than the positive control, possibly because water sorption causes hygroscopic expansion over time [20]. Similarly, Coltosol F produced the highest FR compared with Cavit, IRM, and DiaTemp. In contrast, Alavinejad et al. [22] reported lower FR for Coltosol F than for ENA Soft and GC Fuji II, whereas Maeda et al. [32] found FR comparable to that of unrestored teeth. Tennert et al. [18] further reported that Coltosol F alone could induce fractures in teeth with large MOD cavities.

Coltosol F is a eugenol-free, zinc oxide-based temporary restorative material that sets through water sorption, exhibiting hygroscopic expansion of 17% to 20%. It is intended for short-term restoration of teeth. Laustsen et al. [33] demonstrated that this expansion may cause cuspal deflection, infraction, and fracture. Similarly, Eskandarizadeh et al. [34] reported significantly greater intercuspal expansion and cuspal fracture with Coltosol F than with Cavisol or Coltene. However, manufacturers' information regarding setting expansion may be misleading [2].

The resin-based temporary restorative material NexTemp showed no significant difference in FR compared with Coltosol F or Cavisol in either cavity design. However, FR was

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significantly higher in MO than in MOD cavities restored with NexTemp, reflecting the greater preservation of tooth structure in the MO design.

Similarly, Balkaya et al. [12] reported that the resin-based material DiaTemp exhibited FR comparable to Coltosol F, Cavit G, and IRM in MOD cavities, suggesting that cavity design has a greater influence on FR than the type of temporary restorative material. These findings emphasize that both cavity design and restorative material should be considered when evaluating FR.

As an in vitr**o** study, these findings should be interpreted with caution. Clinical factors such as occlusion, the interval between treatment sessions, restoration thickness, and placement technique may influence FR [25]. Future studies incorporating thermocycling, cyclic mechanical loading, and well-designed clinical trials are warranted to better simulate oral conditions and evaluate the long-term clinical performance of temporary restorative materials.

Conclusion

Among the materials evaluated, Coltosol F was associated with greater FR in teeth with MOD cavities and may therefore represent a suitable temporary restorative material in this clinical setting.

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Conflict of interest

The authors declare no conflicts of interest with respect to the authorship and/or publication of this paper.

Author's Contribution

Mehdi Besharat Far: Literature search, experimental studies, data acquisition, and manuscript preparation. Zahra Sadat Madani: Conceptualization, study design, and manuscript review and editing. Akam Saeidi: Concepts and design. Seyedali Seyedmajidi: Data analysis, statistical analysis, and manuscript preparation and editing. Elham Mahmoudi: Data acquisition and manuscript review.

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