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The Effect of Marginal Ridge Thickness on the Fracture Resistance of Endodontically-treated, Composite Restored Maxillary Premolars

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Clinical Relevance

Preserving the marginal ridge of endodontically-treated composite restored maxillary premolars can act as a strengthening factor and improve fracture resistance.

SUMMARY

This study evaluated the effect of varying thicknesses of marginal ridge on the fracture resistance of endodontically-treated maxillary premolars restored with composite.

Ninety non-carious maxillary premolars, extracted for orthodontic reasons, were selected for this experimental *in vitro* study. The teeth were randomly assigned to six groups (n=15). Group 1 received no preparation. In groups 2 through 6, the premolars were root filled and DO preparations were created, while MOD preparations were also created for group 2. The condition of the boxes was: the gingival seat was 1.5 mm above the CEJ and the buccolingual dimensions were 3.5 mm in gingival and 3 mm in occlusal. In groups 3 through 6, the dimensions of the mesial marginal ridge were measured using a digital caliper as follows: 2 mm, 1.5 mm, 1 mm and 0.5 mm, respectively. All samples in groups 2 through 6 were restored with a dentin bonding system (DBS: Single Bond, 3M) and resin composite (Z 250, 3M). Subsequently, premolars from all six groups were subjected to a thermocycling regimen of 500 cycles between 5°C and 55°C water baths. Dwell time was 30 seconds, with a 10-second transfer time between baths.

The premolars were submitted to axial compression up to failure at a 45° angle to the palatal

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cusp in Universal Test Equipment (Tinius Olsen, Ltd, H5K-S model).

The mean load necessary to fracture the samples was recorded in newtons (N), and data were subjected to analysis of variance (ANOVA) and LSD post-hoc test.

According to these results, the mean loads necessary to fracture the samples in each group were (in N): group 1: 732 ± 239, group 2: 489 ± 149, group 3: 723 ± 147, group 4: 696 ± 118, group 5: 654 ± 183 and group 6: 506 ± 192).

Differences between group 1 and groups 2 and 6, and also differences between groups 3, 4 and 5 compared with group 2 and 6 were statistically significant (*p*<0.05).

INTRODUCTION

Restoring devital teeth represents a major challenge for practitioners.[1] Non-restored, endodontically-treated teeth are prone to fracture and coronal leakage, which can lead to bacterial contamination. In restored, endodontically-treated teeth, catastrophic failures primarily involve failed restorations, crown fractures and secondary caries, often leading to extraction.[2] The traditional method of restoring devital teeth has several drawbacks and risks that have given rise to serious criticism. One of the drawbacks is the considerable treatment time spent on such complex restorations, making them extremely costly.[3] Another drawback is the amount of sound tooth structure that often has to be sacrificed.[4] Other factors include the risk of root perforation and root fracture due to both placement and decementation of posts.[5]

The true breakthrough in the restoration of endodontically-treated teeth has been the introduction of adhesive bonding, propelled by the development of efficient dentinal adhesives.[6] Since the retention of adhesive restorations is based on micromechanical attachment and does not require macroretentive elements,[7] minimally invasive preparations with maximal conservation of dentinal tissues can be realized.[8] This can increase the fracture resistance of teeth.[9]

In order to determine the effect of compressive and shear forces on maxillary premolars,[1] this study evaluated the effect of different thicknesses of the mesial marginal ridge on fracture strength of endodontically-treated, composite restored maxillary premolars.

METHODS AND MATERIALS

Ninety sound, human maxillary premolars extracted for orthodontic reasons within a six-month period and examined macroscopically for defects in enamel and dentin, were stored in a normal saline solution at room temperature. Two weeks before use, all of the premolars were immersed in 0.5% Choloramine T Trihydrate for infection control. At no stage in the investigation were the premolars allowed to dehydrate. The teeth were carefully cleaned with a hand scaler and water-pumice slurry in a dental prophylactic cup. The teeth were of equal buccolingual dimension and were randomly assigned to six groups (n=15) and treated as follows:

Group 1: Intact teeth, no treatment (negative control).

Group 2: Class II MOD cavities (positive control).

Group 3: Class II DO cavities were prepared with a 2 mm thick mesial marginal ridge.

Group 4: Class II DO cavities were prepared with a 1.5 mm thick mesial marginal ridge.

Group 5: Class II DO cavities were prepared with a 1 mm thick mesial marginal ridge.

Group 6: Class II DO cavities were prepared with a 0.5 mm thick mesial marginal ridge.

In groups 2 through 6, standard access cavities were prepared using a coarse, tapered, flat-end diamond bur (TF-13C/MANI Inc, Tochigi, Japan) in a high speed handpiece with abundant air-water spray. After every 10 preparations, the bur was replaced with a new one. Then, root canal therapy was performed in groups 2 through 6.

Next, in group 2, Class II MOD cavities were prepared, with the gingival cavosurface margin located 1.5 mm above the cementoenamel junction (CEJ). The dimensions of the mesial and distal box were approximately the same; a buccolingual width of 3.5 mm was measured at the gingival floor level and convergence of the buccal and lingual walls towards the occlusal was ensured. The cavosurface angle in all walls was approximately 90°. In the remaining groups (3-6), Class II DO preparations were prepared in the same manner as that of group 2, and the mesial marginal ridge was preserved for 2 mm in group 3, 1.5 mm in Group 4, 1 mm in Group 5 and 0.5 mm in Group 6. The thickness of the mesial marginal ridge was measured with a digital caliper within 0.01 mm tolerance. Subsequently, the canal orifices of all the prepared specimens were filled with a 2 mm ball of resin modified glass-ionomer cement (GC Fuji II LC/GC Corporation, Tokyo, Japan) and light cured for 40 seconds using a visible-light curing unit Astralis 7, (Ivoclar North America Inc, Amherst, NY, USA), adjusted to 400 mW/cm^2 intensity. Then, all the prepared teeth (both enamel and dentin) were etched with 35% phosphoric acid, Scotch Bond etchant (3M ESPE, St Paul, MN, USA), for 15 seconds, rinsed for 10 seconds and dried with air, leaving a shiny, hydrated surface of moist dentin.

Adper Single Bond (3M ESPE) was applied with disposable applicators onto enamel and dentin in double layers, air thinned for 2 to 5 seconds to ensure adequate evaporation of the solvent and light cured for 10 seconds for each layer.

Then, using a Tofflemire retainer and an ultra thin (0.0010 inch) stainless steel matrix band (Tofflemire matrix band/Henry Schein, Inc, Melville, NY, USA), the teeth were restored with A3 shade resin (Filtek Z-250, 3M ESPE), using an oblique layering technique. First, an increment no thicker than 1.0 mm was placed against the gingival and pulpal floor and cured for 40 seconds; subsequent increments were then placed in thicknesses no greater than 2.0 mm that did not contact both the facial and lingual preparation walls simultaneously. Each layer was cured for 40 seconds from the occlusal direction. After the matrix band was removed, additional curing from the facial and lingual aspects was done for 40 seconds each, using the pulse program of Astralis 7. In the pulse program, initial light curing used a low-intensity light (150 mW/cm^2) for 15 seconds, followed by a gradual increase in intensity (up to 750 mW/cm^2) until 40 seconds of exposure time was completed.

Forty-eight hours after restoring, finishing was done with extra fine TC- ll E F (MANI Inc, Japan) under air-water spray followed by polishing with a green abrasive-impregnated rubber point (B, spitze point/ Vivadent, Schaan, Liechtenstein). Then, the teeth were stored in an incubator.

Finally, teeth from all the groups were submitted to a thermocycling regimen of 500 cycles between 5°C and 55°C water baths. The dwell time was 30 seconds, with a 10-second transfer time between baths. Each tooth was then vertically positioned, and its root embedded into a plastic cylinder of self-curing acrylic resin up to 1 mm below the CEJ. Subsequently, Universal Test Equipment (H5K-S model/Tinius Olsen, Ltd, Surrey, England) was used to conduct a fracture test at a crosshead speed of 2 mm/minute.

The lingual cusp of each specimen was submitted to axial compression up to failure at an angle of 45° to the palatal cusp and 150° to its longitudinal axis, and the load-extension curve was drawn for each specimen via computer (Figure 1). Fracture resistance was defined as the amount of loading at the peak of the load-extension curve. To compare resistance between groups, analysis of variance one-way ANOVA was performed, and to compare fracture resistance between any two groups, LSD post-hoc analysis was performed.

RESULTS

Table 1 shows the mean values of the fracture strength in the six groups. Statistical analysis revealed that the highest mean fracture resistance was in group 1 (intact teeth) and the lowest was in group 2 (MOD) (Figure 2).

One-way ANOVA analysis (Table 1) showed differences between the groups as being significant (p=0.001). According to pairwise comparison with the Post Hoc LSD test, the intact premolars (group 1) were significantly more fracture resistant than the premolars in group 2 and group 6 (p<0.05), and insignificant fracture resistance was observed between groups 1 and 3, 4 and 5 (p>0.05). Differences between group 2 and groups 3, 4 and 5 were significant (p<0.05) but insignificant between groups 2 and 6. Therefore, the results indicate that a direct relationship existed between a decrease in thickness of the marginal ridge and fracture resistance of the tooth.

DISCUSSION

This study examined the fracture resistance of endodontically-treated maxillary premolars, the anatomic shape of which creates a tendency towards separation of their cusps during mastication.[10] In addition, loss of tooth structure during endodontic access and cavity preparation procedures make these teeth even more prone to fracture.[11]

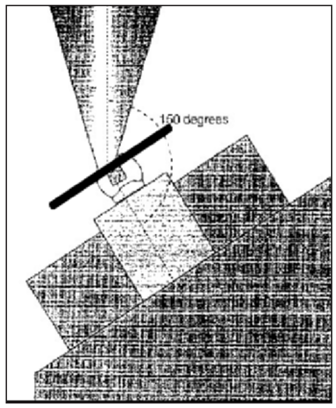

Figure 1: *The angle of loading relative to the axis of the tooth.*

The results showed significant differences between groups 1 and 2,

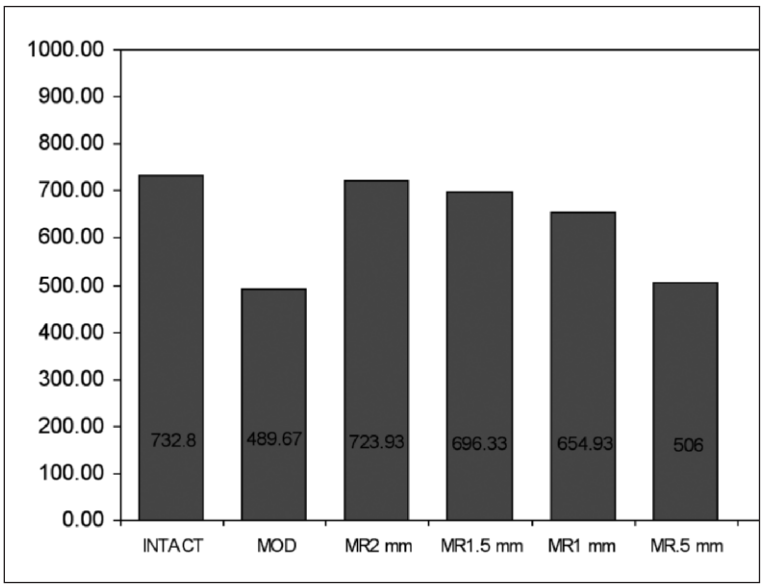

Figure 2: *Mean fracture resistance in groups.*

Table 1: *One-way ANOVA Analysis of Fracture Resistance in Different Groups*

	N	Mean ± Std Deviation	Std Error	Minimum	Maximum
Intact	15	732.8000 ± 239.68855	61.88732	361.00	1134.00
MOD	15	489.6667 ± 149.45791	38.58987	330.00	884.00
2 mm	15	723.9333 ± 147.18184	38.00219	500.00	1055.00
1.5 mm	15	696.9333 ± 118.14801	30.50569	483.00	900.00
1 mm	15	654.3333 ± 183.55477	47.39364	230.00	1030.00
0.5 mm	15	506.9333 ± 192.87430	49.79993	240.00	973.00
Total	90	645.6000 ± 192.31819	20.27212	230.00	1134.00

F: 4.403
Sig: 0.001

which agree with Linn and Messer,[12] who demonstrated that endodontically-treated teeth with MOD cavities were severely weakened due to a loss of reinforcing structures, such as marginal ridges and pulp chamber roof, causing the teeth to become more susceptible to fracture. These findings are supported by Belli and others,[13] who reported that MOD cavity preparations reduced the fracture resistance of root filled teeth. In evaluating the thickness of the mesial marginal ridge, no statistical difference between groups 1, 3, 4 and 5 existed, according to the results of the current study. If the mesial marginal ridge can be maintained, even with a 1 mm thickness, the fracture resistance of the tooth should be relatively unaffected. This may also be due to the reinforcing effect of bonded resin composite, which has been noted in many studies and is in accordance with these results.[10,14-16]

Denehy and Torney[16] were the first authors to propose the use of adhesive materials to reinforce dental structures, and Morin and others[17] showed that restoration of MOD preparation with adhesive materials leads to a significant increase in the fracture resistance of teeth but not to the same level as that of intact teeth.

Troppe and Tronstad[18] compared resistance to fracture of the buccal wall of endodontically-treated teeth following different methods of restoration. The mean force needed to fracture teeth where cavities were acid etched and restored with resin composite was significantly higher than when the teeth were filled with amalgam or resin composite without acid etching. However, separate studies have proposed that significant differences exist in fracture resistance between intact and restored premolars with resin composite and dentin bonding agent, with intact teeth being superior.[15,19-21] These differences in results could reflect the variation in type and size of teeth, preparation design, experimental material, loading speed, direction of load and thermocycling.

In the current study, thermocycling was done to reproduce thermal stresses that occur in clinical situations; according to different studies, thermocycling can increase stress, have a weakening effect on the adhesive bond of teeth and, consequently, lead to a decrease in the fracture resistance of teeth. This means that the reinforcing effect of resin composite may be diminished under clinical conditions.[22]

In group 6, significant differences were observed compared to groups 1, 3, 4 and 5 and insignificant differences were noted compared with group 2 ($p>0.05$). For this reason, it could be suggested that, if, during cavity preparation in endodontically-treated maxillary premolars, the remaining marginal ridge was 0.5 mm, it should be retained. This may not improve strength, but it will improve the esthetic apearance, since restoration of MOD cavities is more difficult than DO cavities due to construction of the proximal contact and contour. In addition, the probability of overhangs at the proximal margin has been shown to occur 25% to 76% of the time[23] and providing the proper anatomic form of MOD restorations in comparison with DO restorations is more time-consuming.

In this study, minimum fracture resistance in all groups was greater than the range of normal biting force for maxillary premolars (100-300 N). The least fracture resistance was observed in group 2 (489 N), which was still greater than the upper limit of normal biting force. However, experimental conditions in this study did not identically duplicate conditions in the mouth, since maxillary premolars are subjected to a mixture of shear and compressive forces. The specimens were stressed in compression at 45° to the buccal slope of the palatal cusp, but some clinical relevance can be suggested.

This study showed that, marginal ridge thickness, even at the 1 mm level, has a positive effect on fracture resistance when teeth are restored with resin composite. However, because occlusal force during clenching has been observed to be as high as 520-800 N, progressive cusp displacement with prolonged loading suggests that clenching and bruxing will result in a predisposition to catastrophic failure. In this situation, retaining the marginal ridge may not be advisable and cuspal protection is recommended to prevent accidental fracture.

The results of this study support the idea that, in endodontically-treated maxillary premolars, when minimal dentin structure connects the buccal and lingual walls of the preparation, a method that could reinforce the tooth should be used.[24] In this study, fracture resistance measurement was used, and, while it is the simplest to perform, it was a destructive test that may not always simulate *in vivo* conditions, because the forces required to fracture specimens *in vitro* may not occur in the oral cavity.[14] This is the most frequently used method to evaluate the strength of prepared and/or restored teeth that use the application of static load until failure occurs,[25] but the clinical loading of teeth is a dynamic process, wherein loading force, frequency and direction vary greatly.[26]

On the other hand, in the mouth, repeated loading could lead to fatigue failure,[22] consequently, interpretation of the results should be done cautiously.

The major disadvantage to an all-destructive method is that the treatment conditions are assigned to the different test teeth. Therefore, variability of the teeth acts as a confounding variable and compromises sensitivity of the test.[25] Also, preparation of access cavities and proximal boxes with accurately similar dimensions is very difficult.[11] In addition, much of the thermal cycling information from laboratory experiments may be of little or no value in predicting the clinical situation.[27]

Future studies should evaluate the effect of preserving the marginal ridge by using non-destructive testing techniques that allow samples to be used repeatedly.[28] These techniques have the advantage of allowing the sequential testing of endodontic and restorative procedures on the same tooth. The relative effects of these procedures on tooth strength can then be assessed. In non-destructive testing, tooth stiffness is measured rather than fracture strength. Loads are within physiologic limits; repetitive testing of the same tooth permits a very efficient experimental design.[12]

Furthermore, long-term clinical trials are needed to measure performance of resin composite restorations *in vivo*[29] and to evaluate bonding stability for longer periods due to the fact that the adhesive bond might fail under clinical situations.[21]

CONCLUSIONS

In this investigation, on the basis of static loading, preserving a mesial marginal ridge with thicknesses of 2 mm, 1.5 mm and 1 mm in endodontically-treated, composite restored maxillary premolars can help preserve the fracture resistance of teeth.

However, a 0.5 mm thickness of the mesial marginal ridge does not fully conserve the strength of restored teeth at the level of intact teeth but is greater than group 2. Thus, these findings suggest that preservation of the marginal ridge is a preferable option in maxillary endodontically-treated premolars.

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