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CASE REPORT

Fracture resistance of teeth with simulated cervical root resorptions restored by various materials

Resistencia a la fractura dental con reabsorciones radiculares cervicales simuladas y restauradas con diversos materiales

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Abstract

This study ***aimed*** to compare the fracture resistance of teeth with cervical root resorptions following restoration with resin composite, resin-modified glass ionomer (RMGI), Biodentine, and mineral trioxide aggregate (MTA).
Methods: 60 sound extracted single-rooted maxillary premolars were divided into 4 experimental (n=10) and 2 control (n=10) groups. Ten intact teeth served as the negative control group. In the remaining teeth, cavities were prepared with 2 mm depth, extending 1 mm above the cementoenamel junction (CEJ), and 2 mm below it. The cavities remained unrestored in the 10 positive control teeth. The cervical cavities in the remaining teeth were restored with Z250 resin composite, Fuji II LC RMGI, ProRoot MTA, and Biodentine. The teeth' fracture resistance was measured using a universal testing machine and recorded in newton (N). Data were analyzed using one-way ANOVA followed by Tukey's test with a 95% confidence interval.
Results and conclusions: Significant differences were noted in the fracture resistance of composite resin and RMGI with the positive control group (P<0.05). No significant difference was noted between the Biodentine and MTA groups with the positive control group in this respect (P>0.05). Within this study's limitations, it seems that the resin composite and RMGI restorations can increase the fracture resistance of teeth with artificially-induced cervical resorption defects. However, Biodentine and MTA as bioactive cement have no strengthening effect on the tooth structure.

Keywords: Biodentine, cervical resorption, fracture resistance, mineral trioxide aggregate, resin composite.

Resumen

El ***objetivo*** de este estudio es comparar la resistencia a la fractura de dientes con reabsorciones radiculares cervicales tras la restauración con composite de resina, ionómero de vidrio modificado con resina (RMGI), Biodentina y agregado de trióxido mineral (MTA).
Metodología: Se dividieron 60 premolares maxilares de una sola raíz extraídos en 4 grupos experimentales (n=10) y 2 de control (n=10). Diez dientes intactos sirvieron de grupo de control negativo. En los dientes restantes, se prepararon cavidades de 2 mm de profundidad, que se extendían 1 mm por encima de la unión cemento-esmalte (CEJ) y 2 mm por debajo de ella. Las cavidades permanecieron sin restaurar en los 10 dientes de control positivo. Las cavidades cervicales de los dientes restantes se restauraron con composite de resina Z250, Fuji II LC RMGI, ProRoot MTA y Biodentine. La resistencia a la fractura de los dientes se midió con una máquina de ensayo universal y se registró en newton (N). Los datos se analizaron mediante un ANOVA unidireccional seguido de la prueba de Tukey con un intervalo de confianza del 95%.
Resultados y conclusiones: Se observaron diferencias significativas en la resistencia a la fractura de la resina compuesta y la RMGI con el grupo de control positivo (P<0,05). No se observaron diferencias significativas entre los grupos de Biodentina y MTA con el grupo de control positivo a este respecto (P>0,05). Dentro de las limitaciones de este estudio, parece que las restauraciones de resina compuesta y RMGI pueden aumentar la resistencia a la fractura de los dientes con defectos de reabsorción cervical inducidos artificialmente. Sin embargo, la biodentina y el MTA como cemento bioactivo no tienen ningún efecto reforzador sobre la estructura dental.

Palabras clave: Biodentina, reabsorción cervical, resistencia a la fractura, agregado de trióxido mineral, composite de resina.

Introduction

External invasive cervical resorption refers to a process through which progressive loss of dentin and cementum occurs because of odontoclasts' activity in the granulation tissues adjacent to the teeth' cervical region[1]. The extent of resorption defects can be classified into four classes based on Hiethersay classification: class I, a small cervical lesion with shallow penetration into dentine; class II, a well-defined lesion close to the coronal pulp but with little or no extension into radicular dentine; class III, deeper invasion of the lesion into the coronal third of the root; class IV, a lesion extending beyond the coronal third of the root[2]. More extensive and potentially more inaccessible lesions have a poorer prognosis[3]. The treatment should be promptly started after the definite diagnosis of cervical root resorption due to this condition's invasive nature[4]. If the resorption has not invaded the pulp chamber and has extended far below the gingival margin, a surgical flap should be reflected, the resorptive tissue should be completely removed, and the cavity should be restored with a suitable restorative material[3]. Based on the resorption defect position, various materials such as glass ionomer cement, resin-modified glass-ionomer cement, resin composite, amalgam, Biodentine, and mineral trioxide aggregate (MTA) have been suggested as appropriate restorative materials[5].

Since tooth structure loss renders teeth susceptible to fractures, the long-term prognosis depends on the overall total volume loss of the resorption's affected root structure[6]. An appropriate restorative material should be applied to seal the area of tooth loss and optimally resist occlusal and masticatory forces[7]. However, there is no information about these dental materials' efficacy to reinforce teeth weakened by cervical lesions. Considering the significance of fracture resistance of the teeth and its effect on their long-term survival and function in the oral cavity, this study aimed to assess the fracture resistance of teeth with artificially-induced cervical resorption defects restored with different dental materials to find the more resistant material for this purpose.

Materials and methods

Sixty extracted single-rooted and single-canal maxillary human premolars were used in this study. The teeth were cleaned and stored in 0.5% thymol solution at 4°C until the testing. The selected teeth were sound and had no anomalies or caries. Also, the teeth were inspected under a stereomicroscope at x20 magnification to ensure the absence of cracks.

Since the artificially created cervical resorption defects had to have a 2 mm depth, and we had to ensure no exposure of root canal during cavity preparation, a minimum of 2.5 mm distance was required between the external root surface and the internal root canal wall. Thus, the selected teeth had a minimum of 2.5 mm distance (dentin thickness) between the external root surface and the internal root canal wall in the mesiodistal and buccolingual directions on radiographs from 1 mm above the cementoenamel junction (CEJ) to 2 mm apical to the CEJ in all directions.

To minimize the confounding effect of variations in size and shape of teeth, their buccolingual and mesiodistal dimensions were measured by a digital caliper (Mitutoyo, Hiroshima, Japan) with 0.01 mm accuracy. According to the tooth size obtained using the following formula, the teeth were divided into two control groups (n=10) and four experimental groups (n=10) using stratified complete block randomization.

$$\text{Tooth height} = \frac{\text{Height of palatal cusp from the CEJ} + \text{height of buccal cusp from the CEJ}}{2}$$

Tooth width = Mesiodistal width of the tooth at the height of contour

$$\text{Tooth size} = \frac{\text{Tooth height}}{\text{Tooth width}}$$

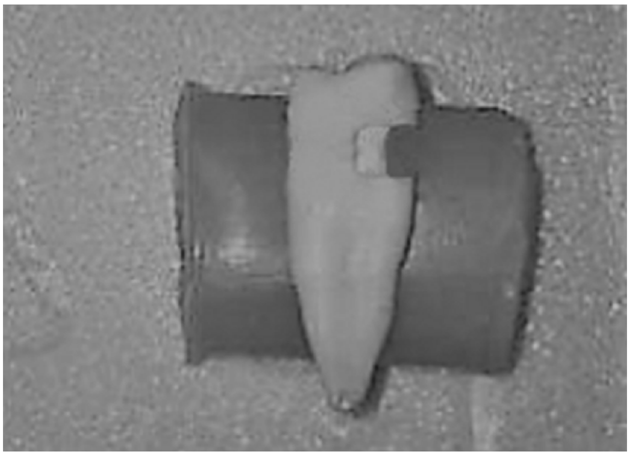
Next, the roots were dipped in melted wax to the level of their CEJ such that a layer of wax with 0.3 mm thickness covered the roots to stimulate the periodontal ligament (PDL). The teeth were mounted in self-cure acrylic resin blocks (Acropars, Tehran, Iran) with 25 mm diameter to the level of their CEJ such that the longitudinal axis of the root was perpendicular to the resin block. The wax-coated teeth were removed from the mounting block, and the wax layer was eliminated from the roots. Ten good teeth served as the negative control and did not undergo cavity preparation. In the remaining teeth, to simulate the class III of invasive root resorption classification of Hiethersay[2], extensive cavities with 2±0.1 mm in depth and 3±0.1 mm in width (from 1 mm above the CEJ to 2 mm apical to the CEJ) were prepared using a fissure bur (Dia. Tessin, Gordevio, Switzerland), such that they extended from the mesial half of the tooth to the distal half of the tooth involving the entire buccal surface (**Figure 1**).

Ten teeth served as the positive control, and the artificially created defects in them were not restored with any restorative material. In the rest of the teeth, Z250 resin composite (3M ESPE, St. Paul, MN, USA), Fuji II LC RMGI (GC America Inc., Alsip, IL, USA), Biodentine (Septodont, Saint Maur-des Fossés, France), and ProRoot MTA (Dentsplay, Tulsa, OK, USA) were used for the restoration of artificially created cervical resorption defects.

To repair with Z250 resin composite, the teeth cavities were the first acid etched by 3M Scotch (3M ESPE,

Figure 1: Artificial cervical root resorption cavity.

Buccolingull view



Mesiodistal view

Minnesota, USA) for 15 seconds, and the cavities were rinsed thoroughly. Then Single Bond adhesive (3M ESPE, Minnesota, USA) was placed on the cavities, and to create a thin layer of bonding, the cavity was gently dried by air spray for 2-5 the bonding agent was light-cured for 15 seconds. Then Resin composite was placed incrementally (up to 2 mm-thick layers), and each resin composite layer was light-cured for 20 seconds.

At first, in the Fuji II LC group, the resin-modified glass ionomer's powder and liquid were mixed to achieve a suitable consistency. For this purpose, a spoonful of powder and two drops of its liquid were placed on a paper pad. With a spatula, the powder was divided into two equal parts, and the first part was mixed with the liquid for 10 seconds, and then the second part of the powder was added, and the ingredients were mixed for 10 seconds. Fuji II LC was placed in the cavities incrementally (up to 2 mm-thick layers), and each layer was light cured for 20 seconds.

According to the manufacturer's instructions, to repair the cervical cavity with biodentine, after gently tapping the capsule containing dentine powder, 5 drops of its unique solution were poured into the capsule. Then, the capsule is placed in the amalgamator device (Kerr, Detroit, USA) to mix for 30 seconds, and the resulting cement was placed in the cavity incrementally and was gently compacted with Schilder pluggers (Hu. Friday, Chicago, IL, USA).

Finally, ProRoot MTA (Dentsplay, Tulsa, OK, USA) was used to repair the last group. According to the manufacturer's instructions, after gradually incorporating its powder with liquid and mixing for one minute, MTA was placed in the cavity then the material was gently compacted by pluggers.

To allow the restorative materials' complete setting, they were incubated at 37°C and 100% humidity (Kavosh Mega, Tehran, Iran) for 7 days[8]. The holes in acrylic blocks were filled with Impregum soft polyether impression material (3M ESPE, Minnesota, USA) to simulate the PDL then the teeth were mounted again in their respective holes in acrylic blocks.

After 1 hour, the teeth were transferred to a universal testing machine to measure fracture resistance (Zwic Roell, Zwic , Ulm, Germany). A flame-shaped bur (Dia. Tessin, Gordevio, Switzerland) was used to create small contact points on the buccal and lingual cusps to prevent lateral deviation upon load application. A compressive load was applied to the cusp slopes along the teeth' longitudinal axis by a round-end rod with 5 mm diameter at a crosshead speed of 0.5 mm/min. Maximum load causing tooth fracture was recorded in N. To determine the mode of failure, the teeth were removed from the resin blocks, and the mode of failure of each tooth was evaluated by two operators and considered as favorable (fractures stopped higher than 1 mm below the CEJ) and unfavorable (fractures stopped lower than 1 mm below the CEJ)[9]. Data were analyzed using SPSS version 25. One-way ANOVA was used to compare the fracture resistance of the groups. Pairwise comparisons were performed using Tukey's test. $P<0.05$ was considered statistically significant.

Results

Table I shows the mean values of the fracture strength in the six groups. The results showed significant differences in fracture resistance of resin composite and RMGI groups with the unrestored positive control group ($P<0.05$). However, the difference in fracture resistance of resin composite and RMGI groups was not significant ($P>0.05$). The difference between Biodentine and MTA was not significant ($P>0.05$), and the two groups had no significant difference with unrestored positive control teeth either ($P>0.05$).

Table I: Fracture resistance of the study groups in Newton.

Group	Minimum	Maximum	Mean	Std. Deviation
Intact	1517.00	1831.00	1684.60	122.02
Resin composite	112.00	2243.00	1186.00	688.99
RMGI	180.00	1546.00	900.20	408.27
Biodentine	175.00	966.00	584.30	279.64
MTA	110.00	733.00	405.70	208.90
Unrestored	37.00	231.00	134.00	77.92

Table II: Frequency percentage of favorable and unfavorable modes of failure in the study groups.

Group	N	Favorable Fractures	Unfavorable Fractures
Resin composite	10	9 (90%)	1 (10%)
RMGI	10	8 (80%)	2 (20%)
Biodentine	10	7 (70%)	3 (30%)
MTA	10	4 (40%)	6 (60%)
Intact	10	8 (80%)	2 (20%)
Unrestored	10	2 (20%)	8 (80%)

Table II presents the modes of failure. Accordingly, the mode of failure in intact teeth, resin composite, RMGI, and Biodentine groups was mainly favorable while it was primarily unfavorable in MTA and unrestored positive control group.

Discussion

Different restorative materials should be necessarily used to reinforce the weakened tooth structure in order to confer resistance against masticatory loads or parafunctional forces[10].

In the present study, maxillary single-canal, single-rooted premolar teeth were used for standardization because maxillary premolars, due to their particular anatomy, are highly fragile when subjected to occlusal forces, particularly when they have lost part of their structure[7].

Cervical resorption is often invasive and results in losing an extensive tooth structure part in a short time[6]. After reaching the protective perianal resorption resistant sheet formed by the prevention and innermost layer of dentin, an extension of resorption towards the pulp often stops, and the defect further extends towards the lateral sides and in incisogingival direction[6]. Due to the lack of a similar study on creating artificial cervical invasive resorption, we considered class III classification of Hiethersay[2], and cavities were prepared as described above.

According to the current results, maximum fracture resistance was noted in teeth with cervical resorption defects restored with Z250 resin composite followed by Fuji II LC RMGI, Biodentine, and MTA. Subash et al.[10] measured the fracture resistance of resin composite, RMGI, and Biodentine as core build-up materials. The resin composite showed maximum fracture resistance, while Biodentine showed minimum fracture resistance[10]. Also, Hiremath et al.[11] showed that the fracture resistance of Biodentine was significantly lower than the reinforced resin composite and sound teeth. Yasa et al.[12] indicated that the fracture resistance of resin composite and glass ionomer when used as an intra-orifice barrier, was significantly higher than the control group; however, MTA Angelus and Micro Mega MTA did not increase the fracture resistance of the teeth compared with the control group; this result was likewise present study's results.

Gupta et al.[8] measured the fracture resistance of RMGI and resin composite as an intra-orifice barrier and reported that their fracture resistance was significantly higher than the MTA. However, RMGI had significantly higher fracture resistance than resin composite[8]. The later result was different from our findings, which may be due to the difference in the two studies' methodology.

In the present study, maximum fracture resistance was noted in the group restored with resin composite. The reason may be the ability of resin composite to reinforce the remaining tooth structure[13]. Moreover, adhesive material provides adequate retention for the resin composite and serves as a bridge and splint between the cavity walls[14].

Higher fracture resistance obtained by the use of RMGI compared with unrestored teeth with defects (positive control) is due to the inherent properties of RMGI, such as high flexural strength and a modulus of elasticity comparable to that of dentin (10 to 14 GPa)[8,15]. Thus, it can resist high levels of stress. Moreover, its chemical bond to dentin surfaces can cause high resistance at the dentin-cementum interface and increase the integrity of the coronal structure and the fracture resistance of the tooth[8].

In the present study, no significant difference was noted in fracture resistance of teeth with cervical defects restored with RMGI and Z250 resin composite. This finding was similar to that of Aboobakr et al[16], who found no significant difference in fracture resistance of Tetric N Flow resin composite and Fuji LC RMGI as intra-orifice barriers.

Considering that glass ionomer's clinical application in cervical areas is much easier and has lower technical sensitivity than resin composite[17], this valuable clinical finding can help in the more efficient and more accessible restoration of cervical resorption defects.

Yasa et al.[12] showed that Biodentine significantly increased the fracture resistance of teeth compared with the control group. Some studies have shown that materials with calcium silicate base can chemically bond to root canal dentin[18,19]. Biodentine, compared with MTA, releases higher amounts of calcium, leading to the formation of an intermediate layer and tag-like structures[19]. This property can increase the bonding ability of Biodentine 20. In addition to this, it has shown demonstrated that Biodentine caused higher absorption of calcium and silicon ions by root dentin and resulted in the higher formation of tag-like structures compared with the MTA[21]. In the present study, although Biodentine, compared with the MTA and control groups, increase the fracture resistance of the teeth with cervical resorption defects, the differences were not significant.

Nagas et al.[15] compared the efficacy of three intra-orifice barriers to reinforce root structure and concluded that MTA, compared with RMGI and fiber-reinforced composite, had no efficacy to reinforce the root structure; this result was in line with our findings. Low fracture resistance of the MTA group, compared with RMGI and resin composite, is due to its inability to bond to dentin, hardness under high pressure, and weakness under tension despite its optimal modulus of elasticity[22].

In the clinical setting, the prognosis of teeth after restorative treatment failure depends on the mode of fracture and position of the fracture line. Dental restorations with fractures extending to below the CEJ are often very hard or impossible to repair[23]. In the present study, the mode of failure in three resin composite, RMGI, and Biodentine were mainly favorable (90%, 80%, and 70%, respectively). However, the mode of failure was unfavorable in 60% of the cases in MTA group. This finding can be due to the MTA's inefficacy to obtain a suitable bond to tooth structure compared with the other three materials.

In general, it seems that although bioactive materials such as Biodentine and MTA enhance tissue healing when applied adjacent to biologic tissues[24,25], the current results revealed that Biodentine and MTA had no reinforcing effect on the tooth structure when applied for restoration of cervical resorption defects due to their physical properties. New bioactive materials with more suitable physical properties are required to serve this purpose.

Some surveys have been conducted in different fields of medical sciences up to know[26-31]. However, to the best of the authors' knowledge, no previous study is available on fracture resistance of the teeth with cervical resorption defects restored with different materials. Thus, it seems that the data obtained in this study can be used to design future studies to find more suitable restorative materials for this purpose. Finally, yet importantly, it should be noted that in the oral environment, the teeth are subjected to several factors such as continuous exposure to moisture, thermal and pH alterations due to the consumption of foods and drinks, different bacteria and enzymes, and masticatory forces. All these parameters have undeniable effects on fracture resistance of the teeth. The clinical setting cannot be completely simulated in vitro. Thus, the generalization of the results of in vitro studies to the clinical setting should be made cautiously.

Within the limitations of this in vitro study, it seems that resin composite and RMGI can increase the fracture resistance of teeth with artificially induced cervical resorption defects when used as a restorative material. However, Biodentine and MTA as bioactive agents have no significant efficacy to reinforce the tooth structure.

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