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Levent Demiriz

PhD, Bülent Ecevit University,
Faculty of Dentistry,
Department of Pediatric
Dentistry, Zonguldak, Turkey

Ebru Hazar Bodrumlu

PhD, Bülent Ecevit University,
Faculty of Dentistry,
Department of Pediatric
Dentistry, Zonguldak, Turkey

Fracture resistance of simulated incomplete vertical fractured teeth treated with different bioceramic based root canal sealers

Levent Demiriz and Ebru Hazar Bodrumlu

Abstract

Introduction: The aim of this study was to examine fracture resistance after filling simulated incomplete vertical fractured permanent teeth using two different bioceramic based sealers.

Material and Methods: Sixty single-rooted maxillary incisors were decoronated to a length of 13 mm. The teeth were randomly divided into four groups (n=15 for each group). In negative control group, the teeth were left with no process. For positive control and two experimental groups, 45 roots were prepared by using Protaper System up to a master apical file size of F3. In these 45 roots, a simulated fracture line (6.5 mm length, 0.25 mm width) extended until the root canal space was created from the root apex towards crown. In positive control group, 15 teeth were filled with only gutta-percha. In experimental groups, first group filled with gutta-percha + Well Root ST sealer, and the other group filled with gutta-percha + MTA Fillapex sealer. Each sample was tested for the fracture in universal testing machine at a crosshead speed of 1.0 mm/min⁻¹. The fracture resistance of each sample was recorded, and the obtained data was analyzed statistically.

Results: The highest fracture resistance value was observed for the negative control group ($P<0.05$). Well Root ST showed significantly higher fracture resistance in comparison to the MTA Fillapex ($P<0.05$). The fracture resistance was significantly higher for both sealer groups than it was for the positive control group ($P<0.05$).

Conclusion: Well Root ST and MTA Fillapex sealer significantly increased the fracture resistance of untreated incomplete vertical fractured roots.

Keywords: Fracture resistance, MTA Fillapex, Well Root ST, vertical root fracture

1. Introduction

Vertical root fracture is described as longitudinally oriented fractures of the root extending from the root canal to the periodontium, covering all or part of the root. This type of fracture usually occurs in non-resorted teeth and endodontically-treated teeth. Although vertical fracture may involve one or more sides of the root, in permanent incisor teeth it is generally bucco-lingual oriented [1]. The correct and early diagnosis of vertical root fractures is difficult to make since its signs and symptoms are similar to endodontic and/or periodontal disease. Additionally, vertical root fractures have a poor prognosis and they generally result in tooth extraction [2, 3]. Although different approaches have been proposed for treatment, no method has been presented that shows reliable results and provides complete healing [4].

As bioceramic-based materials become popular in medicine and dentistry, using bioceramic-based canal sealers in endodontic treatments has become increasingly important [5]. Bioceramic-based sealers stimulate the formation of more durable tissues by interacting with vital tissues through the bioactive materials they contain, such as glass and calcium phosphate [5, 6]. Furthermore, these materials are biocompatible and antibacterial, which are considered to be important advantages [5, 7, 8].

MTA Fillapex® (Angelus, Londrina, Paraná, Brazil) is a bioceramic root canal sealer that has become available in the market for the last years. It contains mineral trioxide aggregate (MTA) and salicylate resin [9]. It is suggested that this sealant material is biocompatible with periapical tissues, and because it contains MTA, it provides effective sealing and obturation. It has also been reported that MTA Fillapex promotes the formation of hard tissue as it interacts with the tissues adjacent to the open root apex and perforation [10, 11].

Correspondence

Levent Demiriz

PhD, Bülent Ecevit University,
Faculty of Dentistry,
Department of Pediatric
Dentistry, Zonguldak, Turkey

Well-Root ST™ (Vericom, Gangwon-Do, Korea) is another bioceramic-based root canal sealer that has recently presented. This ready-to-use injectable bioactive sealer contains calcium aluminosilicate and zirconium oxide, and it is used for permanent obturation of root canals. According to the manufacturer, Well-Root ST does not shrink during setting, and it chemically bonds to dentin. During setting, and thereafter, hydroxyapatite crystals form on the sealer's surface. The pH of the sealer increases to over 12, and this alkaline property results in a high antibacterial effect. Well-Root ST is used for cold lateral compaction and tapered single cone techniques.

Using these proposed specifications of bioceramic-based root canal sealers to heal teeth with incomplete vertical root fracture may provide positive results and enhance the structural strength of the treated teeth. The present study aimed to examine fracture resistance after filling simulated incomplete vertical fractured permanent teeth using Well-Root ST and MTA Fillapex, two newly presented bioceramic-based root canal sealers.

Materials and Methods

Ethics committee approval for the study was obtained from the Ethics Committee of Bülent Ecevit University (2017-27-22/02). In this study, 60 single-rooted and single-canaled human maxillary permanent incisor teeth were used. The teeth were surgically extracted from patients at Bülent Ecevit University, Faculty of Dentistry. The teeth were extracted due to the presence of caries or periodontal disease, and no extraction was performed with the aim of using the teeth in the present study. The soft tissue residuals on the extracted teeth were removed using curettes, and all the teeth were stored in 10% formalin distilled water until the beginning of the study.

Teeth with open root apex or resorption were not included in this study. Additionally, bucco-lingual and mesio-distal oriented digital dental radiographies were used to evaluate the root canal anatomies of all the teeth, and teeth with pathologies, such as root canal obliteration or internal resorption, were also excluded from the study.

At the beginning of the study, a 13 mm root length was measured from the root apex to the crown for all the teeth, and the root and crown portion above this length were removed using a water-cooled diamond disc. After the removal process was completed, the sizes of the coronal surface of the samples were measured. It was observed that the bucco-lingual (5.37 ± 0.4 mm) and mesio-distal (6.76 ± 0.5 mm) sizes were similar for each sample. Fifteen root samples were selected randomly and reserved for the negative control group; no application was performed for these teeth.

For the remaining 45 root samples, the working length of each was adjusted to 12 mm using a #10 K-File. After this process, each canal was prepared using an F3 file from the Protaper® ISO series 0.06 taper rotary assortment files (Dentsply, Konstanz, Germany), until the working length size was obtained. After each file exchange, the root samples were irrigated using 5 ml 5.25% sodium hypochlorite (NaOCl) and 5 ml sterile saline solution. After the samples were prepared using an F3 file, the smear layer was removed by irrigating the samples with 5 ml 17% ethylene diamine tetra acetic acid (EDTA) solution for one minute. A final irrigation was conducted using 5 ml 5.25% NaOCl and 5 ml sterile saline solution. Then, all the irrigated roots were dried using sterile paper points.

After the root canal preparations were completed for 45 root samples, simulation of the incomplete vertical root fracture was carried out for these samples. During the process, a longitudinal oriented fracture line that was half the length of the root (6.5 mm) was created from the root apex towards crown using a TC-11 diamond disc (Figure 1). The fracture line was bucco-lingual oriented and extended until the root canal space, and its thickness, was 0.25 mm. The 45 root samples were randomly separated into three groups each of which consisted of 15 samples; these groups were used as two experimental groups and one positive control group.

Preparation of the experimental and control groups

Group 1 (WRG): 15 root samples were filled using a gutta-percha (GP) cone and Well Root ST root canal sealer following the manufacturer's instructions. For each root sample, the sealer was sent into the root canal by its own injection system, and then a single 0.06 F3 (#30) GP cone was placed at the working length. Each sample was examined by a periapical radiograph to control the integrity of the root filling and to determine whether or not the sealer completely filled the formed vertical fracture line. Thereafter, for each sample, the GP cone overflowing from the root canal was removed by cutting it with a hot hand tool, and the filling process was completed.

Group 2 (MFG): 15 root samples were filled using a GP cone and MTA Fillapex root canal filling sealer following the manufacturer's instructions. The root filling processes and the controls of all the samples were conducted using the same procedures that were applied for Group 1, the WRG group.

Group 3 (PG): 15 root samples were filled with 0.06 F3 (#30) GP cone without a sealer using the single cone technique.

Group 4 (NG): 15 randomly selected samples were reserved and no preparation process was applied to the root samples in this group.

After all the experimental and control groups were prepared all the samples were stored in an incubator at 37°C and 100% humidity for 7 days to allow the complete setting of the sealers. After that, in all groups, the root surface of each sample was coated using a wax layer with a thickness of approximately 0.2-0.3 mm from the root apex to the border 2 mm from the coronal surface in order to mimic the physiological effects of periodontal ligament tissue. Then, the coated part of the root was placed into acrylic cylinder blocks with a diameter of 20 mm, and 2 mm of the uncoated portion of each sample remained out of the block. After all the acrylic blocks polymerized, the samples were removed from the blocks and the wax residues were removed from the root surface and the artificial sockets. The cleared root surfaces were coated with polyvinyl siloxane impression material, and all the samples were replaced into their own acrylic blocks. After the impression material was set, the groups were ready for the fracture test (Figure 2).

Fracture Test

A Universal Testing Machine (Instron Universal Test Machine, Norwood, U.S.) was used for the fracture test (Figure 3). The acrylic blocks were placed on the lower plate of the equipment as the long axis of the root was perpendicular to the ground plane. The upper plate consisted of a steel tip with a 3 mm diameter, and the tip was centered over the canal orifice. The direction of the force applied to the samples was adjusted so it would be parallel to the long axis of the tooth. The speed of force was adjusted as 1 mm/min^{-1} . The units of force applied by the equipment were

demonstrated as Newton (N) units. The N value at the fracture moment, shown as the peak point in the graphs, was considered to be the maximum fracture resistance point for each sample, and that value was recorded. The obtained data for each sample were transferred to Excel software. Tukey's post hoc test and one-way variance analysis were used to conduct multiple comparisons during the statistical analysis of the recorded data. *P* value less than 0.05 was considered as statistically significant.

Results

The mean and standard deviation values of all the groups are shown in Table 1. According to the obtained results, the highest fracture resistance value was observed for the NG group, and the lowest fracture resistance value was seen in the PG group; the difference between these two groups was statistically significant ($P < 0.05$).

When the two experimental groups were evaluated, the WRG group had a high fracture resistance that was statistically significant in comparison to the MFG group ($P < 0.05$). However, the fracture resistance was significantly higher for both experimental groups than it was for the PG group ($P < 0.05$).

When the NG and the experimental groups were compared, the difference between the NG and the WRG groups, and the difference between the NG and the MFG groups were also found to be statistically significant ($P < 0.05$).

Discussion

In general, vertical root fractures have a poor prognosis, and their treatments are complicated since the diagnosis is difficult to make and their symptoms or indications appear in the late term of the fracture. For endodontically-treated teeth, it has been reported that detection of the vertical root fracture may vary from 3 days to 14 years^[1, 12]. Furthermore, it has been found that the prognosis of vertical root fractures generally results in tooth extraction, and 32% of those extractions are performed due to root fractures^[12].

To eliminate the poor results caused by vertical root fractures, and especially considering the loss of the anterior teeth, different treatment procedures have been suggested^[4]. In general, clinicians aim to remove the fragment or bond it with a biocompatible material^[1]. A traumatic extraction of the tooth and replantation of it by a rotational movement after the fracture line is restored by adhesive resins is one of the suggested methods used to treat vertical root fractures^[13]. Similarly Nurrohman *et al.*^[4] examined the bond strength of the fragments bonded with methyl-methacrylate resin in simulated vertical root fractured teeth. Although, these suggested methods have been successful, the bonding process takes at least 20 minutes, which is a long time under clinical conditions. Additionally, ankylosis could occur due to tooth replantation and the fact that the related root resorption is unavoidable^[4, 14]. Extraction of the fragment by a flap operation and applying an effective plaque removing is another method that has been proposed^[15]. Despite successful short-term results, the loss of periodontal tissues may occur for a long-term prognosis. However, if the root canal filling is contaminated, none of these methods can be successful over the long-term. If contamination occurs, the filling should be repeated^[1]. When considering the circumstances, such as the need for retreatment and the risk of probable ankylosis after replantation, an effect course of treatment might be to fill the fracture line with a biocompatible sealer and to strengthen the structure of the incomplete vertical fractured teeth without

interventional operations, such as tooth extraction or flap operations. Nevertheless, the extent to which this method can increase the root structure's resistance to new fractures should also be considered. Hence, this present study aimed to evaluate the efficacy of that treatment method on strengthening the root structure by using a bioceramic-based root canal sealer that can bond to the root dentine chemically^[6] and can stimulate the tissue healing due to its high biocompatibility^[5].

In general, extracted human teeth are used for *in vitro* studies related to endodontics. Previous studies have reported that using human teeth is preferred in order to obtain results that are in keeping with clinical conditions^[4, 16-19]. Hence, Cauwels *et al.*^[20] stated that using animal teeth, which have a different structure and morphology than human teeth, may result in different outcomes; those results would not be comparable to clinical conditions for human teeth. Since this study aimed to adhere to morphological and structural specifications of human teeth and obtain study results that are compatible with clinical conditions, we used extracted human permanent teeth. For the standardization of root canal systems, the same rotary system and files in the same working length were used in this study. Furthermore, a GP single cone compatible with an F3 file was used for each root canal filling, and we tried to achieve samples that adhered to requirements for standard filled samples^[21].

Removing the smear layer still continues to be an approach that is often discussed^[22]. A study on this topic^[23] reported that the existence of a smear layer did not have a negative effect on the bond strength of bioceramic based sealers. It has also been stated that the surface energy that emerges after removing the smear layer improves the fluidity of the sealer and its diffusion into the dentinal tubules, thereby increasing the bond strength to the dentinal walls^[21]. In our study, in order ensure that the presence of the smear layer did not have a positive effect or a negative effect, 17% EDTA and 5.25% NaOCl irrigation solutions, respectively, were used to remove that layer. While this practice is a generally recommended for removing the smear layer^[23], we limited the irrigation time to one minute to minimize the destructive effect of the EDTA solution on the structure of the dentin. Thus, in a previous study, the efficacy of irrigating the smear layer with EDTA for one minute was reported^[24].

When the results of the present study were evaluated, it was found that both bioceramic-based sealers (Well Root ST and MTA Fillapex) strengthened the untreated incomplete vertical fractured tooth significantly against new fractures ($P < 0.05$). This result showed that calcium silicate-based sealers have the ability to strengthen the root structure. Previous studies have reported that calcium silicate-based sealers may strengthen the tooth structure, and provide a firm and homogenous sealing to the applied area^[25, 26]. On the other hand, when both sealers were evaluated comparatively, Well Root ST demonstrated significantly higher fracture resistance than MTA Fillapex ($P < 0.05$).

During the setting reaction, preserving the dimensional stability was one of the most important specifications of the bioceramic-based sealers, and it was reported as another factor that strengthens teeth against fractures^[25]. According to the manufacturer, Well Root ST preserves its dimensional stability during setting without any shrinkage due to its bioactive calcium silicate content, which enables it to chemically bond to dentin. Çobankara *et al.*^[27] emphasized that a sealant's ability to chemically bond to the dentine wall is an important factor for strengthening the tooth structure

against fractures. MTA Fillapex contains both calcium silicate and resin. The most important handicap encountered with resin-based materials is shrinkage during polymerization [28]. It was reported that polymerization shrinkage may have a negative effect on fracture resistance, weakening the bonding strength between the sealer and the dentine wall [17]. This negative effect could be the reason for the significant difference between both of the sealers evaluated in the present study.

In the present study, in addition to the previously mentioned positive features, one of the main reasons for using bioceramic-based canal sealers is that they are biocompatible with periapical tissues; they are also effective in healing as they stimulate hard tissue formation [5]. Additionally, when treating incomplete vertical root fractures, the canal filling sealers that are used in endodontic treatment, without any need for operational and interventional processes, should be able to be injected into the canal, diffuse into the fracture line with the help of their ideal viscosity feature, repair the fracture line so that it chemically bonds to the dentine tissue, and stimulate healing where the fracture line contacts the periapical tissues. Several studies have emphasized that these

expected features exist in bioceramic-based canal sealers [5, 23, 25, 26, 29]. For bioceramic-based root canal sealers, the increase in the pH level during the setting reaction enhances tissue repairment because it stimulates mineralization in the related area. Concordantly, the increased pH level has an antibacterial effect because it inhibits bacterial growth in the area [5-8]. This positive property may also be effective in reducing or eliminating the inflammatory reaction that occurs inside the vertical fracture line. However, further clinical study data is necessary to support that assumption.

Another remarkable result of this present study was that the NG group, which was considered to consist of healthy teeth, showed a statistically significant high fracture resistance in comparison to the Well Root ST group and the MTA Fillapex group. This result shows that neither of the sealers used in the study could protect an incomplete vertical fractured tooth against a fracture as well as a healthy tooth. However, the significant difference between the two experimental groups and the PG group demonstrated that an incomplete vertical fractured tooth may be strengthened structurally and significantly by applying Well Root ST or MTA Fillapex sealers.

Table 1: Mean and standard deviation values of all groups

Groups	N	Mean	Standard Deviation	P
WRG	15	552, 73	± 38, 14	
MFG	15	464, 10	± 26, 21	< 0,05
NG	15	622, 22	± 10, 01	
PG	15	416, 01	± 6,90	

P value was found significant on each double comparison between the groups (P<0.05).

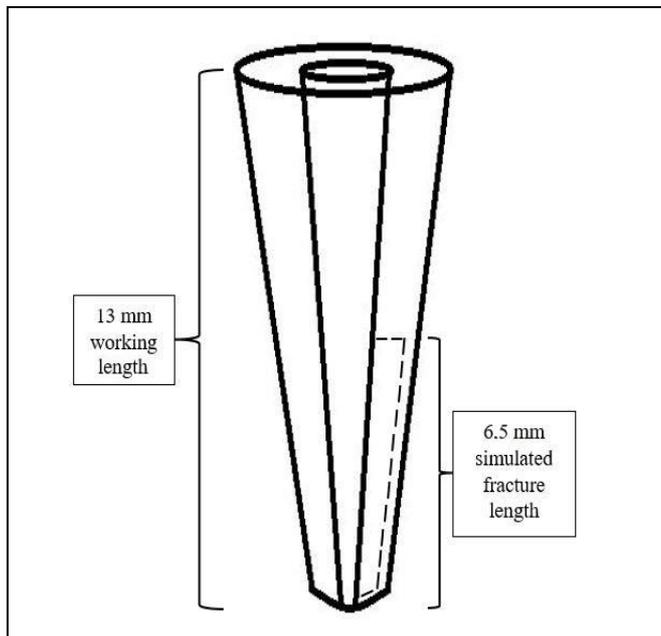


Fig 1: The schematic view of the simulation of incomplete vertical root fracture

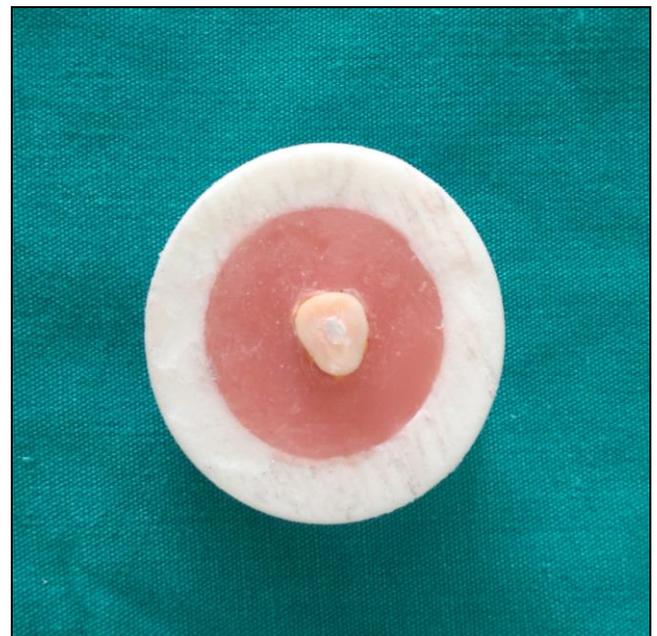


Fig 2: A sample from the Well Root ST group which was ready for the fracture test

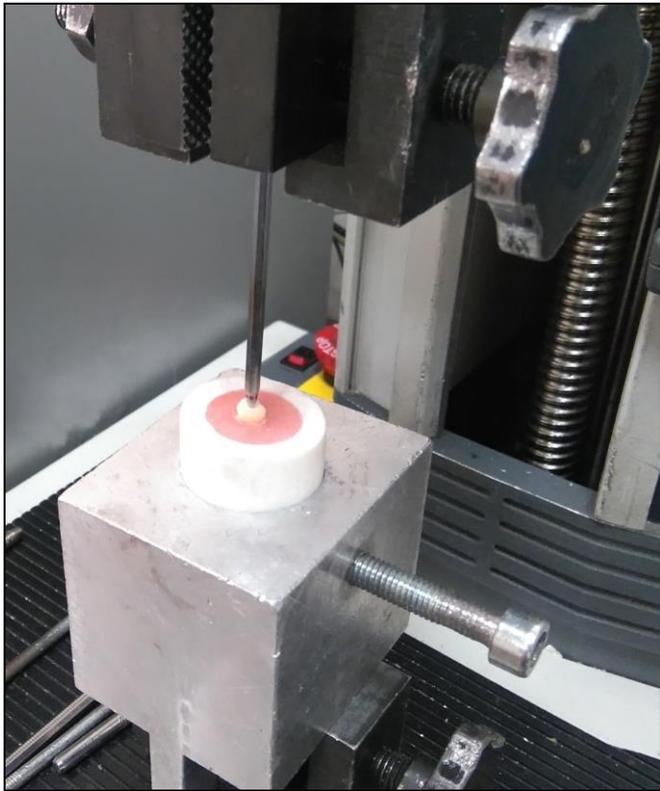


Fig 3: The Universal Testing Machine

Conclusion

This study found that the two bioceramic-based sealers evaluated under laboratory conditions successfully strengthened the structure of incomplete vertical fractured teeth. However, Well Root ST was found to strengthen the tooth structure more effectively than MTA Fillapex. Thus, the results obtained from the treatment of incomplete vertical fractured permanent teeth using bioceramic-based sealers, such as Well Root ST, indicate that this sealer may be considered as an alternative application for strengthening tooth structure. However, further studies are needed to evaluate the success of both Well Root ST and MTA Fillapex root canal sealers under clinical conditions.

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