

# Strengthening effect of bioceramic cement when used to repair simulated internal resorption cavities in endodontically treated teeth

## Wytrzymałość zębów leczonych endodontycznie po wypełnieniu symulowanych ubytków resorpcji wewnętrznej cementem bioceramicznym

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## Abstract

**Background.** The reinforcement of teeth with internal root resorption is essential to prevent their fracture.

**Objectives.** The aim of this study was to assess the fracture resistance of the premolar teeth with internal root resorption cavities (IRCs), repaired with glass-ionomer cement (GIC), gutta-percha (GP) or EndoSequence<sup>®</sup> Root Repair Material<sup>™</sup> (RRM).

**Material and methods.** Forty lower premolars, instrumented to size 50, were used. Ten teeth were assigned to the control group, which received the full obturation of the root canals. In the remaining 30, IRCs were prepared with Gates–Glidden burs. The apical 8 mm was obturated to the level of IRC using the single-cone technique. Then, the teeth were divided into 3 groups according to the material used for repairing the cavities ( $n = 10$ ): GIC; GP; and RRM. The canals were filled with respective materials and backfilled with GP. All of the specimens were scanned at the level of IRC with a micro-computed tomography (micro-CT) system, and the volume of the IRCs and the percentages of voids in the filling materials were measured. The specimens were subjected to fracture testing. The force recorded at the time of fracture was analyzed with the Kruskal–Wallis test and the independent  $t$ -test.

**Results.** The control group showed a significantly higher mean value of fracture resistance as compared to the groups with IRCs ( $p < 0.05$ ). No significant difference was found between GIC and RRM, whereas the GP group had a significantly lower fracture resistance than other tested IRC groups ( $p < 0.05$ ). The percentage of voids was significantly higher in the GIC group as compared to the GP and RRM groups ( $p < 0.05$ ).

**Conclusions.** EndoSequence Root Repair Material provides more strength to the teeth than the GP/sealer technique when both are used to fill a resorption cavity. The fracture resistance of the teeth filled with RRM was close to that obtained with GIC.

**Key words:** glass-ionomer cement, EndoSequence Root Repair Material, root resorption, gutta-percha, tooth fracture

**Słowa kluczowe:** cement szkło-jonomerowy, materiał do naprawy korzenia zęba EndoSequence, resorpcja korzenia zęba, gutaperka, złamanie zęba

## Introduction

Internal root resorption is a progressive loss of the intraradicular dentin, without any repair and with the hard structure becoming replaced with granulation tissue. This resorption is associated with chronic inflammatory conditions and might be associated with bacteria.<sup>1-3</sup>

Internal root resorption is asymptomatic and can be discovered by a routine X-ray examination. It may appear as an oval circumscribed radiolucent area with ill-defined borders and asymmetrical variations in radiolucency. This can potentially extend to root perforation.<sup>4</sup> Extensive internal root resorption, combined with root perforation, could complicate the prognosis of endodontic treatment, as it causes the weakening of the remaining tooth structures.<sup>5</sup>

The management of internal root resorption presents a unique difficulty in preparation and obturation. The resorbed defect inside the root canal is inaccessible to direct mechanical instrumentation. Therefore, the primary goal of root canal treatment is to disinfect the root canal system and fill it with appropriate materials to prevent reinfection. The filling material should be dimensionally stable and biologically compatible<sup>6</sup>; it should also strengthen the treated teeth.<sup>7</sup>

The obturation materials used after internal root resorption should flow into the resorption space and fill it totally. Thermoplasticized gutta-percha (GP) is the most commonly used filling material in the treatment of internal root resorption. The Obtura<sup>®</sup> II system (Obtura Spartan, Fenton, USA) obturates resorptive defects better than cold lateral compaction or other techniques.<sup>8</sup>

Glass-ionomer cement (GIC) is used to fill root resorptive defects and root perforations due to its biocompatibility and antibacterial effects. It provides a satisfactory clinical performance when used as a root canal sealer or as an orthograde filling material because of its good adhesion and strength, which increases the resistance of the teeth to vertical fractures.<sup>9</sup>

In cases involving extensive perforation, there is a need for a reparative biocompatible material that seals perforations and does not irritate the adjacent tissues. For a long time, mineral trioxide aggregate (MTA) has been the material of choice for repairing perforations. The advantages of using MTA include its superior sealing properties and biocompatibility.<sup>10</sup> Other calcium silicate materials are effective in sealing resorptive defects and providing strength to the tooth structures.<sup>10</sup>

The latest calcium silicate cements, such as Endo-Sequence<sup>®</sup> Root Repair Material<sup>™</sup> (RRM) (Brasseler USA, Savannah, USA), have been introduced into the endodontic field. Root Repair Material has a pre-mixed, ready-to-use putty or injectable form and is used as a root repair material as well as for endodontic indications, similar as in case of other calcium silicate materials.<sup>11</sup>

According to the manufacturer, the main composition of both RRM formulations comprises the same calcium silicate, zirconium oxide, tantalum pentoxide, calcium phosphate monobasic, and filler agents, differing only in particle size. The material is biocompatible and bioactive; it also has good sealing properties.<sup>12,13</sup> The Endo-Sequence<sup>®</sup> Bioceramic (BC) sealer increases the resistance to fractures in the premolar teeth to a greater degree than MTA.<sup>14</sup> Moreover, it has a greater push-out bond strength than Biodentine<sup>®</sup> and NeoMTA<sup>®</sup> when used as a perforation repair material after the exposure of the teeth to sodium hypochlorite at the early setting stage.<sup>11,15,16</sup>

In the literature, no study has evaluated the fracture resistance of the premolars after filling the internally resorbed root canals with RRM. The aim of this study was to assess the fracture resistance of the premolar teeth with internal root resorption cavities (IRC), repaired with GIC, GP or RRM.

## Material and methods

### Sample selection

Forty lower premolar teeth with single and wide root canals, confirmed to be radiographically free from open apices, caries, cracks, or fractures, were included for this study. The mesiodistal and buccolingual diameters of these teeth were measured at the cemento-enamel junction with a digital caliper, and the teeth included in the study had a width range of  $\pm 3$  mm. The teeth were cleaned and stored in a 10% formalin solution at room temperature.

### Preparation of the root canals

The access cavities were prepared using diamond burs, and then the Endo-Z<sup>®</sup> bur (Dentsply Maillefer, Ballaigues, Switzerland). The working length was established using a K-file 1 mm short of the apex. The preparation of the root canal was completed with the Pro Taper Next<sup>®</sup> file size X5 (Dentsply Maillefer), combined with intermittent irrigation with 2.5% sodium hypochlorite.

### Preparation of simulated internal root resorption cavities

Internal root resorption cavities were prepared not in the middle of the root, but a bit more coronal, at the level of 8 mm short of the apex using No. 1 and No. 2 Gates-Glidden drills (MANI, Inc., Takanezawa, Japan) with lateral pressure from the mesiodistal and buccolingual directions. The cavities were verified with mesiodistal and buccolingual radiographs.<sup>6</sup> The IRCs were prepared from 30 samples, and the other 10 samples were left intact and considered as a control group.

## Obturation of the root canals

The apical 8 mm of the samples with IRCs was obturated with the Pro Taper Next master cone, matched with gutta-percha points size X5 (Dentsply Maillefer) and the AH Plus® sealer (Dentsply DeTrey, Konstanz, Germany). At the same time, the control group received a full root canal obturation.

## Sample grouping

The samples were randomly distributed among 3 groups (10 teeth each) according to the filling materials used for repairing the IRCs:

- the GIC group received glass-ionomer cement (Fuji IX GP®, GC America Inc., Alsip, USA). The conditioner was applied to the cavity for 10 s; next, GIC was injected using a GIC applicator directly to the cavity, and then condensed with a No. 2 hand plugger (Dentsply Maillefer). After setting, the coronal part was added until the complete sealing of the access cavity;
- the GP group received thermoplasticized gutta-percha using the Obtura II gun (Obtura Spartan) and the AH Plus sealer. It was condensed vertically with a No. 2 hand plugger (Dentsply Maillefer);
- the RRM group received EndoSequence Root Repair Material, delivered by means of a Messing gun (Integra Life-Sciences Corp., Plainsboro, USA), and then compacted vertically with a No. 2 hand plugger (Dentsply Maillefer).

The samples were stored in an incubator at 37°C with 100% humidity for 24 h. Then, the root canals were backfilled with GP, and the coronal access cavities in all samples were sealed with a glass ionomer and stored for 1 week until the fracture resistance test.

## Micro-computed tomography analysis

The samples were scanned at the level of IRC with the micro-computed tomography (micro-CT) SkyScan® 1173 scanner system (Bruker Micro-CT, Kontich, Belgium). The system was operated at 90 kV with 88 mA and at a resolution of 7.4 µm using a 1-millimeter aluminum filter. Projection images were recorded in steps of 0.4°, from 0° to 360°. The collected raw data was reconstructed from the acquired images using the CTAn® software, v. 1.17.2 (Bruker Micro-CT). The CTVol® software, v. 2.2.3 (Bruker Micro-CT) was used to measure the volume of the IRCs in cubic millimeters and the volume of micro-voids in the IRC filling materials.

## Fracture resistance testing

The roots of the samples were covered with a thin layer of polyether impression material, 2 mm below the cervical line, simulating the periodontal membrane.<sup>17</sup> Then, the teeth were mounted vertically in self-cured acrylic resin

blocks, exposing 8 mm of the coronal length. The teeth embedded in the acrylic blocks were placed in a universal testing machine (LR 300K; Lloyd Instruments Ltd., Bognor Regis, UK) and a compressive load was applied at a speed of 1 mm/min with the spherical tips at the center of the cusps (Fig. 1). The force needed to fracture each sample was recorded in newtons.<sup>10</sup> The IBM SPSS Statistics for Windows software, v. 22 (IBM Corp., Armonk, USA) was used to analyze the data. The data was statistically analyzed using the Kruskal–Wallis test and the independent *t*-test with a *p*-value of 0.05 considered as statistically significant.



Fig. 1. Specimens placed in a universal testing machine

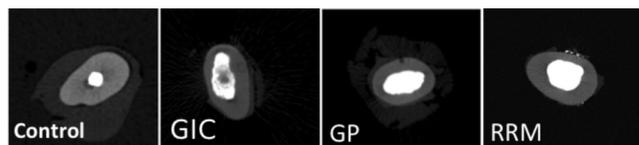
## Results

The mean (*M*) and standard deviation (*SD*) values of the IRC volume, the percentages of voids and the results of the fracture resistance test are shown in Table 1. There were no significant differences between the 3 tested groups regarding the IRC volume ( $p = 0.224$ ), whereas the percentage of voids was significantly higher in the GIC group as compared to the GP and RRM groups ( $p = 0.032$ ) (Fig. 2). The control group showed the highest mean value of fracture resistance as compared to the groups with IRCs ( $p = 0.027$ ). No significant difference was found between GIC and RRM ( $p = 0.104$ ), whereas the GP group had the fracture resistance value significantly lower than other tested groups ( $p = 0.048$ ).

**Table 1.** Fracture resistance values for the control and experimental groups

Group	n (N = 40)	IRC volume [MPa] M ±SD	Filling voids [%]	Force at fracture [N] M ±SD	max [N]	min [N]
Control	10	–	–	773.34 ±133.86 <sup>a</sup>	998.00	510.88
GIC	10	20.34 ±4.46 <sup>a</sup>	8.0 <sup>a</sup>	516.18 ±84.17 <sup>b</sup>	631.08	401.90
GP	10	21.69 ±5.77 <sup>a</sup>	2.1 <sup>b</sup>	494.30 ±102.88 <sup>c</sup>	635.44	370.33
RRM	10	23.49 ±3.92 <sup>a</sup>	1.7 <sup>b</sup>	514.05 ±87.77 <sup>b</sup>	599.65	388.23

Group GIC – glass-ionomer cement; group GP – gutta-percha; group RRM – EndoSequence Root Repair Material; IRC – internal root resorption cavity; M – mean; SD – standard deviation; different superscript letters indicate statistically significant differences ( $p < 0.05$ ).



**Fig. 2.** Cross-sectional view of the representative three-dimensional (3D) reconstruction in the middle of the IRCs filled with respective materials – GIC, GP and RRM. It shows the adaptation of GP and RRM, whereas voids appear within GIC and at the material–dentin interface

## Discussion

Internal root resorption weakens the tooth structures and increases the chance for fractures,<sup>1</sup> which requires selecting a filling material that can strengthen the weakened tooth.<sup>18</sup> The effect of internal root resorption was proven in the current study, in which teeth with root canal fillings without IRCs proved to be more resistant to fractures.

In the present study, IRCs were performed through an access cavity, without either decoronation or root perforation, and this simulates the clinical situation.<sup>6</sup> By contrast, other studies used root perforation and decoronated the samples, which does not occur in the actual clinical situations and may affect the obtained results.<sup>10,18</sup> The research design based on the standardized smooth defects, combined with tooth decoronation, did not replicate the irregular ill-defined IRCs.<sup>10</sup>

In the current study, the total volume of the IRCs was measured using micro-CT.<sup>19</sup> Then, the IRCs were subjected to statistical analysis, which did not reveal significant differences between the groups; that means there was a degree of standardization.

Glass-ionomer cement has a higher compressive strength as compared to RRM.<sup>13,20</sup> Nevertheless, GIC did not reinforce the teeth, because GIC has a long setting reaction time, which can continue for more than 1 year.<sup>9</sup> Such a length of time affects its mechanical properties. Moreover, GIC is sensitive to hydration, unlike RRM, and this could induce more voids as compared to RRM. Both the GIC- and RRM-filled teeth had a significantly higher resistance to fracture than the GP-filled teeth. This could be related to the chemical bonding between the GIC or RRM and the dentin.<sup>21,22</sup> The warm GP technique has been reported as filling resorptive defects better than

other GP techniques.<sup>8</sup> Yet, it still has the lowest value of fracture resistance. These results are in agreement with other studies, which concluded that the GP/sealer combination provided less strength to the tooth structures than calcium silicate cements.<sup>10</sup>

In the current study, the authors tried to simulate the actual clinical situation of using natural teeth, and preparing IRCs without splitting the samples and without any decoronation. However, using these natural premolar teeth, stored at the Department of Surgery, may represent a limitation, as we were unaware of the age and lifestyle of the patients. Furthermore, testing teeth in vitro may differ from testing them in vivo.

## Conclusions

Within these limitations, it can be concluded that the filling of internal root resorption with RRM provided more strength to the tooth structures than the GP/sealer technique. The RRM-filled teeth had the value of fracture resistance close to that obtained with GIC, taking into consideration the biological effect and biocompatibility of RRM for clinical use.

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