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Dentinal Microcrack Formation after Root Canal Filling with Thermoplasticized Gutta-percha: an *in vitro* Study

Irina Tsenova[1], Radosveta Vassileva[2], Emilia Karova[3]

[1] Assistant Professor, Department of Conservative Dentistry, Faculty of Dental Medicine, Medical University – Sofia 1413, Bulgaria

[2] Professor, Department of Conservative Dentistry, Faculty of Dental Medicine, Medical University – Sofia 1413, Bulgaria

[3] Associate Professor, Department of Conservative Dentistry, Faculty of Dental Medicine, Medical University – Sofia 1413, Bulgaria

Abstract: ***The objective of the present study was to evaluate the formation of microcracks after root canal filling with thermoplasticized gutta-percha. Thirty freshly extracted mandibular premolars were selected and evenly distributed into three groups (n=10): negative control, BT-Race (positive control), GuttaCore. Roots in the negative control group were left unprepared. After shaping and filling of the root canals, all teeth were horizontally sectioned at 3, 6, 9 mm from the apex and the presence of dentinal defects was registered. These data were analyzed statistically by Fisher's exact and chi-square tests (p < 0.05). No defects were observed in the negative control group. A complete fracture was present in the apical third of one root canal, filled with GuttaCore. In the positive and GuttaCore groups defects at the apical portion of the root canal were higher than those evaluated at the middle and coronal portion but the differences were statistically insignificant.***

Keywords: filling techniques, GuttaCore, microcracks, thermoplasticized gutta-percha

1. Introduction

The main objective of the initial endodontic therapy is to eradicate the existing microbiota by thorough cleaning and shaping of the root canal, and to ensure its tight-seal, three-dimensional filling to a preliminary estimated working length [1]. Various filling techniques have been used to perform a uniform, void-free obturation of the entire root canal space avoiding the passage of toxins and fluids between the periodontal space and the root canal [2]–[5].

Cold lateral condensation (CLC) of gutta-percha is used and taught for many decades worldwide and is proven to be clinically effective [6]–[9]. However, this method is time-consuming and sometimes root canal fillings lack homogeneity and poorly adapt to the canal walls [10], [11]. Moreover, the attempt to create space for the placement of accessory gutta-cones might cause dentinal defects formation into the root canal wall [12], [13]. In an attempt to overcome the deficiencies of this obturation method, warm vertical compaction has been introduced [3]. Although the root canal filling is homogenous and dimensionally stable, hydraulic forces formed during this procedure could exert pressure on the dentinal surface and induce a wedging effect capable of damaging the root [14]–[18].

Recently, several thermoplasticized, carrier-based obturation techniques have been introduced in the market [19]. The insertion of the pre-heated gutta-percha into the root canal is easily performed and provides better three-dimensional and homogenous sealing of the root canal system compared to CLC [20]. Along with the improved spreadability of the filling material, the tensile stress over the root canal walls is minimized [21].

To date, there is limited knowledge about the ability of thermoplasticized filling techniques to induce dentinal microcracks. The aim of the current in vitro study was to assess dentinal microcrack formation after root canal filling with GuttaCore (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*).

2. Materials and methods

Thirty mandibular premolars with straight roots were included in the study. Immediately after extraction teeth were stored in purified filtered water until use. The external surface of all samples was cleaned from calculus and plaque and examined under stereomicroscope (*Leica S6, Leica Microsystems, Wetzlar, Germany*) for detection of root defects, cracks or fractures. Teeth with more than one root canal, apical curvature, immature root apices, fractured root apex and any root or coronal defects, including cracks, were excluded from the study and replaced with new ones. To ensure standardization, teeth were sectioned under water cooling with a diamond disc at 16 mm from the apex.

The roots were covered with a single layer of aluminum foil and inserted in putty impression material set in an acrylic tube. After removal of the foil, a light body silicon based material (*Oranwash; Zhermak SpA, Rovigo, Italy*) was used to fill the space created in order to simulate the periodontal ligament. Afterwards, the root was returned into the acrylic mould. Fig.1

Apical patency was determined by inserting a size 10 stainless-steel K-file into the root canal until its tip was visible at the apical foramen, and the working length (WL) was set 1.0 mm shorter than this measurement. Then, a glide path was established with a size 15 K-file (*Dentsply Sirona*

Endodontics, *Ballaigues*, *Switzerland*) up to the WL. All root canals were shaped with BT-Race files (*FKG*, *La Chaux de Fonds*, *Switzerland*) with X-Smart endo motor (*Dentsply Sirona Endodontics*, *Ballaigues*, *Switzerland*) according the manufacturer's instructions in the following sequence: BT1 (10/.06), BT2 (35/.0), BT3 (35/.04) and BT4 (40/.04) at 800 rpm and 1,5 Ncm. Each instrument was used per three root canals.

During the shaping procedure the root canals were irrigated with saline using 27G endodontic irrigation needle. All samples were kept moist in purified filtered water in order to prevent dehydration.

The roots were evenly distributed into 3 groups (n=10) as follows:
Group I (negative control): unprepared roots.
Group II (positive control): roots instrumented with BT-Race system, unfilled
Group III (GuttaCore): roots instrumented with BT-Race system, assessed with a metal verifier, and filled with Gutta Core (GC) obturator size 35.04 (*Dentsply Sirona Endodontics*, *Ballaigues*, *Switzerland*) according to the manufacturer's directions. The GC obturator was heated in ThermaPrep Plus oven (*Dentsply Sirona Endodontics*, *Ballaigues*, *Switzerland*) for 30 s and slowly inserted up to the WL into the canal previously coated with AH Plus sealer. Thereafter, the shaft and handle of the obturator were removed by bending the obturator.

After root filling procedures, the coronal 1 mm of the filling materials was removed, the cavity filled with a temporary filling material (*Citodur Hard*, *DoriDent,Wien*, *Austria*), and the teeth stored for 1 week in sterile, distilled water at 37 °C and 100% relative humidity to ensure complete setting of the sealer.

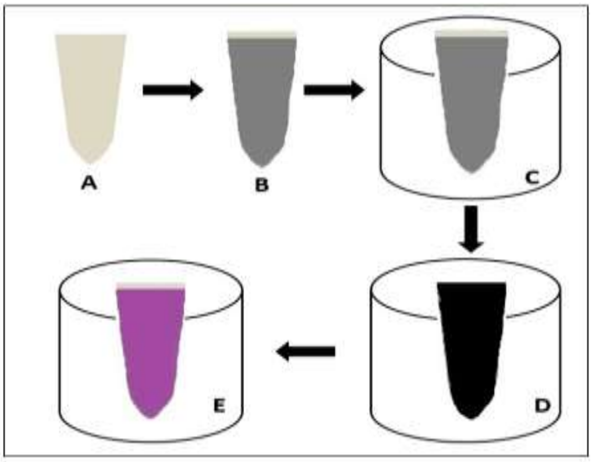

Figure 1: Simulation of periodontal ligament: A) root B) root wrapped in aluminum foil C) placement into an acrylic mould D) space formed from the root E) Placement of light body silicon.

Sectioning and Microscopic Observation
All roots were sectioned horizontally at 3, 6 and 9 mm from the apex with a low-speed saw under water cooling *(Leica SP1600*, *Leica Microsystems*, *Wetzlar*, *Germany*) Fig.2. A total number of 90 slices were obtained and viewed under stereomicroscope by using a cold light source at x 40 magnification (*Leica S6*, *Leica Microsystems*, *Wetzlar*, *Germany*). Digital images of each section were captured with a camera attached to the microscope. The dentin surface was inspected by a single observer and dentinal defects were categorized as follows:
0 = No defect - root dentin devoid of any craze lines, microcracks and fractures.
1 = Other defects - incomplete cracks: a craze line – a line extending from the outer surface into the dentin, without reaching the canal lumen, or a partial crack – a line extending from the canal walls into the dentin without reaching the outer surface.
2 = Fracture - a line extending from the root canal space all the way to the outer surface of the root.

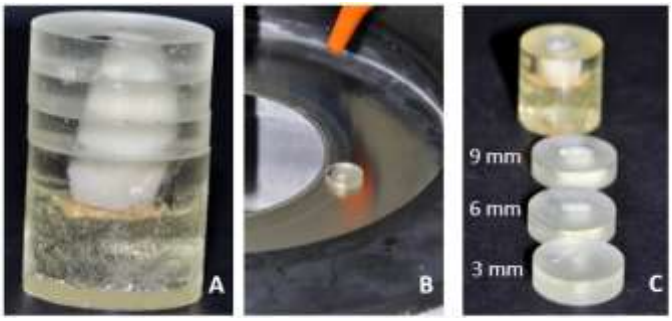

Figure 2: Sectioning procedure A) entire root B) low-speed saw sectioning C) slices at 3, 6 and 9 mm.

3. Statistical Analysis

Fisher's exact and chi-square tests were used for statistical analysis of differences between groups at 95% confidence level ($p < 0.05$).

4. Results

No cracks were observed in the negative control group. No defects were registered in the middle and coronal portion of the specimens in the examined groups. One complete fracture was present in the apical third of one root canal, filled with GuttaCore. Comparison between the instrumented, but unfilled group and GuttaCore group revealed insignificant difference concerning the number of defects registered at the three examined levels. In both tested groups defects at the apical portion of the root canal were higher than those evaluated at the coronal and middle portion but the differences were statistically insignificant Fig.3,Fig.4,Table 1.

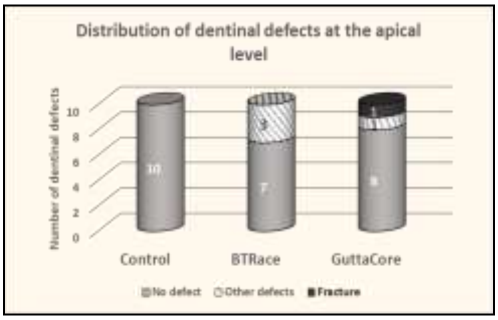

Figure 3: Distribution of dentinal defects at the apical level of the experimental groups

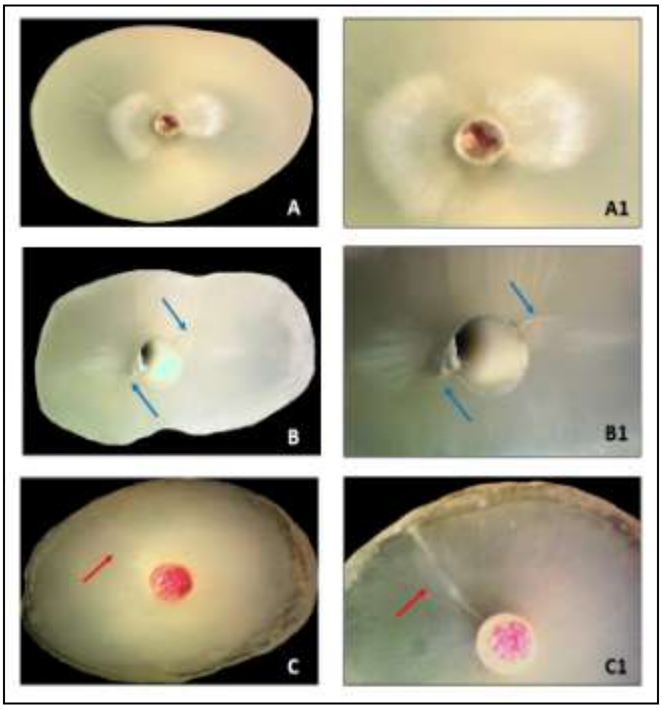

Figure 4: Stereomicroscopic images at the apical level of the root canal: A) unprepared control group at x20; A1) unprepared control group at x40 B) Partial cracks produced by BT-Race instrumentation x20; B1) Partial cracks produced by BT-Race instrumentation x40 C) Fracture after GuttaCore filling x20; C1) Fracture after GuttaCore filling x40.

Table 1: Number and percentage of dentinal defects at different levels in the three groups

Level	Dentinal damage	Number and percentage of defects	Negative control	BTRace	GuttaCore	Total
3 mm	No defect	N	10	7	8	25
		%	100%	70%	80%	83,33%
	Other defects	N	0	3	1	4
		%	0%	30%	10%	13,33%
	Fracture	N	0	0	1	1
		%	0%	0%	10%	3,33%
6 mm	No defect	N	10	10	10	30
		%	100%	100%	100%	100%
	Other defect	N	0	0	0	0
		%	0%	0%	0%	0%
9 mm	No defect	N	10	10	10	30
		%	100%	100,0%	100%	100%
	Other defect	N	0	0	0	0
		%	0%	0,0%	0%	0%

5. Discussion

It is assumed that during root canal filling procedures the dentin is elastic enough to withstand the effect of the accumulated surface strain, without causing a root fracture. Nevertheless, when using different methods for hermetic obturation of the root canal system, certain deformations in the dentinal wall can appear [22]. Microcracks are assumed as possible precursors of vertical root fractures involving the periodontium [23], [24], [25]. This severe complication is one of the major reasons for endodontic failure and usually influences the long-term survival of the tooth [12], [26], [27]. Recently, several in vitro investigations reported direct relationship between canal filling and development of dentinal defects [28]–[33]. Similar results were found in our study, as well, since one partial crack and one complete fracture were observed in the apical root portion in the GuttaCore group. Nevertheless, the relatively small number of the defects and their insignificant difference from those observed in the negative and positive control groups made us speculate that this is due to the instrumentation rather than the filling technique.

The choice of BT-Race system in the current in vitro study is based on their increased cutting efficiency due to the non-active, booster tip with 6 cutting edges at the top. It removes great amount of dentin with each cut, thus enabling faster progression through the canal, while respecting its anatomy and shape, without causing undue stress on the instruments and root canal walls [34], [35]. In the present experiment the positive control group exhibited partial cracks only at the apical third of the root canal in three samples (30%). These findings differ from those of Ahmed et al. who observed dentinal microcracks in the BT-Race group at the apical and coronal root portion (56, 67%) [35]. This discrepancy might be explained by differences in sample selection and size.

Filling the root canal space with a carrier-based thermoplasticized obturator resembles the monophase technique where no additional pressure onto the root canal wall is applied [28], [36]. Thus, the temperature rise during the filling procedure might be questioned as a triggering factor for microcrack initiation. The gutta-percha of the heated obturator as it approaches the canal orifice is approximately 200 °C. Thermoplasticized gutta-percha acts thixotropically, allowing it to flow with less viscosity at faster insertion rates (i.e. with force) [37], [38]. Nonetheless, in the present study only a single complete fracture was observed in the apical level of one root filled with GuttaCore. Currently, several methodologies for dentinal defect detection and registration have been introduced in numerous in vitro studies. Horizontal sectioning of the specimens at different levels of the root followed by their direct stereomicroscopic visualization, is the most prevailing laboratory approach. The major shortcomings of this method are the inability to assess previously existing dentinal defects and the risk of producing artificial cracks [39]. In an attempt to overcome these disadvantages and to ensure reproducible results, we used a negative control group. The lack of dentinal microcracks in the samples from this group, confirmed that any damage occurred during either the instrumentation or the filling procedure, which is in line with the findings obtained in previous studies [28], [30], [31], [32]. Conversely, authors using the same conventional section methodology explained the existence of dentinal defects in the unprepared group with excessive mastication and extraction forces [21], [29], [40], [41]. However, since most of the premolars selected in this study had calculus and staining but no deep carious lesions, an assumption could be made that they were extracted for periodontal lesions with minimal trauma [26], [28].

In order to eliminate the adverse impact of some of the main endodontic irrigants on the dentinal structure, we applied saline throughout the shaping procedure. Our approach differs from other experiments where the irrigation protocol during the endodontic treatment included mainly different concentrations and quantities of NaOCl and EDTA [21], [28], [29], [30]. Furthermore, to enable better stress distribution during the shaping and the filling procedures, we simulated PDL as suggested in previous investigations [17], [21], [28], [30]. The storage medium used to keep the teeth hydrated in our experiment was purified filtered water. This medium was previously recommended for investigation of human dentin as it causes the least changes in dentin over time [28], [42].

6. Conclusion

Within the limitations of the present study, carrier-based, thermoplasticized gutta-percha presented as a safe filling method concerning the preservation of the root canal dentinal matrix. A small number of dentinal microcraks was registered only in the apical third of the root canal and the difference remained insignificant in comparison to the negative and the positive control groups.

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