## Conservative Dentistry

# Preexisting dentinal microcracks in lower incisors – a micro-CT study

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# Предварително съществуващи дентинови микропукнатини при долни резци – компютърно микротомографско изследване

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**Summary**

***Introduction:*** *During the past decade micro-computed tomography has evolved into one of the most precise experimental tools in* ***in vitro*** *endodontic laboratory examinations. It is a non-invasive methodology that enables detailed and reproducible assessment of the root canal system prior to and in the course of the endodontic treatment.*

***Aim:*** *The aim of the current study was to assess the prevalence of preexisting root canal microcracks in lower incisors by means of micro-computed tomography.*

***Materials and methods:*** *Twenty single-rooted, non-endodontically treated lower incisors with straight roots (<5°) were selected and stored in distilled water at 37°C. Immediately after extraction, all root surfaces were gently cleaned using an ultrasonic tip under water cooling to remove calculus and soft tissue debris. All teeth were inspected under a stereomicroscope at x40 magnification to inspect the root surfaces for any defects. The specimens were horizontally sectioned using a diamond bur under copious water cooling at the cementoenamel junction, leaving roots at approximately 15,5 ± 0.5 mm length and scanned using the Bruker-SkyScan 1272 tomograph. The presence of radiolucent lines in micro-CT cross-section images was identified as dentinal microcracks.*

***Results:*** *The total number of cross-sectional images after the scanning of all twenty roots were 30 895. Preexisting microcracks were observed in 601 of them (1.95%). There was no correlation between the location and the type of the cracks observed. In 15 samples a separation between enamel and dentin was observed.*

***Conclusion:*** *Within the limitations of this study, micro-computed tomography emerged as a highly accurate tool for dentinal microcrack detection. A small number of preexisting dentinal defects were registered in non-endodontically treated lower incisors.*

***Key words:*** *micro-computed tomography, non-endodontically treated lower incisors, preexisting dentinal microcracks*

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**Резюме**

***Въведение:*** *През последното десетилетие компютърната микротомография се превърна в един от най-прецизните методи, използвани в ендодонтските лабораторни изследвания. Тази методология е неинвазивна и осигурява детайлно и възпроизводимо наблюдение на корено-каналната система преди и в хода на ендодонтското лечение.*

***Цел:*** *Целта на настоящото изследване е да се установи наличието на предварително съществуващи микропукнатини в кореновия дентин при долни резци чрез компютърно микротомографско изследване.*

***Материали и методи:*** *Използвани са двадесет неендодонтски лекувани, еднокоренови долни резци с прави коренови канали (<5°), съхранявани в дестилирана вода при температура от 37°C. Непосредствено след екстракцията, всички зъбни повърхности са внимателно почистени от калкулус и меко-тъканни остатъци с ултразвуков скалер при непрекъснато водно охлаждане. За да се изследва наличието на дефекти по външната коренова повърхност, всички зъби са наблюдавани стереомикроскопски под увеличение x40. След това резците са срязани хоризонтално чрез диамантен борер и непрекъснато водно охлаждане на нивото на емайло-цементовата граница като получените корени са с дължина приблизително 15,5 ± 0.5 mm. Сканирането на образците се осъществява чрез Bruker-SkyScan 1272 томограф. Наличните линии при напречните компютърно-микротомографски срезове се определят като дентинови микропукнатини.*

***Резултати:*** *Общият брой на снимките на напречните срезове след сканирането на всички двадесет корена бе 30 895. Предварително съществуващи дентинови микропукнатини бяха отчетени на 601 среза (1.95%). Не се установи зависимост между локализацията и типа на дефектите. В 15 от образците се наблюдава разслояване между цемента и дентина.*

***Заключение:*** *Компютърната микротомография е надежден и прецизен метод за наблюдаване на дентинови дефекти. Малък брой предварително съществуващи дентинови дефекти бе отчетен при неендодонтски лекувани долни резци.*

***Ключови думи:*** *Компютърна микротомография, неендодонтски лекувани долни резци, предварително съществуващи дефекти*

**Introduction**

During the past decade micro-computed tomography has evolved into a powerful, non-invasive tool used in the field of *in vitro* endodontic examinations. It is a commonly used method for analysis of root canal morphology, evaluation of the root canal space after initial endodontic treatment and retreatment procedures, assessment of the effectiveness of various filling techniques, and detection of dentinal microcracks and fracture lines into the root canal wall [1].

Diagnosis and management of preexisting root canal dentinal defects is a difficult clinical task [2]. Their occurrence is often attributed to various non-iatrogenic and iatrogenic factors such as patient's age, functional and parafunctional stresses, restorative and endodontic procedures [3, 4, 5, 6].

Preexisting dentinal microcracks in roots of intact teeth have been previously reported by using invasive and non-invasive methods [7, 8]. It is speculated that under masticatory forces those defects can further propagate into vertical root fracture (VRF), which is considered as one of the most common reasons for tooth loss [2, 9, 10, 11]. Endodontic therapy is also regarded as one of the prerequisites for this severe complication [12]. Nevertheless, VRF has been reported in non-endodontically treated teeth as well [5, 13].

The aim of the current study was to assess the prevalence of preexisting root canal microcracks in lower incisors by means of micro-computed tomography.

**Materials and methods**

All samples in the experiment were obtained from a pool of freshly extracted teeth from the Department of Oral and Maxillofacial Surgery, Faculty of Dental Medicine, Medical University – Sofia, Bulgaria. Overall, thirty-five intact mandibular incisors were extracted due to periodontal lesions. The extractions were performed non-traumatically to prevent crack formation during the procedures**.**

Immediately after extraction, all root surfaces were gently cleaned using an ultrasonic tip under water cooling to remove calculus and soft tissue debris. All teeth were inspected under a stereomicroscope at x40 magnification to detect the root surfaces and those exhibiting root caries, incomplete root formation, fracture, external cracks or resorptions were excluded from the experiment and replaced with new ones. Twenty single-rooted, non-endodontically treated lower incisors with straight roots (<5°) were finally selected and stored in distilled water at 37°C until further evaluation. To ensure standardization all teeth were horizontally section using a diamond bur under copious water cooling at the cementoenamel junction, leaving roots at approximately 15,5 ± 0.5 mm length.

All specimens were scanned using the Bruker-SkyScan 1272 tomograph (*Bruker-microCT, Kontich, Belgium*) at 100 kV, 100 μA and voxel size of 10μm. X-rays were filtered with a 0.11mm-thick copper filter. In an attempt to lower the risk of dehydration throughout the scanning procedure, each sample was covered with a plastic wrap and mounted into the device. Images were reconstructed and analyzed using the following software: DataViewer v. 1.5.2.4 (*Bruker microCT*), CTan (*Bruker microCT*) и CTvox v. 3.2.0.0 (*Bruker microCT*). Crack identification was performed according to previously published methodologies [2]. Any radiolucent lines in micro-CT cross-section images were identified as cracks. The identification of a crack was based on the following definition: a crack is a break or disruption in the tooth structure without separation of the parts [2, 5].

**Results**

The total number of cross-sectional images after the scanning of all twenty roots were 30 895. Preexisting microcracks were observed in 601 of them (1.95%), distributed as follows: 32 with direction from the root canal lumen to the outer surface, 13 – from the outer surface of the root canal to the lumen, and 556 were chaotic lines in the inner part of the dentin (fig.1). The number of slices exhibiting dentinal defects is shown in figure 2. There was no correlation between the location and the type of the cracks observed (p>0.05).

In 15 samples a separation between enamel and dentin was observed (fig. 1). These findings were not registered as dentinal defects since their location was at the cementodentinal junction and not in the root dentin wall itself.

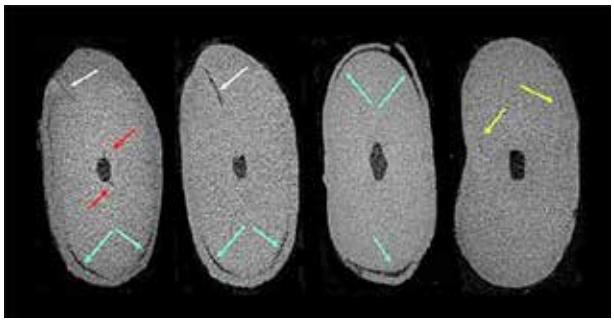

***Fig. 1****. Preexisting microcracks. Cracks with direction from the root canal lumen to the outer surface (red arrows); Crack from the outer surface of the root canal to the lumen (white arrow); Chaotic crack lines in the inner part of the dentin (yellow arrows); Separation between enamel and dentin (green arrows).*

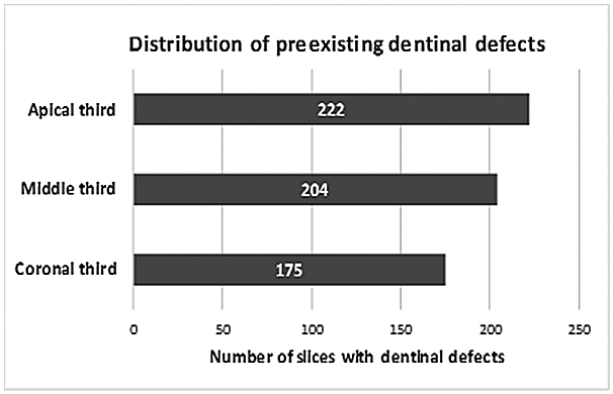


***Fig. 2.*** *Distribution of preexisting dentinal cracks in the different levels of the root canal.*

**Discussion**

The occurrence of dentinal defects into the root canal wall raises a scientific interest in their etiology and their probable relation to vertical root fractures. There are conflicting results in the literature regarding the prevalence of preexisting dentinal microcracks in non-endodontically treated teeth, depending on the method used for their visualization. Nowadays micro-computed tomography has gained an increasing significance in endodontic experiments. It is a non-invasive methodology that allows safe, reproducible, two- and three-dimensional qualitative and quantitative analysis of the root canal system. Unlike sectioning techniques this method enables overlapping further studies on the same sample without destroying it [1,2].

Only intact lower incisors, with no external defects after stereomicroscopic observation were included in the current experiment. Nevertheless, 1.95% of the cross-sectional images obtained after the scanning revealed preexisting defects. Additionally, separation of cement and dentin at different levels along the root length was registered in fifteen samples. They were not considered dentinal defects as they appeared at the cementodentinal junction and not in the dentinal wall itself. We assume, that this phenomenon is likely due to the preliminary cleaning of the root surface from calculus and soft tissue debris. Similar findings were observed in the studies of other researchers [14, 15].

Our results are in correlation with previous micro-CT studies where dentinal microcracks in intact roots ranged from 0.16% to 34.6% [8, 16, 17, 18, 19, 20]. The presence of cracks is in contrast with the accumulated knowledgebase from experiments using the sectioning technique where no defects were observed in the non-treated samples from the negative control groups [21, 22, 23, 24].

Concerns regarding the spatial resolution threshold of micro-CT have been raised previously [5, 18, 25]. Nevertheless, *De-Deus* et al. (2016) have proven the reliability of this method for examination of extracted teeth. All dentinal defects visualized with direct observation of dentin with reflected light microscopy were also registered on the two-dimensional cross-section images after the high-resolution micro-CT scanning [18].

Patient's age, sex, trauma, masticatory forces, parafunctions, extraction forces as well as storage media of the samples are speculated to cause root dentinal defects in non-endodontically treated teeth [5, 7]. Unlike the study of *PradeepKumar* et al*.,* we did not take into account demographic characteristics and used teeth from the same group. In their micro-CT analysis of 633 teeth the authors found that preexisting dentinal microcracks in roots of non-endodontically treated teeth occurred more often in older patients (40–70 years), predominantly in the cervical and middle thirds of the roots and were more likely to be incomplete in nature [5].

In 2018 *Shemesh* et al. highlighted the importance of the degree of hydration and the biomechanical properties of dentin [26]. Loss of water may initiate spontaneous cracking of dentin due to its brittleness [27] and decreased toughness [28, 29]. In an attempt to overcome some of the aforementioned factors, in our research extractions were performed atraumatically, and the samples were stored in purified distilled water to maintain hydration. Moreover, during the course of the scanning procedure, samples were covered in a plastic wrap to prevent further loss of water content.

Recently, several authors utilized fresh cadaver models in *in situ* studies. Nevertheless, the results of such experiments are inconclusive and depend on the methodology used.

Some scientific teams, applying the sectioning techniques and direct microscopic observation, report higher incidence of defects in the untreated control groups [7, 30]. Others, using the micro-CT technology, come to the opposite conclusion. *De-Deus* et al. (2017) reported significantly lower percentage of microcracks in non-endodontically treated teeth – 2.46% [31]. In a pilot study *De-Deus* et al. (2019) investigated 42 maxillary and mandibular bone blocks by scanning the teeth inside and outside of the alveolar bone. Microcracks observed when the tooth was outside the bone-block remained detectable when the entire maxillary segment was scanned, which validated the method of assessing dentinal microcracks in a fresh cadaver model through micro-CT technology. The authors stated that this methodology is close to an ideal experimental model for studying the integrity of dentinal matrix, since the bone and periodontal ligament as well as the viscoelastic properties of the attachment apparatus are preserved [32].

Despite the promising results obtained by the scanning of dento-alveolar fragments, micro-CT cannot be applied *in vivo* due to its higher x-ray radiation exposure and the limited size of the experimental objects [1].

## Conclusion

Within the limitations of this study, micro-computed tomography presented as a highly accurate tool for dentinal microcrack detection. A small number of preexisting dentinal defects were registered in non-endodontically treated lower incisors.

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