Bulgarian Chemical Communications, Volume 48, Special Issue G (pp. 107-110) 2016

3D profilometry of the fracture line in endodontically treated premolars, restored with metal posts

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Received October 10, 2016; Revised November 20, 2016

Endodontically treated teeth tend to be more fragile and susceptible to fracture than vital ones. There are numerous techniques used for their restoration, but the assessment of the survival rates is limited because of the difficulties in diagnostics. The aim of our study was to investigate the application of 3D profilometry for the visualization of cracks and vertical root fractures in endodontically treated teeth. Eighteen extracted premolars, restored with prefabricated metal posts and composite resin, were used. They were divided into 3 groups according to the extent of lost coronary hard dental tissues. After thermocycling, they were tested in a standard mechanical test machine until fracture. The fracture lines were visualized using 3D Profilometry. The results showed deeper, wider cracks with a vertical direction towards the apex of the roots in the groups with extensive tissue loss. In conclusion, 3D profilometry proved to be a quick, easy and highly informative method for assessing vertical root fractures.

Keywords: profilometry, fracture resistance, premolars, vertical root fractures, cracks.

INTRODUCTION

Endodontic treatment is usually associated with a reduction in the fracture resistance and the resilience of the treated teeth [1]. This leads to an increased number of vertical root fractures (VRF), extraction of the tooth and subsequent prosthodontic treatment [2]. The reduced mechanical properties of endodontically treated teeth (ETT) could arise from a variety of factors: changes in the moisture content of dentin with aging and loss of pulp tissue [3], disintegration of the organic matrix [4], the extent of tooth structure reduction, as well as the restorative procedures used. The different treatment options include: size, diameter, length and material of the cemented post, the presence of a ferrule and the cementation of an appropriate crown [5].

The influences of these factors have been extensively studied. Nevertheless, the options for the assessment and visualization of the cracks and fractures of ETT, remain limited. In many cases, the VRF are not diagnosed until after the extraction of the tooth in question. The prevalence of fractures reported in clinical practice varies between 8.8 – 10.9 % [6, 7]. Still, the real percentage is believed to be much higher, the reason being the difficulties in diagnosing and assessing them.

3D profilometry is a fast, accessible and highly informative contemporary method for the measurement of a surface's profile. It provides both qualitative and quantitative information of the examined object's roughness and topography. One of the main advantages of profilometry is that there is no need for any preliminary sample preparation and there is no contact with the sample's surface. Therefore, the objects involved in the study cannot be damaged in any way.

The highly detailed information, provided by the method, is ideal for registering the subtle changes that can occur in hard dental tissues. In dentistry, it has been mainly used for the evaluation of enamel surfaces after treatment with different abrasive techniques [8]. Another possible application is for the assessment of the qualities of new dental materials, such as orthodontic wires that can lessen biofilm adaptation, reduce friction and improve corrosion resistance [9].

There is no available information in the literature about the use of 3D profilometry in the studying of vertical root fractures. Therefore, the aim of our experiment was to explore the potential

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of this technique in assessing the depth, width and topography of cracks that occur in ETT.

MATERIALS AND METHODS

Eighteen human, single root premolars, free of cracks and defects were extracted for orthodontic or periodontal reasons. They were stored in 0.2% thymol solution for no longer than three months. The bucco-lingual and mesio-distal widths of the crowns were measured and only teeth of similar sizes were selected for the experiment. They were divided in 3 groups (n=6): teeth with a prepared endodontic cavity only (E), teeth prepared with a mesio-occlusal cavity (MO) and teeth prepared with a messio-occlusal-distal cavity (MOD). All of the samples were restored with rigid, passive stainless steel prefabricated posts and composite resin.

The teeth were then thermocycled for 5000 cycles between 5±5°C and 55±5°C (LTC 100, LAM Technologies, Italy). Subsequently, their roots were embedded in self-curing resin to a level 2 mm apical to the cementoenamel junction (CEJ) using a modified technique, proposed by Soares et al. [10]. The periodontal ligament was simulated using a polyether-based impression material (Impregum Garant L Duo Soft, 3M ESPE).

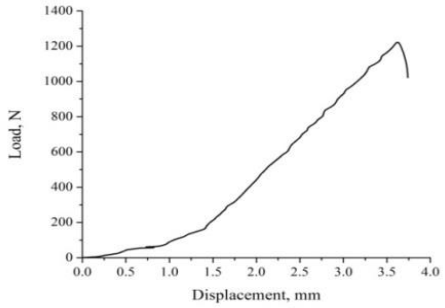

Fig. 1. Typical load-strain diagram of premolars, restored with metal posts.

The specimens were loaded in compression along the axis of the tooth until failure in an universal testing machine Fu1000e at a cross-head speed 4mm/min. For each groups, a diagram of the load at initial fracture was recorded (Fig. 1). Afterward, the mean failure loads were calculated. One-way analysis of variance (ANOVA) was applied to determine statistically significant differences. The significance level was established at a P value < 0.05. They were then examined under magnification for fracture lines determination. One representative tooth of each group was selected for examination with 3D profilometry. The profilometer used was Zeta-20 (Zeta Instruments) with vertical resolution <1 mm, field of view between 0.006 mm^2 and 15 mm^2 and magnification of 5x, 20x, 50x and 100x. The examined region of the tooth was the coronal 1/3 of the root for all the specimens. At each Z position, the profiler records the XY location and the precise Z height of the pixels and this information is used to create a true color 3D image and a 2D composite image.

RESULTS AND DISCUSSION

The summarized results of the width and depth of the examined cracks are presented in Table 1.

Table 1. Width and depth of the cracks for each of the representative teeth (E – endodontic cavity, MO – mesio-oclusal cavity, MOD – mesio-occlusal-distal cavity).

Group	Width (μm)	Depth (μm)
E	3.2 – 6.5	4 – 7.8
MO	25 – 28	14 – 31. 7
MOD	96.7 – 107.6	68.4 – 148.6

A 3D image of the surface topography for each representative tooth is presented in Fig. 2 – Fig. 4.

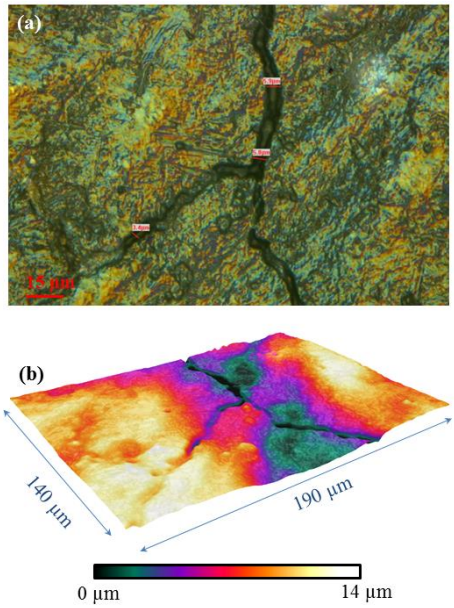

Fig. 2. Topography of the representative sample from group E (50x magnification).

In endodontics, 3D profilometry has been mainly used for the assessment of dentin's roughness, after treatment with different

medicaments. Yassen et al. investigated the effect of various endodontic regeneration protocols (NaOCl, CaOH, EDTA and antibiotic paste) on dentin [11]. The surface roughness was characterized using optical profilometry and the results showed a significant increase in the groups treated with a combination of NaOCl and EDTA. A different approach was successfully attempted by Larimer et al. [12]. Instead of using profilometry on hard dental surfaces, they attempted to measure the biofilm thickness from initial colonization to maturity.

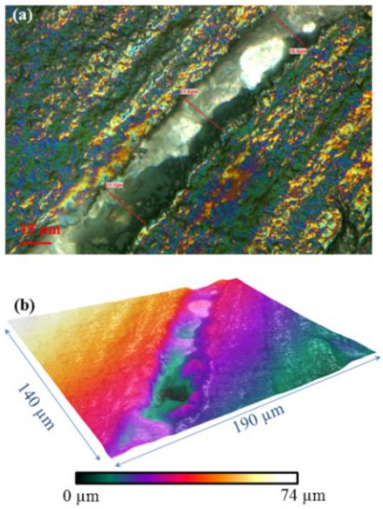

Fig. 3. Topography of the representative sample from group MO (50x magnification).

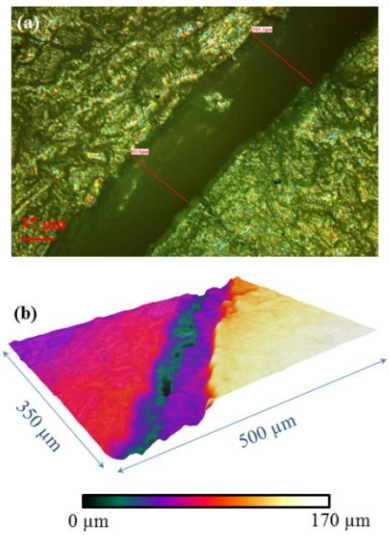

Fig. 4. Topography of the representative sample from group MOD (20x magnification).

The evidence, presented in the literature, shows that profilometry can successfully be used not only in the general field of dentistry, but also in endodontics. This is confirmed by our results. The traditional method for assessment of vertical root fractures is the use of a stereomicroscope [13, 14]. Another way for achieving a better visualization is through the use of different dying techniques [15]. These methods, like profilometry, provide a quick and easy way of investigating cracks, without the need of any sample preparation. They, however, rely only on the subjective visual assessment of the operator, in order to determine the severity of the cracks/vertical root fractures. In contrast, the method of profilometry can provide quantitative information about their depth and width.

In our study, there is a clear tendency in the formation of wider and deeper cracks on the surface of the teeth with the increase in dental tissue loss (Table 1). This is in agreement with the information that is available in the literature. Teeth with extensive cavity preparations and loss of dentin (because of caries, fracture and endodontic treatment) tend to be more fragile and show higher rates of catastrophic vertical root fractures. According to Reeh et al., endodontic treatment alone decreases the fracture resistance of premolars with 5%, but when combined with a mesio-occlusal or mesio-occluso-distal preparation, the percentage rises to 20% and 63%, respectively [16].

The obtained 3D images of the surface topography are also highly informative. The image of tooth in the group with endodontic cavity only (Fig. 2) shows a network of narrow cracks that span vertically towards the apex, as well as horizontally. In contrast, the images of the teeth in the groups with MO and MOD cavities (Fig. 3 and Fig. 4) show one wide, deep crack that extends towards the apical region. Therefore, in teeth without extensive loss of dentin, the formation of the cracks tends to be in a more horizontal direction, which in turn can result in a more favourable outcome. Teeth with cracks that do not extend beyond the coronal 1/3 of the root can be restored with a combination of surgical or orthodontic methods. On the other side, the deep, vertical fracture lines observed in the teeth with extensive loss of dentin (groups MO and MOD), are less likely to be restorable. In most cases, the only choice of treatment remains the extraction of the tooth, in combination with prosthodontic or implant dental treatment.

CONCLUSIONS

In conclusion, the method of 3D profilometry

proved to be applicable in the study of vertical root fractures in ETT. The obtained information showed highly-detailed topographic images, as well as quantitative data on their widths and depths. The results between the examined groups can be easily compared and showed more severe cracks in teeth with considerable dentin loss. The comprehensive examination of the surfaces proved that optical profilometry is a method with great potential in the field of dental medicine. It could successfully be used in vivo for the surface assessment of hard dental tissues, as well as various dental materials, after exposure to the oral environment.

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3D ПРОФИЛОМЕТРИЯ НА ЕНДОДОНТСКИ ЛЕКУВАНИ ПРЕМОЛАРИ, ВЪЗСТАНОВЕНИ С МЕТАЛНИ ЩИФТОВЕ

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Постъпила на 10 октомври 2016 г.; коригирана на 20 ноември, 2016 г.

(Резюме)

Ендодонтски лекуваните зъби (ЕЛЗ) са по-крехки и податливи на фрактури от виталните. Съществува разнообразие от техники и материали за тяхното възстановяване, но възможностите за оценка на преживяемостта на лекуваните зъби са ограничени. Основни причини за това са трудностите в диагностиката, пред които се изправя всеки лекар по дентална медицина. Целта на нашето изследване е да се оценят възможностите на 3D профилометрията за визуализация на пукнатините и вертикалните коренови фрактури, които настъпват при ЕЛЗ. В изследването са включени 18 екстрахирани премолара, възстановени с фабрични метални щифтове и композитен материал. Образците са разпределени в 3 групи, според степента на загуба на коронарни твърди зъбни тъкани (ТЗТ). След термоциклиране, те са подложени на тест за фрактурна издръжливост в стандартна изпитателна машина, до настъпването на фрактура. Фрактурните линии са визуализирани с помощта на 3D профилометрия. Резултатите за групите с екстензивна загуба на ТЗТ показват наличието на пукнатини с голяма ширина и дълбочина, които се разпространяват във вертикална посока към апекса на зъба. В заключение, 3D профилометрията е бърз, достъпен и високо информативен метод, който успешно може да се прилага за оценка на вертикални коренови фрактури при ЕЛЗ.