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Analysis of stress in the walls of simulated artificial root canals during instrumentation with Reciproc system: a pilot study using a photoelastic model

Análise de estresse nas paredes de canais artificiais simulados durante a instrumentação com sistema Reciproc: um estudo piloto usando um modelo fotoelástico

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ABSTRACT

Objective: The aim of this pilot study was to perform in vitro analysis of the stress related to instrumentation of artificial root canals with Reciproc System by using the photoelasticity method. **Material and Methods:** Photoelastic models consisted of two epoxy resin blocks simulating root canals, which were attached with cyanoacrylate adhesive to a base and placed at the centre of a circular polariscope in a dark-field configuration. The Reciproc R25 instrument was mounted to a VDW motor and used in block 1 up to 12 mm (working length) and then the same instrument was used in block 2. The images were captured by video camera and analysed at the time of the fourth penetration. Isochromatic fringes were observed in the cervical, middle and apical thirds at mesial and distal regions of each block. Therefore, they were divided into cervical-mesial (CM), cervical-distal (CD), middle-mesial (MM), middle-distal (MD), apical-mesial (AM) and apical-distal (AD). **Results:** In the first instrumentation, it was found that the greatest stress occurred at the middle-distal region (1.38), followed by middle-mesial (1.20), apical-distal (1.20) and apical-mesial regions (1.20). In the second instrumentation, the greatest stress occurred at the middle-mesial (1.20), apical-distal (1.20), apical-mesial (1.20) and middle-distal regions (0.90). **Conclusion:** The greatest stress occurred in the middle and apical thirds during the first instrumentation. Re-utilization caused less stress.

KEYWORDS

Dental Stress Analysis; Endodontic; Instrumentation.

RESUMO

Objetivo: O objetivo deste estudo piloto foi realizar a análise in vitro do estresse relacionado a instrumentação de canais artificiais utilizando o sistema de instrumentação Reciproc por meio da fotoelasticidade. **Material e Métodos:** Modelos fotoelásticos de dois blocos de resina epóxi com um canal simulado foram fixados com adesivo de cianoacrilato sobre uma base no centro de um polariscope circular na configuração de campo escuro. O instrumento Reciproc R25 foi inserido no motor VDW e utilizado no bloco 1 até 12 mm (comprimento de trabalho) e, sem seguida, o mesmo instrumento foi utilizado no bloco 2. As imagens foram captadas pela câmara de vídeo e analisadas no tempo da quarta penetração. As franjas isocromáticas foram observadas nos terços cervical, médio e apical, em regiões mesial e distal de cada bloco. Sendo assim, divididos em: CM - cérvico-mesial, CD - cérvico-distal, MM - médio-mesial, MD - médio-distal, AM - apical-mesial e AD - apical-distal. **Resultados:** Na primeira utilização do instrumento, o maior estresse ocorreu na região médio-distal (1,38), seguido por médio-mesial (1,20), apical-distal (1,20) e apical-mesial (1,20). No segundo uso, o maior estresse ocorreu na região médio-mesial (1,20), apical-distal (1,20), apical-mesial (1,20) e médio-distal (0,90). **Conclusão:** O maior estresse ocorreu nos terços médio e apical na primeira utilização, sendo que a reutilização promoveu menos estresse.

PALAVRAS-CHAVE

Análise do estresse dentário; Endodontia; Instrumentação.

INTRODUCTION

One of the main steps of endodontic treatment is the root canal preparation. It is important to use appropriate instruments and these are constantly evolving, with rotary systems representing a new generation for improvement and simplification of the root canal treatment [1]. They can be considered a new reality in the daily activity of endodontists, as well as in the practice of general practitioners who apply this specialty.

The idea of reciprocating movement was developed by Yared [1], who used manually a #08 file in the working length and then prepared the root canal with a F2 ProTaper file in reciprocating motion. The advantage of this technique included reductions in the number of instruments, root canal contamination, cost and fatigue of the instrument.

Reciprocating files are made of special Ni-Ti alloy (M-Wire) developed via thermal-mechanical processing [2]. According to the manufacturers, they are recommended for single use, but Park et al. [3] observed that both Reciproc system and WaveOne files can be re-used for up to five times without critical changes. The instrument design coupled with the reciprocating movement promotes greater resistance to cyclic fatigue in Reciproc instruments compared to WaveOne system [4,5].

Although manufacturers recommend prior use of the reciprocating handpiece, De-Deus et al. [6] found that the Reciproc R25 instrument could be used even without handpiece. However, the prior use of manual instrumentation improved the root canal centralisation [7].

One way to assess the stress generated in the root canal walls is by photoelasticity. By means of transparent solid material, this enables visualisation and measurement of the stress magnitude when this material is submitted to stresses. Under load conditions, the photoelastic material becomes isotropic and anisotropic in unirefringent and birefringent mediums respectively. Consequently, it is possible to identify the orders of isochromatic fringes (stress magnitude) in the walls of epoxy resin block (i.e. simulated root canals) by using white light. Here, the colour scale is generated with use of circular polariscope in dark-field configuration [8].

There have been few studies using photoelasticity in endodontics, but it is an important tool to verify stress distribution. In fact, this was observed by Mayhew et al. [9], who noted the possibility of fracture in nickel-titanium rotary instruments.

The aim of this pilot study was to assess the stress distribution in the walls of a photoelastic model when subjected to Reciproc system instrumentation, as well as to evaluate the influence of the second use of the instrument on stress.

MATERIAL AND METHODS

Two epoxy resin transparent blocks were pre-fabricated with a 30-degree curved canal (IM do Brazil Ltda, São Paulo, SP, Brazil). The lumen of the canal was identified by using a K-file #10 (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland) and the working length was determined at 12 mm. One block was prepared by using a Reciproc #25 file (VDW, Munich, Germany), representing the first use, whereas the second block was prepared with the same file, that is, its second use.

The photoelastic model was positioned on a rotating platform, which was previously marked to facilitate accurate placement. The model was observed with a polariscope before force application in order to verify the absence of residual stress in the material (Figure 1).

Figure 1 - Photoelastic model: A – Positioning on a rotating platform. A video camera was positioned in front of the polariscope lens. B - The model was observed by using polariscope before application of force in order to verify absence of residual stress in the material. C - The R25 file was mounted to the motor handpiece and inserted into the simulated canal as much as possible without forcing the instrument.

Next, the R25 file was mounted to a motor handpiece (Silver Reciproc, VDW, Munich, Germany) and inserted into the simulated canal as much as possible without forcing the instrument, according to the manufacturer's recommendations. The file was moved in and out until being removed from the canal after the fifth penetration. A video camera was positioned in front of the polariscope lens and the entire sequence of preparation with R25 file during the first and second instrumentations was recorded (Figure 1). Next, the video was analysed and the image of the fourth penetration was copied. To evaluate the fringes formed, the blocks were divided into cervical, medium and apical thirds of 4 mm each, completing 12 mm of working length. The order of the fringes formed was evaluated in the cervical, middle and apical thirds at mesial and distal areas, considering the colour sequence produced in the photoelastic material (Table 1) as follows: cervical-mesial (CM), cervical-distal (CD), middle-mesial (MM), middle-distal (MD), apical-mesial (AM) and apical-distal (AD).

The analysis of the fringes followed the ASTM colour scale (2001) [8] (Table 1). The absence of stress is shown in Figure 2.

Figure 2 - Absence of stress.

Table 1 - Sequence of colours produced in a dark-field White-light polariscope. (Source: ASTM D4093-95, 2001)

Colour	Relative delay (δ) Nm	Fringe order δ/λ
Black	0	0
Grey	160	0.28
White	260	0.45
Light yellow	350	0.60
Orange	460	0.79
Intense red	520	0.90
Red-Blue transition	577	1.00
Intense blue	620	1.06
Blue-Green	700	1.20
Green-Yellow	800	1.38
Orange	940	1.62
Pinkish red	1050	1.81
Red-Green transition	1150	2.00
Green	1800	3.10
Pink	2100	3.60
Pink-Green transition	2300	4.00
Green	2400	4.13

RESULTS

The graphic analysis (Figure 3) of the distribution of stresses on the first instrumentation shows that the area of greatest tension occurred at the middle-distal region

(1.38), followed by middle-mesial (1.20), apical-distal (1.20) and apical-mesial regions (1.20). In the cervical third, stress was greater in the distal face (1.00) than in the mesial face (0.79), with difference of two fractions in the fringe order. In the second instrumentation, it was observed that the greatest stress occurred in the middle-mesial (1.20), apical-distal (1.20) and apical-mesial areas (1.20). In the middle third, the difference was greater in the mesial (1.20) than in the distal (0.90) area, with difference of four fractions in the fringe order. The distributions of stresses associated with the first and second instrumentation are shown in Figures 4A and 4B, respectively.

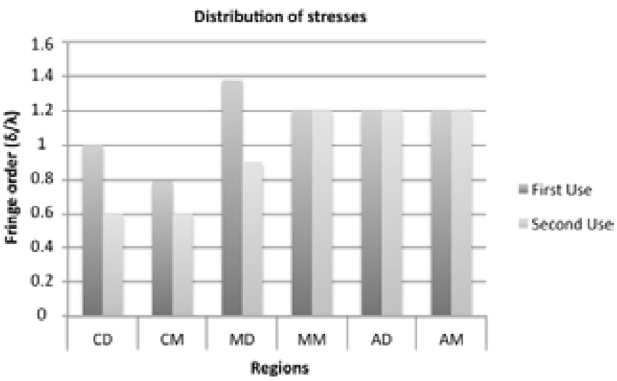

Figure 3 - Order of isochromatic fringes (stresses) resulting from preparation with Reciproc file during the first and second instrumentations in the cervical, middle and apical mesial thirds and distal regions.

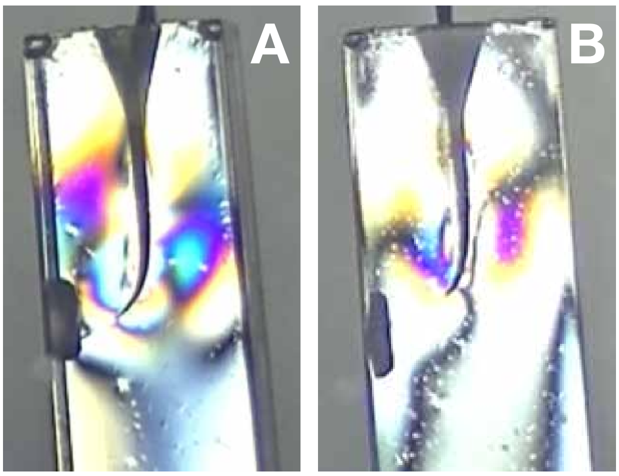

Figure 4 - The distribution of stresses associated with the first and second use of instrument are shown in Figures 4A and 4B, respectively.

DISCUSSION

Rotary instruments are currently widely used in endodontics because they have a greater taper than manual instruments, meaning that they can reduce the canal preparation time and provide better shaping. However, these systems offer at least three instruments for instrumentation, which increases the working time [10]. The longer the instrument is kept in the canal, the greater the risk of fracture. To avoid this inconvenience, new technologies have been proposed involving a single instrument. For instance, the Reciproc and WaveOne systems can be employed for root canal shaping with single instrument and without continuous movement, thus preventing the locking of the instrument and subsequent fracture [10].

In this study, we carried out an in vitro analysis of the distribution of stresses generated during root canal preparation using Reciproc R25 file under precisely controlled laboratory conditions. Simulated root canals allow standardisation of the samples as anatomical variations and texture of dentine are avoided, features which could compromise the outcome. Although the use of resin blocks simulating root canals does not reflect the results of instruments inside root canals of real teeth because the hardness and abrasion behaviours of acrylic resin and dentine may not be identical [11], resin blocks allow the evaluation of the fringes formed along the whole canal length. A major drawback of using rotary instruments in resin blocks is the heat generated, which can soften the resin material [12] and lead to binding of cutting blades and separation of the instruments [13]. Thus, because of the difference in the nature of the materials, care should be taken in the extrapolation of the present results to these instruments when real root canals and dentine are involved [14].

A model of photoelastic resin has been widely studied and accepted for evaluation of stress distribution in the fields of orthodontics, implants and prosthesis, but little research on this model has been carried out in endodontics [15,16]. It is a useful technique for evaluating the stress responsible for structure failure as magnitude and direction of the stresses are determined at any point [17]. However, no photoelastic study was found assessing the stress in root canal walls by using endodontic instruments, which did not allow any comparison to be made with our study.

When evaluating the results between first and second instrumentations, it was observed that the stresses decreased in the cervical third and middle-distal region and remained the same in the other areas.

An instrument fractured during the pilot experiment, an event not reported by Burklein et al. [18], who observed that systems using only one instrument could maintain the curvature and were secure. Mayhew et al. [9] also reported that the possibility of fracture in nickel-titanium rotary instruments is minimal, except when dentine is involved, and Arias et al. [4] found that Reciproc instruments are more resistant to cyclic fatigue than the WaveOne system. In the present study, we followed the manufacturer's recommendations contra-indicating the use of manual instrument prior to using the Reciproc System. We accept this recommendation as it would be difficult to standardise the use of manual instruments [7]. However, the absence of previous space created by manual instrument may have caused locking and the resulting fracture. It was observed in this study that it is important to create a previous access for manual tool in order to decrease the risk of fractures.

Although the purpose of this instrument is to work with the free end to prevent fractures, it was observed that the greatest stresses were generated in the middle and apical thirds, which contradicts the manufacturer's recommendations. In this regard, it could be concluded that this instrument might generate micro-fractures in the walls of the canals, as found by Burklein et al. [18]. On the other hand, this contradicts the findings by De-Deus et al. [19], who did not observe any new micro-cracks after biomechanical preparation of the root canal with reciprocating system.

According to De-Deus et al. [19], the file used in the present study (i.e. Reciproc R25) is able to reach the apical foramen in root canals with moderate curvatures in most cases. However, in this study, there was some difficulty of penetration with this instrument. Although the manufacturer recommends that the instruments should not be re-used, we chose to use the same instrument twice as Park et al. [3] had used the same file five times without deterioration of its performance. However, it was observed that the stress decreased in the cervical and middle-distal areas and was maintained in the others. Thus, it is recommended that future studies should investigate the influence of the re-use of instrument on the stress in root canal walls after the fifth instrumentation.

CONCLUSION

Based on the results of the present pilot study, it was found that the greatest stress occurred in the middle and apical thirds after first use of the file, whereas the re-use of the file resulted in partial reduction of stress.

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