Analysis of forces developed during root canal filling by different operators

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ABSTRACT

Objectives: Endodontic procedures might contribute to the development of vertical root fracture as well as other localized defects such as craze lines or incomplete cracks in root dentine. The objective of this study was to evaluate the maximum fracture resistance and the force produced by five different operators in lateral and vertical condensation during root canal filling. **Methods:** 74 human teeth, superior canines (SC) and inferior premolars (IPM) were selected. In order to determine the maximum fracture resistance during condensation, 24 teeth were submitted until failure to an axial compression load in a universal testing machine. Fifty teeth were used in order to measure the axial condensation force by means of a device developed to simulate clinical working conditions. **Results:** Fracture resistance mean values in kg were: SC = 14.96±2.65 and IPM = 7.56±1.05. Mean values of force applied by each of the five operator in Kg were, respectively: 2.49; 3.75; 2.24; 2.08 and 1.18. None of the operators achieved teeth's maximum fracture resistance during procedures. **Conclusions:** Different behaviors among five professionals monitored were observed for the same technique of root canal filling. The increase in strength during condensation had no radiographic improvement of root canal filling. During the root canal filling, lateral and especially vertical condensation, must be performed with reduced apical strength and pressure, avoiding excessive and unnecessary stress to root dentin.

Keywords: Lateral condensation technique. Root canal filling. Condensation force.

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Introduction

Endodontic procedures may contribute to the development of the vertical root fracture as well as other defects such as fissures and incomplete cracks on root dentin.[1] These located defects may have the potential to develop fractures[2] and should, therefore, be prevented. Vertical root fracture is a clinical implication that may be associated with endodontic treatment[3] and, being a longitudinal fracture, it extends throughout the entire thickness of dentine from the root canal to the periodontium.[4] The prognosis is very unfavorable, resulting in tooth extraction or resection of the affected root.[3,4]

Several factors may be responsible for increasing the root fracture risk; some may not be controlled by the dentist such as tooth structure's reduced physical properties caused by physiological and pathological processes.[5] But there are many other factors that may be controlled during and after the endodontic treatment. Amongst others, we can list: access cavity and root canal preparation, irrigation, obturation, post space preparation[1,5] and coronal restoration.[5]

In vitro studies examined the effect of various obturation techniques on endodontically treated teeth's fracture resistance.[1,2,6-11] Greater forces occur when lateral condensation obturation warm vertical compaction or thermomechanical compaction techniques are used, in comparison with the thermoplasticized condensation technique.[6,7] During lateral condensation, the use larger than # 25 spreaders caused a significant reduction on roots fracture resistance.[11] This is due to the fact that the insertion of the spreader during obturation can generate stresses within the root canal.[12] However, even when thin spreaders are used during lateral condensation, root surface craze lines occur.[2] The pressure applied during lateral condensation is no sufficient to cause vertical root fracture,[10] but it can produce a greater number of root dentin defects[12] than noncompaction canal filling was used.[1]

This way, the present study evaluated the fracture resistance and the force produced by five different operators in lateral and vertical condensation during root canal filling.

Material and Methods

Seventy-four freshly extracted single canals human teeth (superior canines and inferior premolars) were stored in 10% aqueous formol solution. Teeth were horizontally sectioned by means of a diamond disc (KG Sorensen, Barueri, SP, Brazil) under water cooling, near their cement-enamel junction. Then, the measured roots were stored individually and their moisture was maintained using a piece of gauze soaked in physiological solution.

Roots were embedded into Adesivo B Flexible Epoxi Resin (Polipox, Interlagos, São Paulo, Brazil), parallel to the walls of 25 mm- height PVC cylinders with an external diameter of 25 mm and an internal diameter of 21 mm. Silicone was used to facilitate the positioning and fixation of the roots inside the cylinder.

Passed 48 hours from the teeth´s inclusion, which corresponded to the period of resin's final polymerization, the samples were randomly divided. Fifty samples were used to measure the axial force applied during lateral and vertical condensation. Five endodontists participated in this study. The professionals were named as A, B, C, D and E. Each professional received 10 samples, being the 2 first used to calibrate the equipment during the monitoring of the lateral and vertical condensation procedures according to each professional. The remaining 8 samples were obturated by the lateral and vertical condensation obturation. Aiming to reproduce dentists working conditions in their offices, a device was specially developed for this study: a 60 cm metallic stem was adapted to the universal testing machine (EMIC DL-2000, São José dos Pinhais, PR, Brazil) with a 20 kg load-cell in a way that the samples' position was similar to that in the oral cavity (Fig 1A). Besides that, over this bar, a metallic support was used so that the professionals could rest their hands on it during the clinical procedures (Fig 1B). During the procedures, the generated forces were recorded by the testing machine M Test software and turned into graphs in order to analyze the applied forces in Kg afterwards.

Root canal instrumentation was carried out with the concern of standardizing its dilatation, following the technique described by Goerig, Michelich and Schultz.[13] After canals drying, the main gutta-percha cone was selected, in way that it presented a locking 1 mm short the radicular apex, matching the work length. A sealer based on zinc oxide and eugenol (Endofill, Dentsply, Petrópolis, Brazil) was inserted into the canal using the main cone and it was applied to the whole canal wall. After the positioning of the main cone, spaces were generated by means of a finger spreader (Maillefer, Ballaigues, Switzerland) compatible to the accessory cones used. During lateral condensation, all the accessory cones were embedded in sealer and inserted in each space, followed by a new condensation successively, until obturation was completed. Excess filling material was removed by Paiva´s pluggers (Golgran, São Paulo, Brazil) heated and held vertical condensation.

During the lateral and vertical condensation experimental tests, the efforts made by the five operators were captured by the load-cell, transferred and saved (Fig 1B). From each condensation procedure, a graph was obtained demonstrating the value and the behavior of the load applied by the professional, as well as the maximum load. All the tests were carried-out at a crosshead speed of 2 mm/min, with a working time of approximately 4 minutes. Data was analyzed allowing the working profile of each operator to be established.

Ten obturated teeth were radiographically evaluated (Agfa Dentus M2 Comfort Dental Film - Speed Group D - Agfa Gevaert N. V., Belgium). For the radiographic examination, all teeth were removed from their PVC cylinders and epoxy resin. Radiographs were taken from each tooth in the buccolingual and mesiodistal positions by means of an X-Ray machine calibrated with an exposure time of 0.3 sec and a focal distance of 8 cm from the roots.

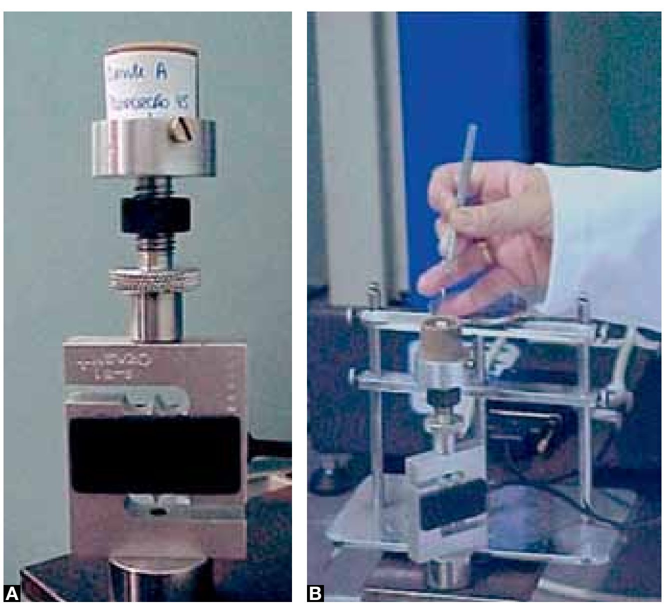

Figure 1. Sample couple with the cylindrical device attached to the load-cell of the universal testing machine (**A**) and monitoring of the long-axis loading force applied during obturation (**B**).

The 24 remaining samples were used to measure the maximum fracture resistance of the roots during lateral condensation. Samples were submitted to a fracture resistance test using a finger spreader compatible to the canal's diameter as a load applying device coupled to the universal testing machine (EMIC DL-2000) at a crosshead speed of 2 mm/min until failure. Data was analyzed and displayed in graphs.

Results

During the mechanical tests, the applied forces were monitored as the lateral and vertical condensation was performed, generating graphs that represent the behavior and magnitude of the maximum force applied during tests. The mean fracture resistance values were: Superior canines = 14.96±2.65 and inferior premolars = 7.56±1.05 Kg. Mean values of the loading forces applied by each operator were, respectively: 2.49 Kg; 3.75 Kg; 2.24 Kg; 2.08 Kg and 1.18 Kg (Table 1).

The difference between the five operators graphs could be verified, demonstrating the individual characteristics of each professional (Fig 2).

The radiographic image of the obturations performed by the all five professionals showed a satisfactory quality, as a compact obturing mass, without voids could be seen inside the root canals in all samples.

Discussion

The comparative evaluation of the axial loading force applied during lateral and vertical condensation of this research aimed to know the magnitude of the force and the load applying behavior of five endodontists, which used the same obturation technique. Using standard mechanical tests, similar to clinical conditions and with samples coupled to the load cell, it was possible in this study and former others to register the behavior of each professional, as in previous studies.[6,7,8]

The use of an electronic monitoring device fitted with the mechanical testing machine, such as that developed in this study, in which the forces generated during the filling steps are recorded in real time and transformed into graphs is of great value for teaching and enhancement of endodontics. For this device was able to verify the pressure at the time of root canal filling, during insertion of the finger spreader in the lateral condensation and the plugger in the vertical condensation. Graduate and undergraduate students learn with their use,

Table 1. Maximum loading forces applied by the professionals during root canal filling (kg) and their mean values (kg).

Professional	Maximum loading force								Mean Values
A	2.31	2.62	2.43	2.64	2.91	2.95	2.22	1.83	2.49
B	4.09	4.20	3.98	4.10	3.95	4.10	2.75	2.85	3.75
C	2.44	1.84	2.36	1.91	2.22	2.22	2.25	2.69	2.24
D	1.60	1.68	1.85	2.88	2.19	1.95	2.36	2.17	2.08
E	1.28	1.34	1.10	1.12	1.10	1.07	1.26	1.20	1.18

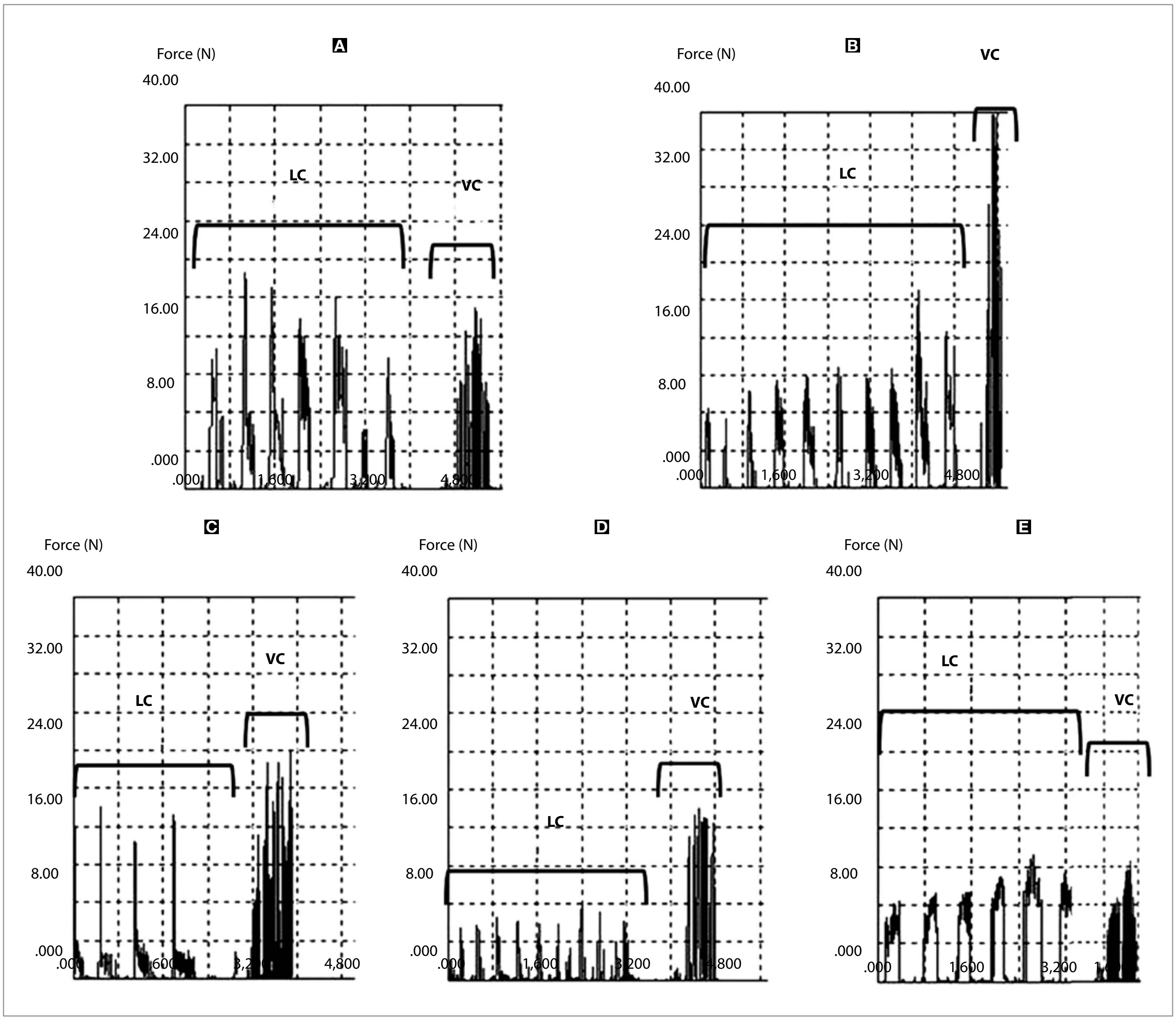

Figure 2. Registering of the behavior and the maximum load force applied by the professionals during lateral (**LC**) and vertical condensation (**VC**).

adequate force of condensation in different techniques of root canal filling, without generating excessive and unnecessary stress to root dentin.

The results of this study demonstrated that there was a variation in the load forces in magnitude as well as in constancy applied by each of the five endodontists. The loads averaged professionals A, C, D and E, are consistent with the loads found in previous studies.[6,7,8]

The behaviors registered from professionals A and E, as shown in graphs were similar. A practically constant load force was maintained from the beginning of obturation, from the insertion of the first cones to its end, with vertical condensation of gutta-percha and their graphs presented a constant curve from the beginning to the end of the procedures. The professionals differed from each other regarding the magnitude of the force applied during the whole procedure. The mean value of the loading forces applied by professional A (2.49 Kg) was different from professional E (1.18 Kg). Regarding the usage of finger spreaders, it could be verified that both professionals applied an apically directed pressure, inserting the spreader from 1 to 2 mm short the working length during lateral condensation.

Professionals B and C also demonstrated similar behavior regarding the distribution of the applied effort and not the magnitude of the loading force. Graphs show an upward curve, revealing that this professionals started obturation using a small amount of force which was increasing until the canals were completely filled. In relation to the magnitude of the applied load, a great difference could be verified amongst theses operators. The mean value of loading forces exercised by professional B was 3.75 Kg and by professional C 2.24 Kg, both distributed in an increasing way.

The graph generated from professional's D behavior during lateral condensation was similar to professionals' A and E graphs, as a constant load was applied in this stage of the procedure. In the moment of vertical condensation, an increase of applied effort was verified, which was demonstrated by a peak in the curve, comparing to the force that had been previously exercised. This way, operator D ranged from a constant low force to a higher one during vertical condensation. This increase of loading force during vertical condensation could be also observed during the tests of operator B, but varying its mean values: 2.88 Kg for professional D and 4.20 Kg for professional B.

Investigating the maximum load force applied by finger spreaders and capable of inducing root fracture, Holcomb, Pitts and Nicholls[9] observed the presence of vertical fracture in teeth tested with a loading force ranging from 1.5 to 3.5 kg. These values are close to the ones registered from the test of operator B. However, the groups of teeth tested this previous study[9] had smaller dimensions when compared to the teeth used this research, which could explain the fracturing of roots submitted to smaller forces.

None of the five endodontists has reached the maximum fracture resistance load fracture because the pressure applied during the lateral and vertical condensation was insufficient. However, studies show that this technique of obturation may cause major defects in the root dentin[12] than noncompaction canal filling was used.[1] The most common defects are the fissure lines and cracks in the root dentin that can result after conclusion of endodontic treatment in vertical root fracture,[6,7,11] because the simply by forces applied to the root during mastication[1] and additional treatments such as post-space preparation.[2]

Each of the five endodontists examined demonstrated a different working profile when performing the same obturation technique and taking in account that the radiographic images revealed a satisfactory and homogenous obturation mass in all specimens. Facing these results, it is recommended that during the process of lateral condensation, professionals apply a constant loading and reduced pressure in the apical direction, always respecting the limit of work and the space provided by the finger spreader. In the vertical condensation, in which we found three endodontists (B, C and D) within the highest values of force applied during the root canal filling, it is recommended using the plugger with a reduced loading in the apical direction. This is because increase of loading did not generate radiographic improvement in the final result of the filling, and can generated, especially in weakened or less dentinal structure roots, the appearance of defects such as fissure lines and/or incomplete cracks.[1] Following these recommendations, the professional will obtain a proper root canal filling, generating little stress on dentin structures. What is an important factor, as the vertical root fracture do not occur instantly, but are, indeed a result of a gradual diminishment of root structure coupled with the use of force and pressure to root dentin.[1]

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