The use of microcomputed tomography in the evaluation of accumulation and removal of the hard-tissue debris from root canal system with isthmuses

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Aims
During biomechanical preparation of the root canal system, the cutting action of instruments on dentine result in the formation of hard-tissue debris, which can be packed in some areas of the root canal system, mainly in anatomical variations as isthmus, branches and flattening (1, 2). Accumulated hard-tissue debris in the root canal system may compromise thorough disinfection and filling favoring the reinfection and failure of root canal treatment (3, 4). In this regard, irrigation procedures are fundamental in cleaning up the root canal, removing debris from within the root canal space, during and after the root canal preparation. Traditionally, the debridement and cleaning of the root canals has been evaluated by means of histology, scanning electron microscopy and sectioning methods (5-7). However, they are destructive methodologies which during its processing, promotes the specimens decalcification with inorganic tissue removal, as well as section procedures that may result in the deposition of smear or changes in the location of debris (8). Microcomputed tomography (micro-CT) is a non-destructive method that allows sequential analysis of endodontic treatment steps. Recent studies has also been quantified the hard-tissue debris accumulated after different biomechanical preparation protocols using micro-CT (9, 10, 11, 12, 13, 14). Even though there is accumulating evidence on the efficacy of several irrigating methods using conventional methodologies, a comprehensive knowledge regarding the activation of irrigants in different final irrigation protocols, aiming to remove hard-tissue debris from the isthmus area by means of micro-CT technology is still lacking. Thus, the aim of this study was to evaluate, quantitatively and qualitatively, the accumulation and removal of the hard-tissue debris from root canal system with isthmuses of mesial roots of mandibular molars subjected to different final irrigation, using microcomputed tomography analysis.

Method
Twenty mesial roots of mandibular molars with moderate curvature and two mesial canals with a single and continuous isthmus detected by micro-CT scanning were selected. The canals were prepared by reciprocating instrumentation technique (WaveOne Small and Primary). Then, the composition of the experimental groups was performed by a stratified sampling method, resulting in two groups (n=10), according to the final irrigation protocol: apical positive pressure (conventional irrigation) or passive ultrasonic irrigation. The protocols were performed with 5.5 mL of 2.5% NaOCl per canal during 2 minutes. The specimens were scanned preoperative and following preparation, and final irrigation by using a micro-CT device (SkyScan1176; Bruker-microCT, Kontich, Belgium). The scanner parameters were set at 90 kV, 278 μA, isotropic resolution of 8.6 μm, 180° rotation and rotation step of 0.4°, using a 0.1 mm-thick copper filter. The acquired projection images were reconstructed and co-registered by pairs (preoperative and after preparation/ preoperative and after irrigation) using DataViewer v.1.5.1.2 software. Then, the accumulated hard-tissue debris analysis after
preparation and after irrigation was performed with CTAn v.1.14.4.1+ software using a Custom Processing tool following the schematic representation in Figure 1. The presence of a material with density similar to dentine in regions previously occupied by air in the prepared non-prepared root canal space was considered debris and quantified. The total volume of accumulated hard-tissue debris was calculated in cubic millimeter (mm³) and expressed as the percentage of the total canal system volume after preparation (vol%). The percent volume and percent reduction of accumulated hard-tissue debris after final irrigation were statistically compared among groups using test-T with a 5% significance level.

Figure 1. Schematic representation of the morphologic operations through Custom Processing tool to accumulated hard-tissue debris analysis. Obtaining in (A) the binary image of the preoperative root canal and in (B) the binary image of the root canal after preparation. (C) ROI definition by the binary image of the preoperative root canal added the binary image of the root canal after preparation by applying the plug-in Arithmetical Operations. (D) ROI used in difference image (between preoperative/after preparation and preoperative/after irrigation) which obtained from the co-registration and accumulated hard-tissue debris binarization.

Results
It was observed a reduction in the percentage of accumulated hard-tissue debris after final irrigation in all groups. The Passive Ultrasonic Irrigation group showed lower mean of volume and percent volume (%vol) of accumulated hard-tissue debris (0.05±0.06mm³ and 0.61±0.75%, respectively) when compared with apical positive pressure group (0.36±0.13mm³ and 3.73±1.59%, respectively) (p<0.05). Furthermore, the percent reduction of accumulated hard-tissue debris was greater in passive ultrasonic irrigation group (94.05±7.21%) compared with apical positive pressure group (45.74±15.76%) (p<0.05) (Table 1).
Table 1. Accumulated hard-tissue debris (mean ± standard deviation) of the mesial root canal systems of mandibular molars.

<table>
<thead>
<tr>
<th></th>
<th>Apical Positive Pressure</th>
<th>Passive Ultrasonic Irrigation</th>
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<tbody>
<tr>
<td></td>
<td>n=10</td>
<td>n=10</td>
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<tr>
<td>Mean ± SD</td>
<td>Range</td>
<td>Mean ± SD</td>
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<tr>
<td>Volume (mm³)</td>
<td></td>
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<tr>
<td>After preparation</td>
<td>0.67±0.26</td>
<td>0.31-1.11</td>
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<tr>
<td>After irrigation</td>
<td><strong>0.36±0.13</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td><strong>0.08-0.53</strong></td>
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<tr>
<td>Volume (%)</td>
<td></td>
<td></td>
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<tr>
<td>After preparation</td>
<td>7.00±3.01</td>
<td>2.68-10.67</td>
</tr>
<tr>
<td>After irrigation</td>
<td><strong>3.73±1.59</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.69-5.77</td>
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<tr>
<td>Reduction (%)</td>
<td></td>
<td></td>
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<tr>
<td>After irrigation</td>
<td><strong>45.74±15.76</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.44-74.19</td>
</tr>
</tbody>
</table>

Different superscript bold letters in the same line mean statistical significant difference between groups (test T; p < .05).

Qualitatively, the remaining accumulated hard-tissue debris were mainly located in the apical third after passive ultrasonic irrigation protocol; and in the middle and apical thirds after apical positive pressure protocol (Figure 2).

![Figure 2](image)

Figure 2. Distal views of representative 3D reconstructions of the mesial root canal systems of mandibular molars before (in green) and after (in red) preparation with reciprocating instruments and after final irrigation with apical positive pressure and passive ultrasonic irrigation protocols. Accumulated hard-tissue debris (AHTD) are depicted in black. c: coronal third; m: middle third; a: apical third.

Conclusion

It may be concluded that the microcomputed tomography method is suitable to quantitative and qualitative evaluation of accumulation and removal of the hard-tissue debris. Furthermore, the passive ultrasonic irrigation protocol showed greater accumulated hard-tissue debris reduction from root canal system with isthmuses of mesial roots of mandibular molars compared to conventional irrigation with apical positive pressure protocol.

References:

1. BARATTO-FILHO, F.; DE CARVALHO, J. R., JR.; FARINIUK, L. F.; SOUSA-NETO, M. D.; PECORA, J. D.; DA CRUZ-FILHO, A. M. Morphometric analysis of the effectiveness of different concentrations of sodium hypochlorite associated with


