Assessing the Accumulated Hard-Tissue Debris by \( \mu \)CT

J.R. S. Marins¹, H. Alves², G. D. Deus³, C. Reis⁴, S. Parcionik⁵, R. T. Lopes²

¹State University of Rio de Janeiro, Brazil
²Federal University of Rio de Janeiro, Brazil
³Federal Fluminense University, Brazil
⁴Federal University of Espirito Santo, Brazil
⁵Pontifical Catholic University of Rio de Janeiro, Brazil

Aims

The aim of present work is to present and explore the powerful potential of the use of free software to longitudinally and quantitatively debris accumulation. This means that an image processing and analysis routine was developed using only free software in order to identify, measure and three-dimensionally map the accumulation of hard-tissue debris inside the root canal space. A step-by-step description of the method as well as its advantages over proprietary image analysis software packages and also its limitations were carefully addressed.

Materials and methods

Criterion of tooth selection

This study was revised and approved by the Ethics Committee, Nucleus of Collective Health Studies, Rio de Janeiro State University, Rio de Janeiro, Brazil. One hundred twenty human mandibular first and second molars with completely separated roots were obtained from the department’s collection of extracted teeth.

In order to attain an overall outline of root canal anatomy, these teeth were pre-scanned using a high-resolution micro-computed tomography scanner (1173 Skyscan, Aartselaar, Belgium) with an isotropic resolution of \( \sim 30 \) \( \mu \)m at 70 kV and 114 \( \mu \)A. Based on the 3D models of these pre-scans set of images, 37 mandibular molars with joining mesial root canals and an with large isthmus width between the mesiobuccal and mesiolingual canals (Frank Paqué) were selected by fulfilling the aforementioned criterion. Three teeth were selected for the present study and others were kept for further use. The distal roots were sectioned at the level of furcation and discarded in order to reduce the total volume of the tooth to be scanned; in this way, the total time required to complete the scanning process was reduced significantly.

\( \mu \)CT scans

Two high-resolution scans were accomplished per each tooth; the first, prior to treatment and, the second one, after the endodontic procedure. Teeth were scanned using a high-resolution micro-computed tomography scanner (1173 Skyscan, Aartselaar, Belgium) with an isotropic resolution of \( \sim 30 \) \( \mu \)m at 70 kV and 114 \( \mu \)A. It was used a rotation step of 0.5°, frame averaging of 5 and X-rays were filtered with 1 mm aluminum filter. Several two-dimensional projections through 360° rotation were saved in a TIFF format. The stored images were reconstructed using N-Recon software with a beam hardening of 40% and ring artifact correction of 10, resulting in the acquisition of 700-800 cross-sectioned images per tooth in a BMP format. After preparation, all specimens were re-scanned using the same parameters for scanning and reconstruction. The volume of interest was selected extending from the furcation region to the apices of the roots.

Quantitative Image Analysis
By the use of software Seg3D (version 2.1, Utah, USA), an interactive threshold (function that performs segmentation of grey values) was applied in order to separate discriminate dentine, debris and the empty root canal space (fig.1). After that, colored masks were created. This process is called as segmentation and it is designed to recognize regions of a given image dividing it into its specific component parts of interest. The final result is a binary image (where the black pixels represent the background and the regions of white pixels are considered as objects of interest).

The masks of the roots before and after instrumentation were co-registered by an automatic process of superimposition based on the outer root contour using 1,000 interactions between two full images stacks (Seg3D).

After superimposition of the pre- and pos-preparation images, masks created in the Seg3D software were imported to Fiji software to be normalized. Therefore, binary images were imported to CTanalyser software and the region of interest of images was restricted to the outer contour of the root using the system tool named ROI shrink-wrap. The canal space was segmented as result of an automatic bitwise operation of exception between the region of interest and the empty root canal space. The outer borders that influenced measurements and 3D model creation were removed by an erosion morphological operation.

Once the reconstruction, register and segmentation processes ends, it was possible to perform the measurements of the accumulated hard tissue debris inside the root canals space. Debris quantification was calculated by the difference between the root canal space observed in the non-prepared and prepared teeth using the post-processing procedures in Fiji software. Regions occupied by air in the non-prepared teeth - identified as radiopaque material in the post-operatory images - were considered debris and could be quantified by the morphological operation of intersection of images of prepared teeth with and without dentine inside.

**Results**
The volume of matched canal space before and after preparation and the total volume of accumulated hard tissue debris were calculated by CTAnalyser software in cubic millimeter in absolute values.

For 3D models visualization, CTVol software, provided by Skyscan webpage, was used (fig. 2). It's possible to identify the accumulated hard tissue in the mesial root canal system after preparation either with sodium hypochlorite solutions and distilled water.
As results we could notice that canal submitted to irrigation with sodium hypochlorite accumulated significantly less debris than the one irrigated with distilled water (table 1).
Table 1: Results of Debris analysis

<table>
<thead>
<tr>
<th>Teeth</th>
<th>Non-prepared canal (pixel^3)</th>
<th>Prepared canal (pixel^3)</th>
<th>Volume Debris (pixel^3)</th>
<th>%Volume Debris</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>1737742,479</td>
<td>3038469,813</td>
<td>656717,075</td>
<td>57,19</td>
</tr>
<tr>
<td>38</td>
<td>583893,929</td>
<td>1670572,833</td>
<td>329592,9708</td>
<td>34,95</td>
</tr>
</tbody>
</table>

Conclusions
Accumulated hard tissue debris are directly related to the irrigation method and to the canal anatomy. Isthmuses are filled by hard tissue debris more easily once the instruments don’t achieve it physically and the complex anatomy turns the penetration of the irrigation solution desfavorable. Although Sodium hypochlorite solution is the largest used substance in clinical practices of endodontics, it is not able to dissolve all the inorganic tissue formed during the root canal preparation.

References


