Visualizing synthetic dental biofilm on teeth using dual energy micro-CT

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Objectives

Ultrasonic scalers are used to remove plaque and calculus from teeth to reduce the risk of dental disease (Figure 1).

Figure 1 http://tinyurl.com/lqyylnv

Imaging plaque and calculus on the whole tooth would indicate areas where it is most resistant to removal, and a 3D overview could show us how effective ultrasonic scaling instruments are, and help to improve their efficiency. This study uses micro-CT for the first time to image an artificial biofilm made from a hydrogel on a tooth in 3D.

Methods

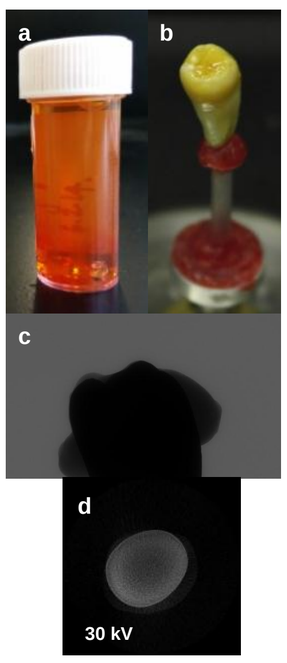


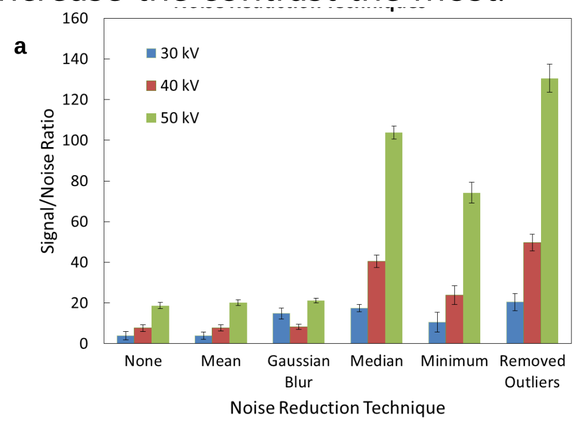
Figure 2: Stained hydrogel (a) applied to pre-molar for microCT imaging (b). (c) Micro-CT projection image and reconstruction slice (d)

Macedo et al. (2014) [1] have formulated a hydrogel for mimicking biofilm in the root canal. An identical gel was made, but by substituting 10 ml of water for 10 ml of Lugol's stain (iodine and potassium iodide) to enhance contrast.

A SkyScan 1172 micro-CT scanner (SkyScan, Kontich, Belgium) was used. A range of dual energy scans were performed and combined so both hydrogel and the mineralised bone tissue could be seen and segmented.

Noise Reduction

A range of filters were applied in Fiji to the reconstruction slices to reduce noise. Images taken at 50 kV had the most contrast, and the median, minimum and 'removed outliers' filters seem to increase the contrast the most.



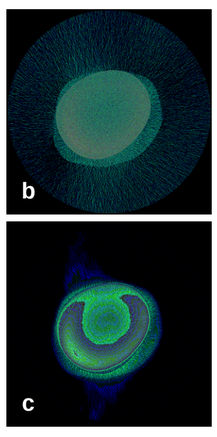
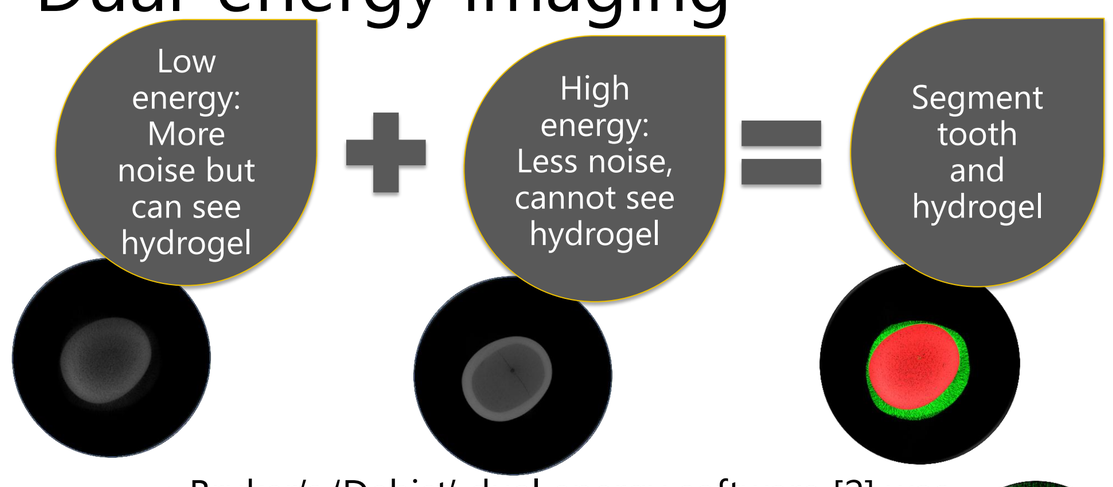
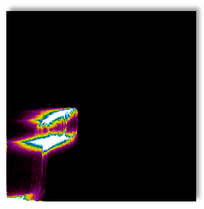


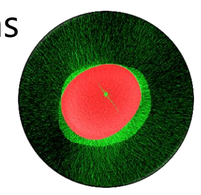
Figure 3: (a) Graph of signal/noise ratio after noise reduction for samples scanned at 30, 40 and 50 kV. (b) 30 kV reconstruction slice without noise reduction (c) same slice after applying 'removed outliers' filter.

Dual-energy imaging





Bruker's 'Dehist' dual energy software [2] was used to segment hydrogel (green) from the tooth (red). The process was aided by inspection of the dual histogram (L). Using Dehist without noise reduction includes noise in the segmentation (R).



3D Micro-CT reconstruction of hydrogel on tooth

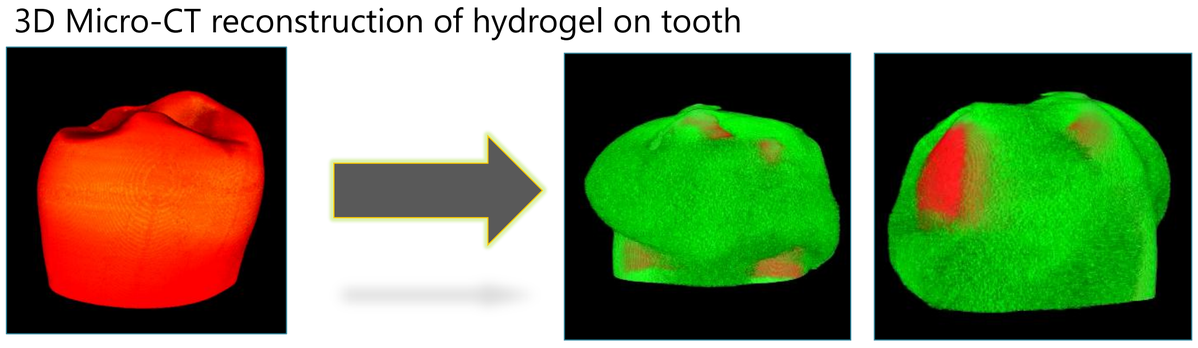
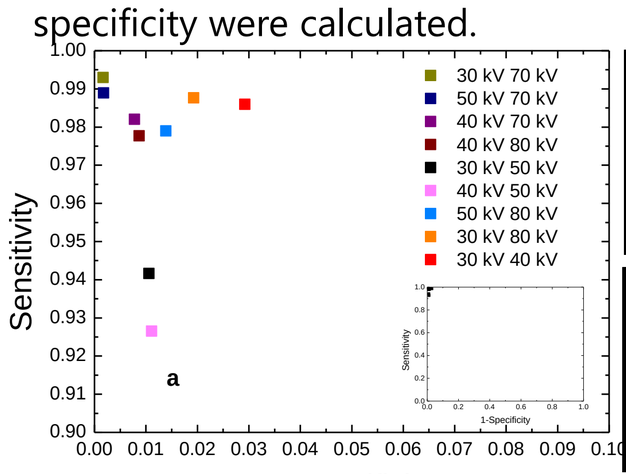


Figure 4: L: tooth without hydrogel; R: tooth with hydrogel (green) segmented using Dehist

Dual energy segmentation

Dual energy segmentations were evaluated for their accuracy. Images were taken before hydrogel application & subtracted from images taken after application to leave only hydrogel. These were used as references to compare with Dehist segmentations. Sensitivity & specificity were calculated.



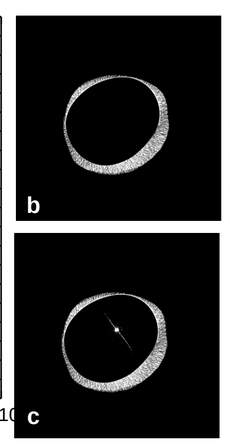


Figure 5: (a) Reciever operator characteristics curve for different dual energy combinations in Dehist. Inset shows unscaled graph. Values were calculated by comparing 'true' hydrogel segmentation (b) with Dehist's segmentation (c).

Conclusions

We have developed methods for 3D imaging of artificial biofilm on teeth using micro-CT by implementing image processing techniques to remove noise in low energy images, which enables segmentation of the artificial biofilm from the tooth using dual energy imaging.

This work opens possibilities for imaging natural biofilm grown on teeth using micro-CT. We will look at improving the segmentation tools and imaging a mineralised hydrogel to mimic dental calculus more effectively, with the eventual aim of imaging disrupted biofilm on teeth.

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References: [1] Macedo, R. G., Robinson, J. P., Verhaagen, B., Walmsley, A. D., Versluis, M., Cooper, P. R., & Sluis, L. W. M. (2014). A novel methodology providing insights into removal of biofilm mimicking hydrogel from lateral morphological features of the root canal during irrigation procedures. *International endodontic journal.*
[2] Dehist software downloaded from *http://www.skyscan.be/products/downloads.htm*

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