Applications of Image Processing Techniques to Optical Coherence Tomography Images of Bonded Veneers

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INTRODUCTION

The optical coherence tomography (OCT) is a non-ionizing, non-destructive, and non-invasive imaging method. It is an indispensable tool in ophthalmology and other fields of medicine. In dentistry, the OCT is an emerging tool as numerous studies have successfully demonstrated the potential of the OCT for dental applications. OCT imaging can be used to image the adhesive surface between tooth structure and bonded veneers. However, OCT images inherently contain noise which degrades the quality of the image and creates limitations in the diagnostic capabilities of the OCT.

AIM

The aim of this study is to implement image processing techniques for OCT images that enable better evaluation of the adhesive interface between tooth structure and bonded veneers.

MATERIALS & METHODS

OCT scans of teeth with bonded veneers were made (Figure 1.0). The images were obtained from an OCT system working in Time Domain mode at 1300 nm (Figure 1.1). 3D reconstructions of the OCT scans were made and selected (Figures 1.2a and 1.2b) to undergo further image processing. The images were subjected to image processing techniques commonly used in medical imaging using Matlab R2021a software. The techniques applied were contrast enhancement, image sharpening, and image segmentation through k-means clustering algorithm.

Fig. 1.0 Samples used in study. Sectioned teeth with bonded veneers

Fig. 1.1 Time Domain OCT system used in this study (Victor Babes University of Medicine and Pharmacy, Timisoara, Romania)

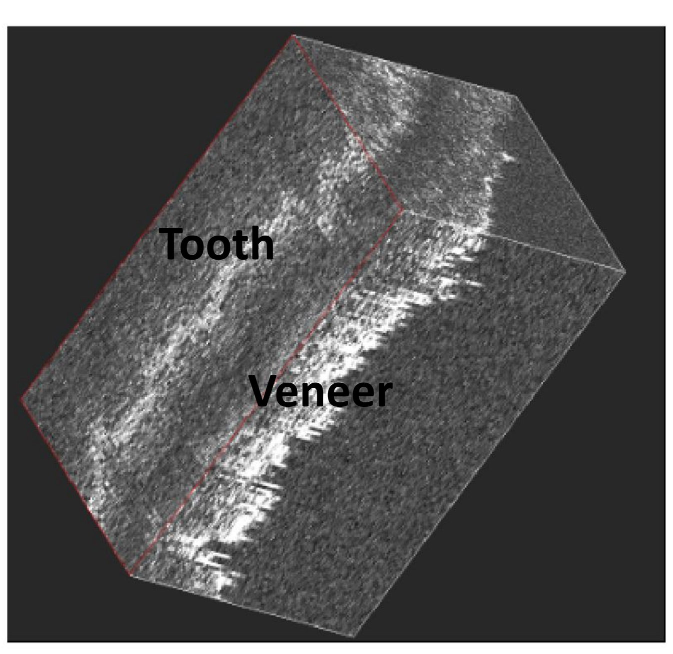

Fig. 1.2a. Original Image 1. OCT 3D reconstruction before image processing showing the adhesive tooth-veneer interface.

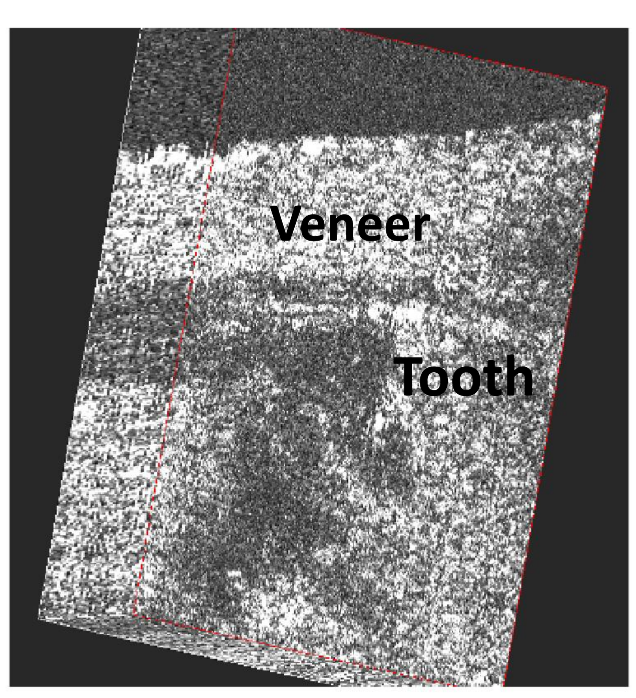

Fig. 1.2b. Original Image 2. OCT 3D reconstruction before image processing showing the adhesive tooth-veneer interface.

CONTRAST ENHANCEMENT

Contrast is given by the difference between the maximum and minimum values. To improve the image quality, the images have been enhanced using three different contrast adjustment techniques: imadjust (Figs 2b & 3.b), histeq (Figs. 2c & 3c), adapthisteq (Figs. 2d & 3d).

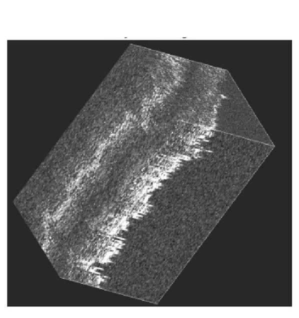

Fig. 2a original image 1

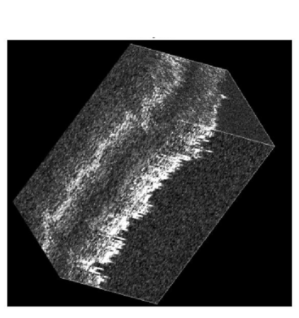

Fig. 2b imadjust of image 1

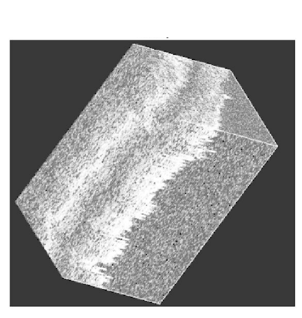

Fig. 2c histeq of image 1

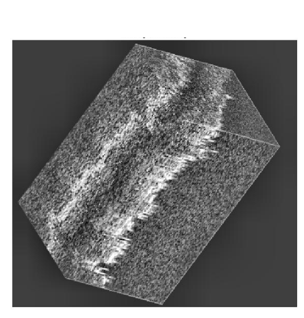

Fig. 2d adapthisteq of image 1

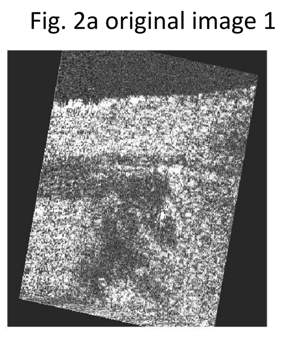

Fig. 3a original image 2

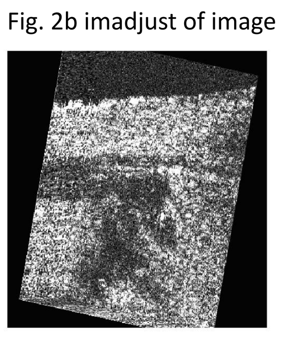

Fig. 3b imadjust of image 2

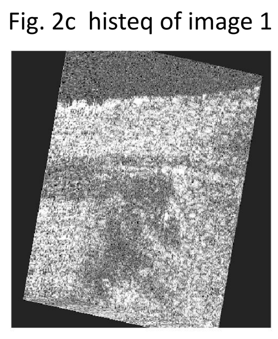

Fig. 3c histeq of image 2

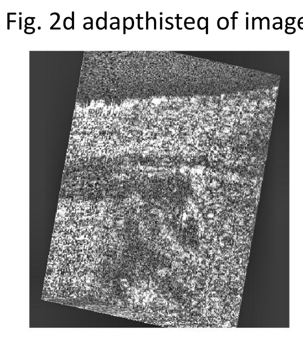

Fig. 3d adapthisteq of image 2

From the above images it can be noticed that the images with the best contrast are ones subjected to “imadjust” (Figures 2b and 3b). These images will be used for further processing.

IMAGE SHARPENING

Sharpening the image will increase the contrast along the edges were different shades of gray in the image meet. As seen in Figures 4.1 and 4.2, the technique used below sharpens the image by subtracting a blurred (unsharp) version of the image from itself (imsharpen).

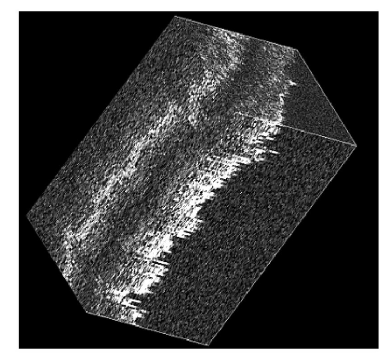

Fig. 4.1 imsharpen of image 1

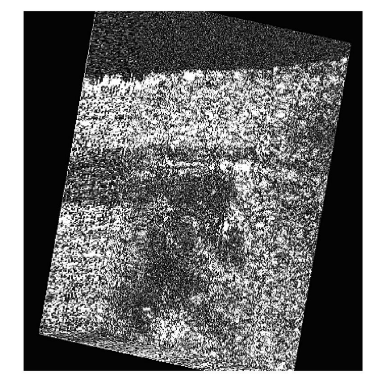

Fig. 4.2 imsharpen of image 2

HISTOGRAM-BASED COLOR THRESHOLDING

In order to make the image more crisp, colour thresholding is implemented (Figures 5b and 6b). Since the images are mostly grayscale, the Hue histogram does not show any significant information. For colour thresholding (in this case, 'shade' thresholding), the value histogram will be used (Figures 5a and 6a). The min and max values for shade thresholds are based on information provided by the value histogram.

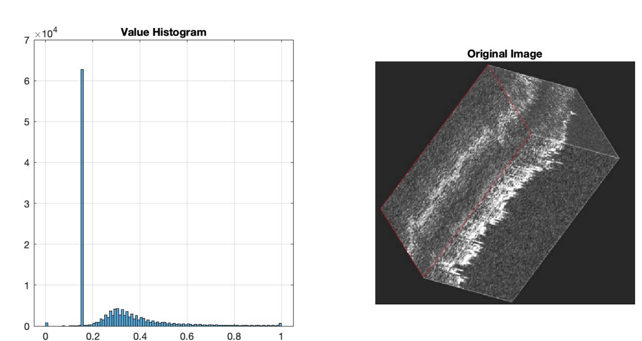

Fig. 5a. Value histogram for Original Image 1

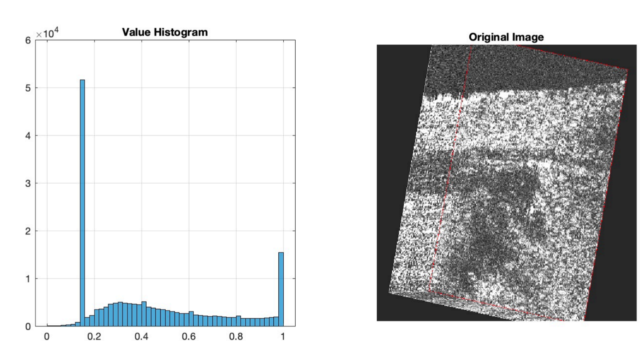

Fig. 6a. Value histogram for Original Image 2

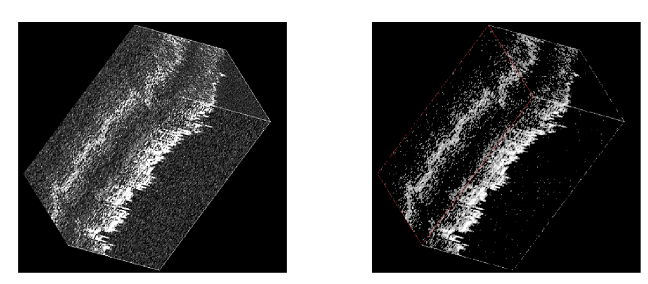

Fig. 5b Color thresholding applied to Image 1. Before and after.

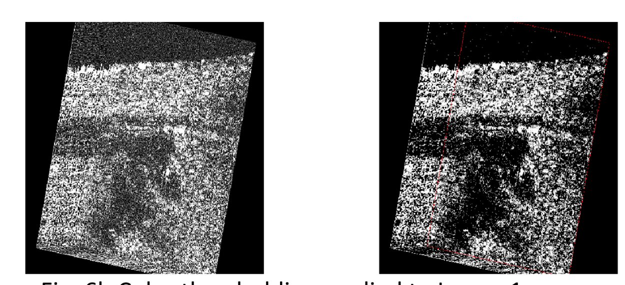

Fig. 6b Color thresholding applied to Image 1. Before and after.

IMAGE SEGMENTATION

Going forward, the images obtained through colour thresholding are subjected to segmentation. In this case K-means clustering is employed (Figures 7a and 8a). Next, the edges are refined by freehand region of interest selection feature. This is done by converting the mask resulted from segmentation into an interactive freehand ROI object (Figures 7b and 8b).

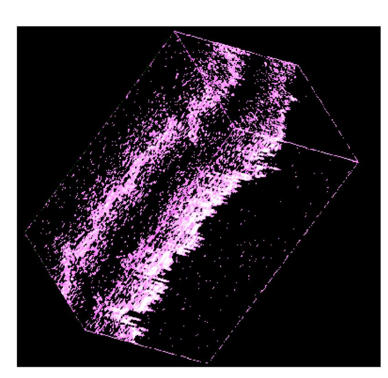

Fig. 7a K-means Clustering Applied to Image 1

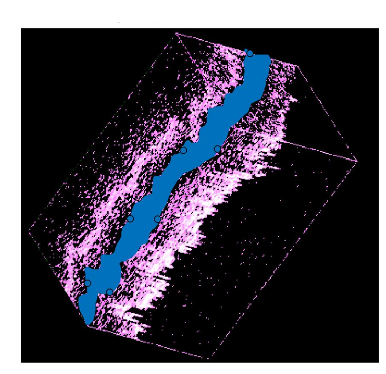

Fig. 7b Freehand ROI Selection Applied to Image 2

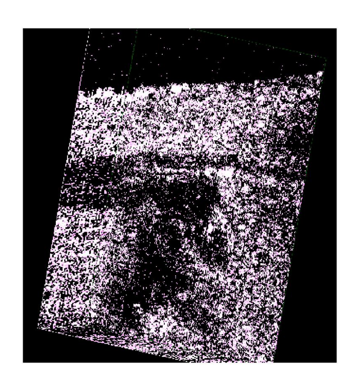

Fig. 8a K-means Clustering Applied to Image 2

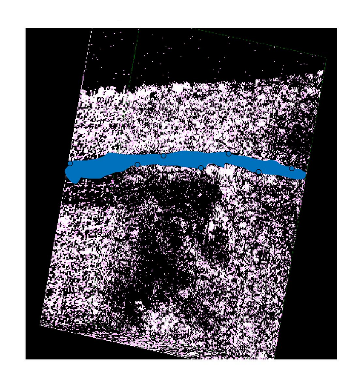

Fig. 8b Freehand ROI Selection Applied to Image 2

RESULTS

OCT image processing through contrast enhancement, image sharpening, and segmentation is a challenging process, but yields useful results. No single process can be uniformly applied to all OCT images. However, common steps can be taken to enhance the original image to aid in the evaluation of the tooth-veneer adhesive interface. Image processing of OCT images is useful in reducing noise, improving the quality, and allowing for better evaluation and image analysis.

How can image processing of OCT images be useful in future work?

- Better mechanism for observation of the tooth-veneer interface and possible defects
- It can be used for training purposes as the clear separation of objects is difficult in some cases
- Future studies can be aimed at determining the area and volume of the interface in relation to different curing methods
- Future work can aimed to measure the area/volume of the interface and quantifying defects

CONCLUSION

OCT has great potential for dental applications. The image processing techniques depicted in this study are helpful in providing more information that may not be visible with the unaided human eye and help in the evaluation of the tooth-veneer adhesive interface.

References:

Shimada Y, Sadr A, Sumi Y, Tagami J. Application of Optical Coherence Tomography (OCT) for Diagnosis of Caries, Cracks, and Defects of Restorations. Curr Oral Health Rep. 2015;2(2):73-80. doi: 10.1007/s40496-015-0045-z. PMID: 26317064; PMCID: PMC4544493.

Presented at the 97th Annual Session of the Greater New York Dental Meeting in 2021