MEASUREMENT OF BONE LOSS BY THREE-DIMENSIONAL IMAGE PROCESSING FOR ASSESSMENT OF PERIODONTITIS

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ABSTRACT

In this paper, we describe a CAD system for quantifying and visualizing alveolar bone loss caused by periodontitis, based on three-dimensional (3-D) image processing of dental CT images. The system enables quantification of bone loss by measuring its amount both inside and outside of the tooth of interest, and visualization of the 3-D shape and quantification result of the lesions. Experimental results in two cases of 3-D dental CT images and comparisons of the results confirmed that the system gives satisfying results, including less than 0.4 mm of bone loss depth measurement (Virtual Probing) error and fairly intuitive presentation of the measurement results.

1. INTRODUCTION

We have been working on developing a set of automated methods for measuring alveolar bone loss caused by periodontitis. Estimation of bone loss regions and its measurement and visualization around the tooth of interest has already been dealt with by the method of Virtual Probing[1]. In addition, we have developed a method for measurement of bone loss in the inter-radicular region. Integrated with the Virtual Probing method, we can provide a total system of diagnostic aid for assessment of alveolar bone loss.

The distribution of inter-radicular bone loss could not be easily observed by the visual representations we developed before for the Virtual Probing result. Therefore we sought another visual representation of the inter-radicular bone loss which gives both the position of the bone loss and the amount of it at the same time.

In this paper, we describe a method for quantitatively measuring and visualizing the amount of inter-radicular bone loss on 3-D dental CT images as well as the Virtual Probing method. Since the inter-radicular bone loss is a very difficult disease to observe mainly due to its location, conventional methods for it are quite limited.

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2. METHODS

2.1. Inter-radicular region separation

Before quantifying the amount of bone loss in the inter-radicular region, we have to define the inter-radicular region. The inter-radicular region is defined by fitting a stack of two-dimensional convex hulls to the tooth substance (dental and enamel) region. The region inside the convex hulls is the inter-radicular region. The region, especially the bone loss region outside of them, is used by the Virtual Probing method. It measures the bone loss depth by finding the bottom point of bone loss and the reference point at the interface between the enamel and the cement (CementoEnamel Junciton; CEJ), which is also used in the clinical probing inspection. A brief description of the Virtual Probing method is as follows:

1-1 Input dentin, enamel, alveolar bone, and bone loss regions outside the convex hulls and the axes of inertia A_1 and A_2.

1-2 Let $\theta := 0$.

1-3 Set up a half plane $\Pi(\theta)$ with the tooth axis A_1 as its edge, oriented at the angle of θ to A_2.

1-4 Search on $\Pi(\theta)$ for the element of the enamel region that is nearest to the root tip as a point of CEJ $P_{\mathrm{CEJ}}(\theta)$.

1-5 Search on $\Pi(\theta)$ for the bottom point of bone loss $P_{\mathrm{B}}(\theta)$.

1-6 Calculate the bone loss depth as the distance between $P_{\mathrm{CEJ}}(\theta)$ and $P_{\mathrm{B}}(\theta)$ projected onto A_1.

1-7 Let $\theta := \theta + \Delta\theta$; If θ is 360 degrees or larger, quit. Otherwise, go to 1-3.

2.2. Measurement and visualization

Here we describe a method for measuring and visualizing the inter-radicular bone loss. It measures the amount of bone loss by the length of it along the tooth axis. Because it gives results comparative to those given by Virtual Probing, the results are quite acceptable to dentists, who are used to attachment levels which are also measured along the tooth axis (details in

the next paragraph). The measurement result is visualized in pseudo-color according to the amount of the bone loss and laid over a visualization of the tooth. By visualizing the tooth from the root side, position of the bone loss in relation to the tooth can be easily observed.

The measurement and the visualization are achieved almost at the same time. A plane perpendicular to the tooth axis is set up. The length of the bone loss is then measured along a line parallel to the tooth axis and recorded on the plane. The measurement is repeated for each pixel through which the line is placed. The measurement procedure is as follows:

2-1 Input inter-radicular bone loss region V_{i} and axes A_1, A_2.

2-2 Set up a plane Ψ perpendicular to A_1.

2-3 Let p_i a pixel on Ψ.

2-4 Let l_i the line through p_i parallel to A_1.

2-5 Find v_{c} and v_{r} in V_{i} that are the farthest voxels along l_i on the crown and the root side, respectively.

2-6 Calculate the distance between v_{c} and v_{r}, and record it on Ψ at p_i. The value is used to create the pseudo-color map of bone loss distribution.

2-7 If all the pixels on Ψ are visited, quit. Otherwise, let p_i a voxel that has not been visited and go to 2-3.

3. RESULTS

We used two cases of 3-D dental CT images for experiments. The size of the volume images were $321\times321\times244$ [voxel] and the voxel size was $0.125\times0.125\times0.125$ [mm^3]. The visualization results of the inter-radicular bone loss and that of the Virtual Probing are shown in Fig. 1. The maximum length of the inter-radicular bone loss for each case was 6.8 and 1.8 [mm], whereas (maximum, average, minimum) of the Virtual Probing results were (10.6, 6.0, 2.4) and (6.3, 4.9, 3.1) [mm]. The average measurement error of the Virtual Probing method was 0.36 [mm]. By integrating quantification and visualization methods for both inter-radicular bone loss and the region surrounding it (Virtual Probing), the results gave fairly intuitive description of the disease's total condition. Although evaluation of the quantification and visualization is yet to be done using more cases, we believe our methods will contribute to the higher quality of the disease's treatment.

4. CONCLUSIONS

We have developed a method that quantifies and visualizes the distribution of alveolar bone loss in the inter-radicular region. By measuring the length of bone loss along the tooth axis, we could provide quantification results that were not only comparable to probing results but also easily acceptable to dentists. The measurement results were visualized in pseudo-color laid over an image of the tooth of interest, giving intuitive perception of the location of the bone loss.

Future work will include experiments using more cases of CT images and statistical investigation of the method's effectiveness.

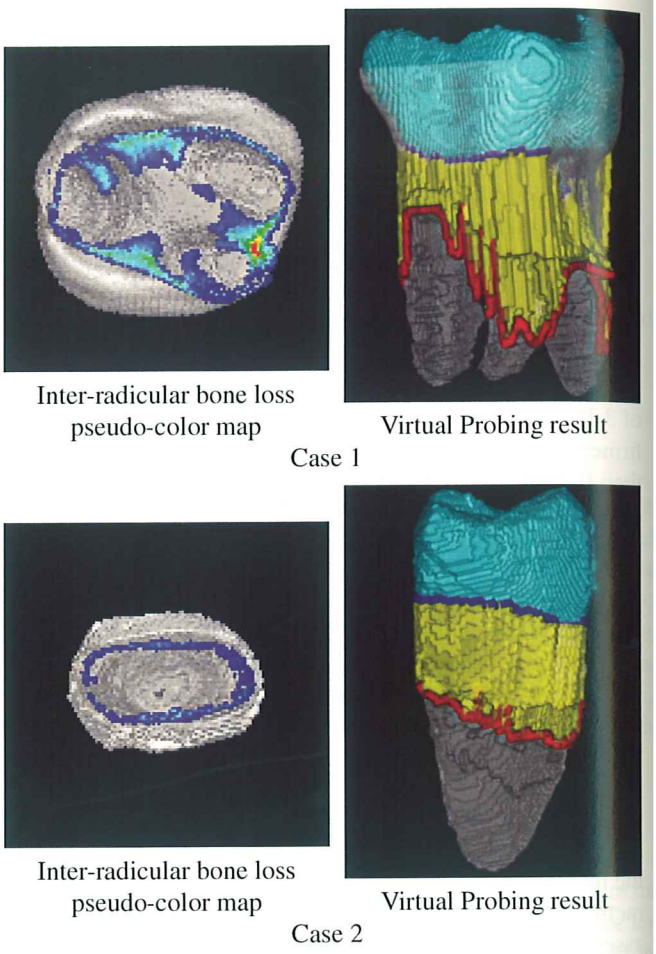

Fig. 1. Visual representation of the results by the Virtual Probing and the inter-radicular measurement methods.

5. REFERENCES

[1] J. Nagao, D. Ito, T. Kitasaka, K. Mori, Y. Suenaga, S. Yamada, and M. Naitoh, "Automated Method for Measuring Alveolar Bone Resorption using Three-Dimensional Image Processing," in *CARS*, H. U. Lemke, K. Inamura, K. Doi, M. W. Vannier, and A. G. Farman, Eds., 2005, Proc. CARS, p. 1420.