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Evaluation of tooth root surface area using a three-dimensional scanning technique and cone beam computed tomographic reconstruction in vitro

Tong Wang[a,b,1], Xibo Pei[a,b,1], Feng Luo[a,b], Lingling Jia[a,b], Han Qin[a,b], Xinting Cheng[a,b], Yiyuan Xue[a,b], Jian Wang[a,b], Qianbing Wan[a,b,*]

[a] State Key Laboratory of Oral Diseases, National Clinical Research Center for Oral Diseases, West China Hospital of Stomatology, Sichuan University, Chengdu, China
[b] Department of Prosthodontics, West China Hospital of Stomatology, Sichuan University, Chengdu, China

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ABSTRACT

Objective: To study the feasibility of measuring root surface area (RSA) by 3D scanning technique and cone beam computed tomography (CBCT) reconstruction in vitro.
Design: Twenty extracted teeth (10 single-rooted teeth and 10 multi-rooted teeth) were collected in this study. The RSA of the extracted teeth was measured by the membrane technique, 3D scanning technique, and CBCT reconstruction. A standard part was also designed to check the accuracy of each method. All statistical analyses were performed using the SPSS software.
Results: According to the results of one-way ANOVA, there was no significant difference among the values of RSA measured by the three techniques ($p > 0.05$). The results of Wilcoxon matched-pairs signed-rank test further demonstrated that there was no significant difference among the values of RSA in both single- and multi-rooted teeth measured by the three techniques ($p > 0.05$).
Conclusions: The membrane technique, the 3D scanning technique, and CBCT reconstruction are novel reliable techniques for measuring the RSA in both single- and multi-rooted teeth, which will provide wide clinical applications in the future.

1. Introduction

Periodontal disease can involve the progressive loss of the alveolar bone around the root surface. The root surface area (RSA), where periodontal tissues attach to, is very important for predicting the prognosis of teeth that suffer from periodontal disease. Moreover, the RSA is also very useful for the selection of potential abutment teeth in designing fixed partial dentures according to Ante's law. Therefore, evaluating the RSA accurately is of great clinical importance (Lulic, Brägger, Lang, Zwahlen, & Salvi, 2007; Rosemarie, 2010).

Many methods were reported in the literature for the assessment of RSA, such as division planimetry or stereogrammetry, weight conversion, membrane technique, 3D scanning technique, and computed tomography (CT) reconstruction. As we know, the tooth root is not composed of homogeneous material, and it is difficult to fully and homogenously cover the RSA with a coating agent. Therefore, division planimetry or stereogrammetry and weight conversion method are not accurate to measure the RSA (Chen, Chen, & Jeng, 2002; Hujoel, 1994; Ktock, Gjerdet, & Haugejorden, 1993; Mowry et al., 2002; Pereira, Oliveira, Costa, & Mendes, 2015). Regarding the membrane technique, the properties of easy operation and high accuracy make it the most commonly used and classic technique in previous studies (Hujoel, 1994; Yamamoto et al., 2006). However, in recent years, the development of digital technology such as 3D scanning and CT reconstruction provide more convenient and accurate means to obtain the exact profile of the tooth. For instance, Chen, Pan, Chen, & Jeng, 2004, 2005) measured the RSA of single-rooted tooth by the 3D probe scanning technique combined with a computer engineering program; when compared with stereogrammetry technique, the 3D probe scanning technique showed high accuracy. Unfortunately, when measuring the RSA of multi-rooted tooth, some problems arise because of the existence of several roots and undercuts.

Compared with conventional 2D radiographs, CT can provide more information by acquiring 3D radiographic images of both soft and hard

Abbreviations: RSA, root surface area; CBCT, cone beam computed tomography; CEJ, cementoenamel junction; PVA, polyvinyl alcohol; SA, sodium alginate; SDBS, sodium dodecyl benzene sulfonate; MWCNTs, multiwalled carbon nanotubes; DPI, dots per inch; BMP, bitmap; STL, stereolithography; DICOM, digital imaging and communications in medicine; One-way ANOVA, one-way analysis of variance; K-S test, Kolmogorov–Smirnov test; CI, confidence interval

* Corresponding author at: Department of Prosthodontics, West China Hospital of Stomatology, Sichuan University, No. 14, Section 3, South Peoples Road, Chengdu 610041, China.
E-mail address: champion@scu.edu.cn (Q. Wan).
[1] These authors contributed equally to this work.

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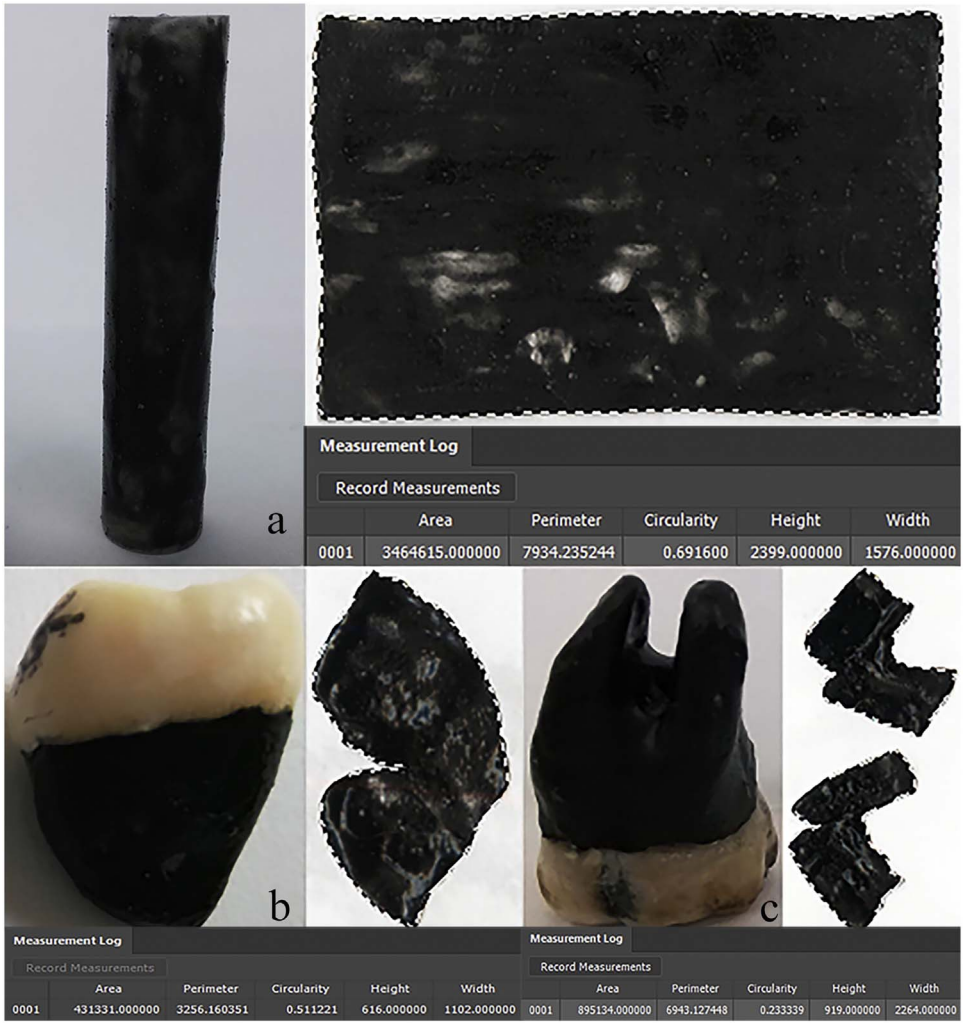

Fig. 1. Membrane coating to samples and total pixel value calculated by Photoshop. (a) Membrane coating to standard part, (b) membrane coating to a typical single-rooted tooth, (c) membrane coating to a typical multi-rooted tooth.

tissues. There are some studies that measured the RSA by multi-slice CT and micro-CT. However, the disadvantages of long scanning times and high radioactivity has limited their application in dentistry (Gu, Tang, Zhu, & Feng, 2016; Kupczik & Dean, 2008; Versiani, Pécora, & de Sousa-Neto, 2012). Cone beam CT (CBCT) overcame those limitations and is becoming increasingly popular in dentistry as it is cost reducing and dose sparing. The advantages of relatively smaller voxel size and no distortion also make CBCT superior in measuring the area of a specific structure (Ludlow & Ivanovic, 2008). However, few studies have measured the RSA of single- and multi-rooted teeth by CBCT. Therefore, measuring the RSA of teeth using CBCT reconstruction is necessary and of great importance in dentistry.

The aim of this study is to evaluate the RSA of single- and multi-rooted tooth by 3D scanning technique and CBCT reconstruction in vitro. In addition, the accuracy of these methods is investigated by comparing with that of the classic membrane technique. We hope to determine whether 3D scanning technique is capable of measuring the RSA of teeth with complicated tooth morphology and know whether CBCT reconstruction could be effective in estimating the RSA of a certain tooth.

2. Materials and methods

The study protocol was approved by the ethics committee of West China Hospital of Stomatology (ethical approval number WCHSIRB-D-2015-012). Standard parts were designed and manufactured to compare the accuracy of each method. Specifically speaking, a plastic cylinder was used as the standard part for membrane technique, a gypsum circular truncated cone for 3D scanning technique, and a metal cylinder for CBCT reconstruction.

Twenty extracted teeth (10 single-rooted teeth and 10 multi-rooted teeth) were collected from the Department of Oral and Maxillofacial Surgery, West China Hospital of Stomatology, Sichuan University, Chengdu, China. Teeth with root surfaces altered by caries or restorations or with unintact cementoenamel junction (CEJ) were excluded. Adherent soft and hard tissues, calculus, and stains were removed carefully from teeth using hand scalers. All teeth were immersed in 100% sodium hypochlorite solution for 30 min for sterilizing and then rinsed in sterile water for 5 min. After air-drying, each tooth was assigned an identification number (written on the crown), and CEJ was highlighted with a black marker. Standard parts and all teeth were used in the following experiment.

2.1. Membrane technique

Polyvinyl alcohol-sodium alginate (PVA-SA) solution was prepared by dissolving in a water bath at 90 °C and 0.1-kW ultrasound dispersing. Sodium dodecyl benzene sulfonate-multiwalled carbon nanotubes (SDBS-MWCNTs) solution was prepared by magnetic stirring and 0.1-kW ultrasound dispersing. PVA-SA-SDBS-MWCNTs film-forming mixture could be obtained by mixed them together by dissolving in a water bath at 90 °C and 0.1-kW ultrasound dispersing. The final concentration of PVA, SA, SDBS, and MWCNTs was 10%, 1.5%, 5%, and 1% (all m/v), respectively.