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Root surface area measurement of permanent dentition in Indian population – CBCT analysis

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ABSTRACT

The area of the root surface of human teeth has been investigated extensively in the dental literature. All previous attempts mainly rely on the use of physical methods to calculate surface area on extracted teeth or use virtual 3D Models for the same. The aim is to develop an algorithm using MATLAB software that estimates the dimensions of 3-D image produced with the help of CBCT so that the same can be utilized to calculate the root surface area of teeth among Indian population. Present research utilizes CBCT images of samples of extracted teeth mounted on a customized jpg. A descriptive chart for statistical analysis has been prepared to obtain average root surface area of each tooth type. The currently developed algorithm has been successfully applied to the CBCT images of complete sample of teeth to obtain their root surface area. The algorithm developed to calculate root surface area of the teeth holds wide spread application in the field of dentistry pursuing its high expediency in even various specializations of dentistry including orthodontics, prosthodontics, periodontology and implantalogy. It is concluded that it has now become a reality to accurately determine the surface area of the root of human teeth without extracting them using the CBCT radiographs of the patients.

1. Introduction

Root surface area of teeth plays a major role in anchorage of tooth within the socket and is of vital significance in planning various dental treatments. The root surface of any given tooth doesn't have a fixed value, and this inconsistency in root surface area of teeth among selected population and permanent dentition is an important component for determining the prognosis of various dental treatments [4]. In orthodontics, the duration of the entire treatment including the amount of force required to move the teeth are associated with root surface area [2]. Likewise, in other branches of dentistry including prosthodontics, periodontics, and endodontics, the major criteria in determining the procedure for the treatment depends upon the size of the root surface areas [2–5]. The study for the same has been going on since 1940's still there exists a gap between the available information regarding the normal range of values where the root surface area should lie.

Earlier studies by the scholars broadly utilized four methods for measurements: (a) the membrane technique [6], (b) weighting conversion [7], (c) division planimetry [9], and (d) computerized image analysis of the 2D radiographs or photographs [9,10]. The existing methodologies have shown various shortcomings including lacking in accuracy and precision, or being complicated to operate [11].

To scrutinize tooth morphology micro-computed tomography or micro-CT is being applied over the years, due to the micrometre resolution and non-destructive nature of the tooth [12–14].The internal and external anatomy of the teeth can be precisely demonstrated by 2D cross-sectional images and 3D models generated by micro-CT. Research scholars have thus constructed databases using this technique for 3D human tooth models that provide a wide scope for research purposes [15]. Several programs also exist that efficiently and accurately measures these mathematical models. Measurement of Root Surface Area of human permanent teeth using CBCT technique seems unique till date.

The work presented here is an attempt to investigate whether it is

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possible with reasonable certainty to determine the root surface area of any tooth by CBCT images of the teeth in individuals and obtain average values for each tooth type excluding third molars.

2. Subject and method

420 human extracted teeth have been radiographed with medical grade CBCT machine and the images so obtained have been programmed using the newly developed algorithm to obtain their root surface area. A large sample has been assessed to acknowledge the wide anatomical variation that naturally appears in human dentition. Teeth have also been randomly selected to extract their cross sections at random slices in order to check the exactitude of the algorithm in question.

2.1. Study population

A total of 420 intact, extracted human permanent teeth (30 samples of maxillary and mandibular central incisors, lateral incisors, canines, first premolars, second premolars, first molars and second molars excluding third molars) were collected in the Department of Dentistry, Civil Hospital, Gurgaon, Haryana from June 2014 to December 2015. All subjects under study were native Indians. Teeth were extracted because of non-restorable caries, trauma, periodontal disease, or orthodontic or prosthodontic reasons. The tooth type of the specimen was accurately identified by the operator according to its external anatomy, position in the dental arch, tooth sockets in the jaw bone, and dental history.

2.2. Sample storage

The first step is to carefully wash the extracted teeth with normal tap water to remove any type of blood, debris and adherent tissues. These were then stored at room temperature in a solution of 0.1% thymol (w/v) for disinfection to inhibit bacterial growth till the time they were mounted on wax loaded custom jig and radiographed using medical grade CBCT machine as shown in Fig. 1(a).

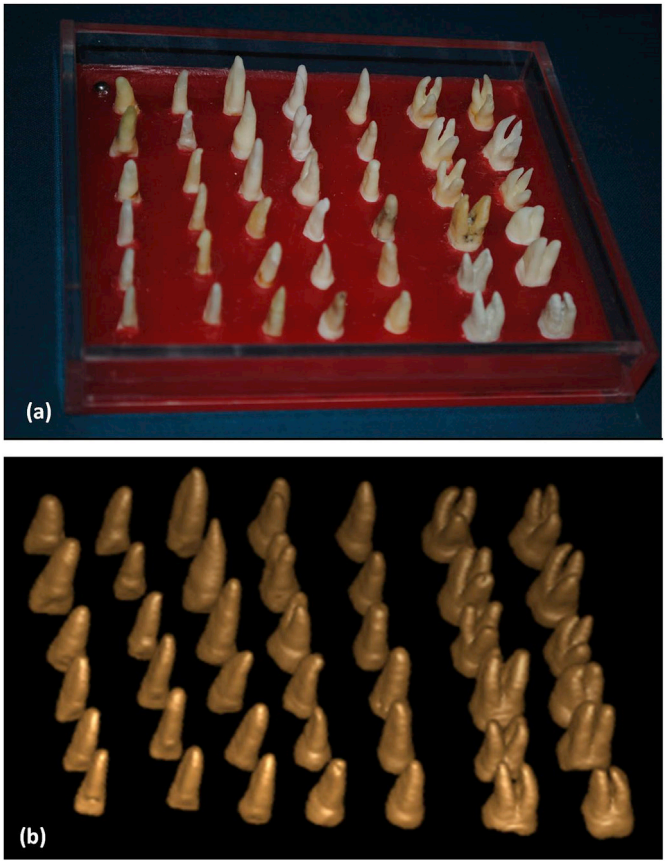

Fig. 1. (a): Sample of extracted teeth mounted on a customized acrylic jig with wax filler for easy placement of the teeth. (b): CBCT-acquired 3D image on the same sample of teeth.

2.3. Selection of teeth

Sample teeth were selected on basis of following criteria:-

1. Inclusion Criteria
   a. Teeth with intact roots are included.
   b. Tooth with no history of pretreatment with chemical agents.
   c. No root caries or root fractures.
   d. No root surface defects like abrasion and abfraction.
   e. No external or internal root resorption.
2. Exclusion Criteria
   a. Root surface cracks or damage due to forceps extraction or any other cause.
   b. Restorations on the root surface.
   c. Malformed teeth.
   d. Teeth presenting with root pathology like hypercementosis, cemental dysplasia, cemental aplasia, etc.
   e. Teeth presenting developmental anomalies like concrescence, dentin dysplasia, taurodontism, etc.
   f. Teeth with open apices or obliterated cement-enamel junctions because of caries or restoration.

2.4. Tooth scanning and 3D modelling

Tooth scanning was done at Mahajan Imaging and Diagnostic Centre, Hauz Khas, New Delhi using i.CAT CBCT machine with the voxel surface of 0.25×0.25 (0.0625) mm^2 in longitudinal axis. The 3D image data so obtained in the form of DICOM format (Digital Imaging for Communication in Medicine, a format devised and exclusively dedicated to medical imaging) was the uploaded into i.CAT Vision software (version 1.9) that rebuilt and generated digital 3D models of tooth surface and shape as shown in Fig. 1(b).

3. Analysis and measurement of teeth

After obtaining 3D images from CBCT in DICOM format, the same were evaluated using the following algorithm developed and programmed using MATLAB software (version X3) to estimate the root surface area of each tooth.

Based on the surface characteristics, the cement-enamel junction was determined through manual delineation and was considered as the boundary between crown and root by the software. The 3D tooth model has been divided into two parts based on the cement-enamel junction. The surface area of root(s) of each sample was calculated by the software.

To check the exactitude of the algorithm in question, teeth were randomly selected to extract their cross sections at random slices as shown in Fig. 2. Further to assess the accuracy of the algorithm to measure the surface area, a rectangular resin block was scanned and reconstructed 3-dimensionnally by the CBCT resulting in obtaining the digital model of surface area. The length of the edges (x, y, and z) of the resin block was measured by using a digital Vernier calliper (Mitutoyo, Japan) with an accuracy of 0.01 mm. The formula for determining the surface area used is: $2 * (x * y + y * z + x * z)$. The results were obtained four times (1082.60, 1083.96, 1083.78 and 1083.52 mm^2) and were compared with that derived from Mimics (1083.88 mm^2). The incongruity was found to be lower than 1.5% of the total surface area.