Computers in Biology and Medicine 70 (2016) 202–209

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

A new computational method for automatic dental measurement: The case of maxillary central incisor

L. Di Angelo [a], P. Di Stefano [a,*], S. Bernardi [b], M.A. Continenza [b]

[a] Department of Industrial and Information Engineering, and of Economics, University of L'Aquila, L'Aquila, Italy
[b] Department of Life, Health & Environment Sciences, University of L'Aquila, L'Aquila, Italy

ARTICLE INFO

Article history:
Received 28 August 2015
Accepted 14 January 2016

Keywords:
3D biomedical image analysis
Computer methods for tooth analysis
Dental dimensions
Measurement accuracy
Measurement protocols in biomedicine

ABSTRACT

This paper proposes a new automatic approach to determine the accurate measure of human teeth. The aim of the proposed computer based method is to reduce inaccuracy of measurement with respect to traditional approaches. Starting from a 3D model of the teeth which is obtained from 3D scanning, the method algorithmically evaluates the most important dimensional features detectable in central incisors. For this purpose, specific rules are put forward and implemented in original software with a view to identifying repere points, from which to detect dimensional features both unambiguously and accurately. The automatic method which is proposed here is verified by means of the analysis of real teeth and is then compared with the current state-of-the-art methods for teeth measurement.

1. Introduction and related works

In dentistry, knowledge of root morphology is of great importance for endodontic, periodontal and orthodontic reasons. Whereas the endodontic morphology has been looked at in depth in many studies, the gross anatomy of root surfaces has been somewhat neglected. This is probably for clinical and methodological reasons. Clinically the anatomical variability of the canals and the need to describe all the variations and anomalies found in a clinical examination is difficult. Methodologically no standard techniques have been clearly identified.

In dental anatomy textbooks [1,2] definitions of tooth surfaces, features of each tooth and different crown and root morphologies have been reported, but no information can be found concerning the methodology used to identify them. This gives rise to a lack of standard protocols to perform a valid comparison of results obtained in different studies. Although in the literature many attempts concerning the acquisition of the 3D geometrical model of the teeth are reported by using different technologies (intraoral camera [3], CT imaging [4] and [5], laser scanning system [6], radiographs [7]), currently the investigations concerning the dimensional and morphological characterization of teeth are carried out in vitro by using the traditional sliding calliper [8]. Indeed, the 3D geometrical model does not furnish directly dimensional and morphological information, but a complex processing of 3D data are required. The complexity derives from the fact that geometrical and morphological features have to be preliminarily recognized from discrete models which contain just low level geometric information. Hermann [9] provided a method to determine the loss of ligament attachment in molars. This method includes the 1-mm dissection of the root and the measurement of the tooth circumference taken from projected color slides with a calibrated opisometer. Gher and Dunlap [10] have also used this method to take measurements of the molar root area. Storrer et al. [11] carried out a morphometric study of the maxillary lateral incisor root length using the digital calliper and described the grooves on the root surfaces. Fantozzi et al. [12] tried to standardize and update the root anatomy information by using a manual calliper and by setting reference points in order to determine the root tapering in the anterior tooth. More recently, with a view to improving the MCI morphological characterization and seeking relationship patterns so as to establish morphological groups, Lazos et al. [14] identified some new dimensional features.

As shown by an investigation carried out by the present authors [15] in previous work, the measurement uncertainties obtained on biological objects by the manual calliper, could be too wide for a significant investigation of the anatomical dimensions to establish morphological groups.

This paper presents a new method to measure the most important dimensional features detectable in central incisors. In the following, we refer to this method as CATM (Computer-Aided Teeth Measurement). A further aim of this study is to demonstrate the efficacy and precision of the computer based method which can give us more precise information about the dental macro-anatomy and remove any possible human contribution to measurement inaccuracy. For this purpose, the potential inaccuracy of the manual calliper are examined and used as a point of comparison with the merits of the new computer based method.

* Corresponding author.

http://dx.doi.org/10.1016/j.compbiomed.2016.01.018
0010-4825/

2. The manual calliper method protocol

The measurement protocol used in this study is the same as that used by Lazos et al. [14]. Each step, reference point and dimension are shown in Fig. 1:

- The tooth is placed along its longitudinal axis in a red wax support. This support is molded in order to guarantee the stability and allow location of the longitudinal axis;
- The maximum crown contour or anatomic equator (E) is drawn on the tooth's crown with a graphic pencil;
- On its labial side, the most apical point of the cement–enamel junction (CEJ) is marked as Point 1;
- The most apical points of the anatomic equator are marked as Point 2 on the labial surface, and Point 3 on the lingual surface;
- The most basal points of the equator on the mesial and distal surfaces are marked as Points 4 and 5, respectively;
- Two reference points are marked in the root tooth (Points 6 and 7). For this purpose, a line surrounding the whole root is drawn 3 mm from Point 1. Points 6 and 7 are on this line in the middle of labial and lingual surfaces.

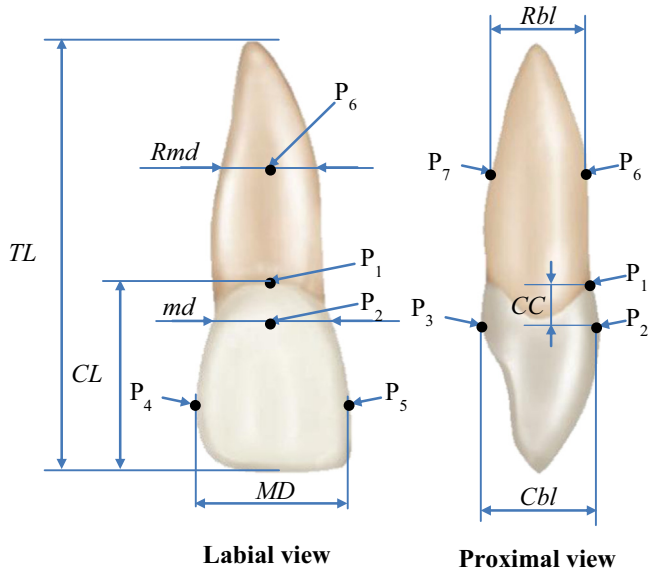

Fig. 1. The reference points and the measuring features of the MCI according to [14].

The following dimensional features are identified (Fig. 1):

- Crown length (CL): defined as the distance between the CEJ (Point 1) to the incisal edge of the crown;
- Total length (TL): defined as CL plus root length to the apex (total tooth length);
- Cervical axial diameter or cervical convexity (CC): measured from Point 1 to Point 2;
- Major mesio-distal diameter (MD): from mesial Point 3 to distal Point 4;
- Minor mesio-distal diameter (md): parallel to MD at labial Point 2;
- Root mesio-distal diameter (Rmd): parallel to MD at Points 6–7 height;
- Crown buccolingual diameter (Cbl): from labial Point 2 to lingual Point 3;
- Root buccolingual diameter (Rbl): from root labial Point 6 to root lingual Point 7.

3. The computer-aided teeth measurement method

The proposed method is performed in seven phases, as shown in the flow chart of Fig. 2. The first four steps, in which some interaction

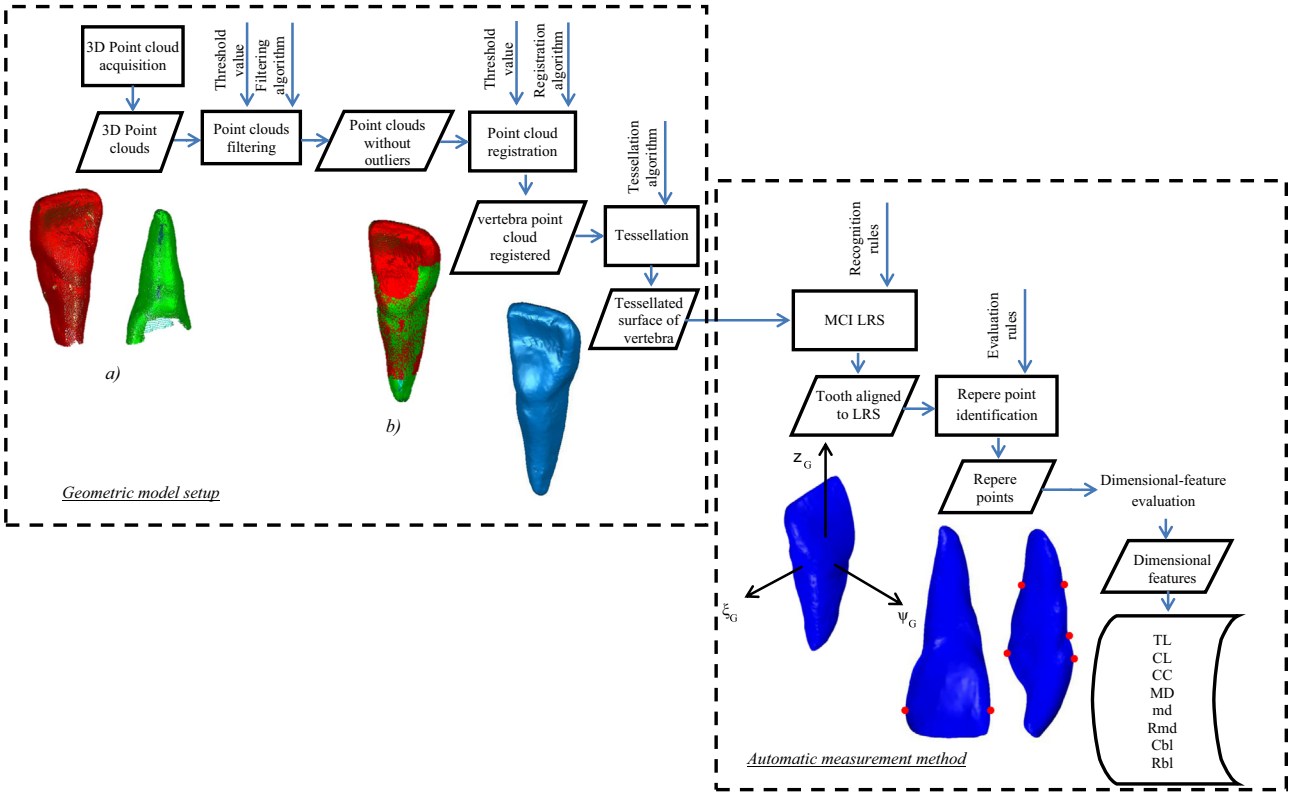

Fig. 2. Flow chart of the proposed method.