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Title: Error Measurement And Calibration Of Cone Beam Computed Tomography Thresholding Based Segmentation In Dentistry.

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Purpose: Segmentation process allows to delineate and define structures separating them with the final purpose to obtain 3D virtual models and clear visualization of each component. Spreading of cone beam computed tomography (CBCT) in dentistry led clinicians and researchers to learn, improve and better understand these image processing technique. The segmentation could be manual or automatic. Manual segmentation requires the operator to delineate structures slice by slice, while automatic or semi-automatic segmentation uses different density values (grey level units) of tissues to delineate their boundaries. Neverthless automatic segmentation is not always and completely user-bias free. Thresholding based segmentation uses density values to detect objects from a background. The segmentation object can be defined based on one lower threshold and it will contain all pixels in the images with a value higher than or equal to the threshold value.
The segmentation of the teeth from cbct images allows to analyze their position, dimension and size in order to perform diagnoses and treatment plans in dentistry. The accuracy and reliability of the thresholding based segmentation could vary on the thresholding value which could be manipulate by the user in most of DICOM viewers and softwares. The aim of this study was to test reliability and reproducibility of choosing thresholding value during thresholding based segmentation process of teeth compared to the standard dimension of virtual dental casts.

Methods: The method validation was carried out by the use of extraoral typodont which underwent to cbct scan with two different machine of the same type (CBCT A1 and CBCT A2. Scan protocol: 90 KV, 10 mA, 18 s) and one of different type (CBCT B. Scan protocol: 85 KV, 7 mA, 4 s). The image data consisted of 537 slices, with a slice thickness of 1.5 mm, a resolution of 2200 x 1700 pixels for upper and lower arches, respectively. Then digital scan using an intraoral scanner (3Shape TRIOS®, 3Shape A/S, Copenhagen K, Denmark) of the typodont were performed in order to obtain a reference 3d model.
DICOM files were loaded to a computer with a i7 processor, running Windows 7 Professional (Microsoft, Redmond, Wash) operating system. The software used to perform segmentation of cbct scans was 3D Slicer (Open source software, version 4.3.1 64bit).
One expert user was asked to indicate the most accurate thresholding value to perform teeth segmentation in his perception. The 3D Slicer software allows to indicate thresholding value by scrolling a bar with immediate feedback of segmentation computed on image slices. Then 3 higher and 3 lower thresholdings were defined by starting from the expert thresholding value with a step defined by the software. Then surface rendered 3d models were built correspondent to every thresholding value. All the segmentation derived 3d models were registered with a best fit alignment technique to the scan obtained by the intraoral scanner used as reference using Cloud

Compare software (Open source software, version 2.6.0). The segmentation error was calculated by color displacement maps on 3d superimposition for the evaluation of the discrepancy between the different thresholding values and the reference 3d model. The SPSS software, version 13.0 (SPSS® Inc., Chicago, Illinois, USA) was used to perform the statistical analyses. Parametrical methods were used after having tested the existence of the assumptions though the Shapiro-Wilk test and Levene test for the normality of the distributions and equality of the variances among the three sets of superimpositions, respectively. The data were analyzed for maximum outer displacements and maximum inner displacement form the reference 3d model. Analysis of variance (ANOVA) test was used to determine if there were statistically significant differences among the three sets of superimpositions. Bonferroni correction was applied for statistically significant differences after post – hoc analysis. Alpha was set at 0.05.

Results: ANOVA results showed significant volumetric differences of the 3d models obtained from CBCT A1 when compared to CBCT A2 and B, respectively ($P<0.01$). On the contrary, 3d models obtained from CBCT A2 and B showed no significant differences when compared.

Conclusions: Thresholding based segmentation showed poor reliability and reproducibility in using 3d models as reference for clinical measurements. Further studies are needed to confirm the present results and to provide for standardization methods for the choice of correct thresholding in dental practice and research