Accuracy of Linear Measurements using 2 Different Software Programs and Artificial Intelligence CBCT Derived STL Models

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Purpose: The aim of this study was to compare the reliability of linear measurements using 2 software programs and a web-based AI dental diagnostic tool STL models.

Materials & Methods: A total of 100 CBCT scans were retrospectively analyzed and enrolled in this study. Firstly DICOM files were imported into Maxilim® software to create a 3D hard tissue representation. Besides this a Convolutional Neural Network-based machine learning algorithm and MIMICS software program were used to generate STL images. Five mandibular linear measurements were performed by using MIMICS software STL images, Maxilim software and AI generated STL files (Diagnocat, CA, USA). Bonferroni adjustment was used for pairwise comparisons. Absolute agreement among three programs and between pair of programs were assessed by intraclass correlation coefficient (ICC).

Results: Overall ICC values demonstrated a reliable reproducibility and ranged from 0.760 to 0.911. The most reliable measurement was between the angulus mandible (ranging from 0.876 to 0.939) and the measurement with lower ICC was between the mental foramens (ranging from 0.657 to 0.795). The measurements showed statistically significant differences between 3 software programs except for distance between the incisura mandibles.

Conclusions: STL images showed significant differences and may be used with caution in the mandible. It tends to over or underestimate the distances which measured in this study.

Introduction

Cone-beam computed tomography (CBCT) has revolutionized the diagnostic process in both oral and maxillofacial imaging and orthodontics by delivering precise, high-resolution 3D imaging using easy and cost-effective equipment, since it was first used in dentistry in 1998.1 CBCT, in particular, has played a significant role in dentistry recently because of its lower radiation doses compared to multi-slice computed tomography (CT). 2 The transformation of CBCT scans into virtual 3D models of pertinent anatomic regions of interest, such as the mandible, the maxilla, and the teeth, is a crucial step in the identification of dentofacial anomalies and deformities. Consequently, CBCT is being utilized more frequently for the diagnosis and treatment planning of the cleft lip and palate, impacted teeth and craniofacial skeletal discrepancies that require surgical treatment in orthodontics.(3, CBCT in orthodontics: assessment of treatment outcomes and indications for its use)

CBCT images converted to the Digital Imaging and Communications in Medicine (DICOM) files for storage and transmission of the 3D data. The most frequent representation provided to the examining physician is a series of 2D cross-sections displayed in three planes of space via a DICOM file.4 The file should be converted to Standard Tessellation Language (STL) format in order to produce a user-friendly 3D landscape using the DICOM data. Any computer running a common operating system like Microsoft Windows can access STL files, which are used for 3D printing of industrial and medical products. A CBCT DICOM images of the teeth and jaws may also be automatically converted to STL files.5 In dental radiology, artificial intelligence (AI) can quickly segment an STL picture into its various tissues using a 3D DICOM package generated from a CBCT scan.6

STL files may be used to make diagnoses and plan treatments, however model accuracy is a serious problem that needs to be considered and addressed.

Objective

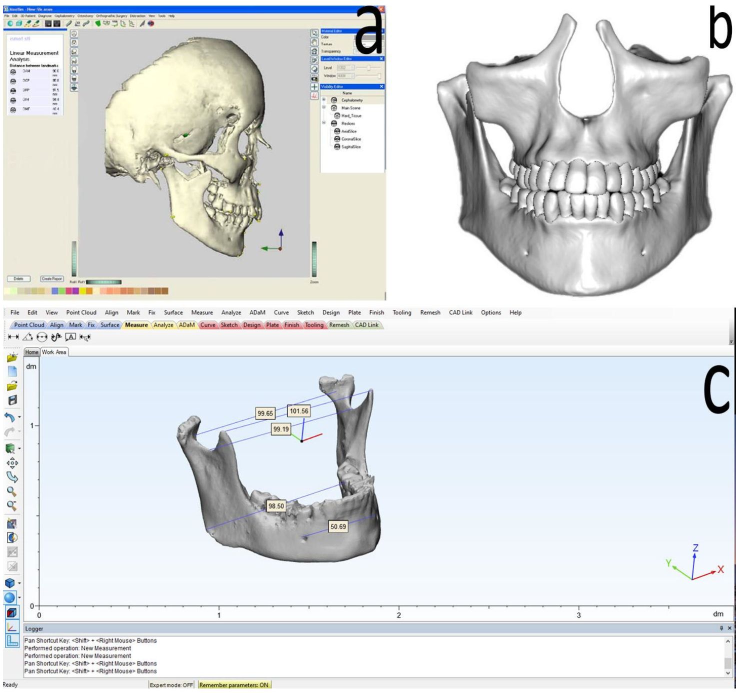
The aim of this study was to compare the reliability of linear measurements using 2 software programs and a web-based AI dental diagnostic tool STL models.

Materials and Methods:

Data from CBCT scans of 100 patients, who had been referred to the Near East University Department of Dentomaxillofacial Radiology during a 8-year period, were retrospectively analyzed enrolled in this study. DICOM files were firstly imported into Maxilim® software to create a 3D hard tissue representation. Besides this a Convolutional Neural Network-based machine learning algorithm (Diagnocat (DC)) and MIMICS software program were used to generate STL images. In total ten anatomic landmarks were identified and five linear measurements were performed as follows; distance between the right and left angulus mandibula, the coronoid process, fovea pterygoidea, incisura mandibulae, and mental foramen. Five mandibular linear measurements were performed by using Maxilim software. MIMICS software STL images and AI generated STL files measurements were performed using 3D-matic. The

distributions of distance measurements were examined by Shapiro-Wilk's test, normality plots and skewness-kurtosis statistics.

Distance measurements performed by three programs were compared by repeated measures ANOVA. Bonferroni adjustment was used for pairwise comparisons. Absolute agreement among three programs and between pair of programs were assessed by intraclass correlation coefficient



(ICC) and 95% confidence interval (CI) based on single-rating and two-way mixed-effects models.

A p-value of less than or equal to 0.05 was considered as statistically significant. All statistical analyses were performed via IBM SPSS Statistics 22.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).

Results:

	Software									P-values			
	STL (n=98)			DC STL (n=96)			Maxilim (n=89)			Overall (n=87)	STL vs. DC STL (n=96)	STL vs Maxilim (n=89)	DC STL vs. Maxilim (n=87)
Distance	Mean±SD	Median (IQR)	Min-Max	Mean±SD	Median (IQR)	Min-Max	Mean±SD	Median (IQR)	Min-Max				
between angulus mandibula	93.27±7.50	93.16 (88.35-98.97)	65.83-110.97	92.84±7.52	92.28 (87.87-98.77)	66.72-110.59	92.88±7.21	92.80 (87.45-98.40)	72.90-111.80	0.028	0.229	0.007	0.915
between coronoid process	95.51±6.36	94.39 (90.53-100.32)	82.51-112.26	95.29±6.45	94.15 (90.55-99.97)	83.73-112.91	98.32±6.32	96.20 (93.90-102.20)	85.50-116.00	<0.001	>0.999	<0.001	<0.001
between Fovea Pterygoidea	97.43±6.95	97.14 (93.13-101.57)	76.81-112.26	97.20±6.95	97.54 (92.50-102.08)	75.18-113.01	99.13±7.09	97.70 (94.05-103.35)	84.80-118.90	<0.001	>0.999	0.006	0.001
between incisura mandibulae	96.80±5.77	96.50 (93.34-101.12)	79.32-114.21	96.38±5.61	95.95 (93.07-100.05)	79.49-111.81	97.28±5.38	96.50 (94.25-101.05)	86.30-111.00	0.079	-	-	-
between mental foramens	48.31±3.74	48.38 (45.59-50.83)	40.18-58.26	46.42±3.40	46.45 (44.23-48.78)	35.12-54.52	47.19±3.85	47.40 (44.45-49.80)	39.30-58.40	<0.001	<0.001	<0.001	0.051
n: Number of observations, SD: Standard deviation, IQR: 1st – 3rd quartiles, Min: Minimum, Max: Maximum													

Table 1. Distribution of the distances measured by the programs and comparisons of three programs with respect to five distances

In order to investigate the reliability of the methodologies, all measurements were performed after a period of time. Overall ICC values demonstrated a reliable reproducibility and ranged from 0.760 to 0.911. ICC scores of all distance measurements were high and showed good to excellent reliability (ranging from 0.857 to 0.911) except the mental foramen distance which demonstrated a moderate reproducibility (0.760)

The measurements showed statistically significant differences between 3 software programs measurement except for distance between the incisura mandibles. Coronoid R - Coronoid L and Fovea Pterygoidea R - Fovea Pterygoidea L distances were calculated to be longer in Maxilim software compared to the STL and STL DC measurements. Only distance between the mental foramen showed statistically significant differences between the STL and DC STL (Table 1).

Discussion

Reliability of the measurements obtained with cephalometric analysis using 3D CBCT data is very important for the correct diagnosis and proper treatment planning. Huotilainen et al. used a patient's CBCT data to demonstrate the inaccuracies and differences caused by the DICOM to STL conversion process and they reported marked differences in the structures of the various skull models were between the three reconstructed 3D skull models in STL file format.4 According to Kamio et al., the STL model's form changes slightly between different software programs. The quality of the STL data has an impact on 3D printing, and bad STL data might result in failure of 3D model fabrication. 8

On the other hand Ferry Et. al. reported no statistically significant difference in between the mean values of DICOM+STL registrations for all locations of histological measurements.9

D'Addazio et al studied the clinical accuracy of two different protocols for data matching which were DICOM-DICOM vs DICOM-STL and reported no statistically significant differences between the two protocols in terms of precision and accuracy.10

Conclusions: STL images showed significant differences and may be used with caution in the mandible. It tends to over or underestimate the distances which were measured in this study.

References:

1. Assessment of treatment outcomes and indications for its use, Dentomaxillofac. Radiol. 44:1, 2015., . Silva, M.A.G.; Wolf, U.; Heinicke, F.; Bumann, A.; Visser, H.; and Hirsch, E.: Cone-beam computed tomography for routine orthodontic treatment planning: A radiation dose evaluation, Am. J. Orthod. 133:640.e1-640.e5, 2008.

2. Pauwels, R., et al.; SEDENTEXCT Project Consortium. (2012) Effective dose range for dental cone-beam computed tomography scanners. European Journal of Radiology, 81, 267–271.
3. Carter JB, Stone JD, Clark RS, Mercer JE. 2016. Applications of cone-beam computed tomography in oral and maxillofacial surgery: an overview of published indications and clinical usage in United States academic centers and oral and maxillofacial surgery practices. J Oral Maxillofac Surg.74(4):668–679.
4. Huotilainen, E.; Jaanimets, R.; Valášek, J.; Marcián, P.; Salmi, M.; Tuomi, J.; Mäkitie, A.; and Wolff, J.: Inaccuracies in additive manufactured medical skull models caused by the DICOM to STL conversion process, J. Craniomaxillofac. Surg. 42:259-265, 2014.
5. Abdelkarim, A. and Jerrold, L.: Clinical considerations and potential liability associated with the use of ionizing radiation in orthodontics, Am. J. Orthod. 154:15-25, 2018.
6. Hosny, A.; Parmar, C.; Quackenbush, J.; Schwartz, L.H.; and Aerts, H.J.W.L.: Artificial intelligence in radiology, Nature Rev. Cancer 18:500-510, 2018.
7. Kamio et al. 3D Printing in Medicine (2020) 6:17
8. Ferry K, AlQallaf H, Blanchard S, Dutra V, Lin WS, Hamada Y. Evaluation of the accuracy of soft tissue thickness measurements with three different methodologies: An in vitro study. J Periodontol. 2022 Mar 15. doi: 10.1002/JPER.21-0692. Epub ahead of print. PMID: 35289938.
9. D'Addazio G, Xhajanka E, Traini T, Santilli M, Rexhepi I, Murmura G, Caputi S, Sinjari B. Accuracy of DICOM-DICOM vs. DICOM-STL Protocols in Computer-Guided Surgery: A Human Clinical Study. J Clin Med. 2022 Apr 22;11(9):2336. doi: 10.3390/jcm11092336. PMID: 35566462; PMCID: PMC9101796.