Volumetric analysis of preoperative cystic jaw lesions using Manual segmentation and semiautomated segmentation

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Abstract
ObjectivesThe aim of this study was to assess the volume of cystic jaw lesions using semiautomatic and manual image segmentation.**Materials and methods** 49CBCT archived radiographs were assessed to estimate the volume of cystic lesions. Cronbach's alpha test was used to detect interobserver agreement.Simple linear regression analysis between the two methods in different-sized lesions and Correlation between the two methods in different-sized lesions was assessed.**Results**Volume showed no statistically relevant p-value (0.051 and 0.087) for small and large-sized lesions respectively, therefore this parameter does not exhibit proportional bias.**Conclusion**A semiautomated method for CBCT images has several advantages the risk of nonobjectivity and interobserver variability is greatly reduced by minimizing the active manual input of the user.
Key words:jaw cyst, cyst volume , manual image segmentation, semiautomated image segmentation

INTRODUCTION

According to cyst size, jaw cysts can be classified into small, median, and large mandibular cysts, which often invade teeth and can seriously affect quality of life. Cysts tend to enlarge and grow, leading to resorption of bone tissue. Depending on the degree of resorption, cysts may cause severe damage such as bone fractures. Treatment planning for cysts depends on cyst location, size, the extent of tissue damage, the availability of surgical access, patient's age, the proximity of the cyst to vital structures, and the significance of the affected teeth in terms of eruption. Marsupialization or decompression is the first consideration if the lesion invades adjacent structures or if primary enucleation could cause pathological fractures or neurological damage.[1-3]

After the development of Computer Aided Diagnosis and Detection (CADD), the radiologists mostly depend on the computer for very efficient and early diagnosis. Radiological size delineation has its relevancy in the context of diagnostic and therapeutic management decisions. Volume analysis is therefore a useful parameter for risk stratification, which provides stronger evidence about volume changes and, indirectly, about the healing rate and improve patient individualized treatment.[4-6]

This is a definite indication for a three-dimensional assessment of cysts and the segmentation of cysts in bone tissue. This detailed assessment provides surgeons with information about the total volume of a cyst and the spatial relationship between the cyst and surrounding high-risk structures. In

addition, surgeons can evaluate the real dimensions of the cyst when removing a cyst from the bone.[7,8]

Image segmentation techniques can be divided into manual, automatic, and semi-automatic techniques. Manual segmentation techniques require the user to manually mark voxels on each slide by outlining the structure of interest slice by slice on a 3D image. This requires prior knowledge about the shape of the structure of interest and the intensity of grey values that compose its image. This technique is exact; however, it is user-dependent, time-consuming, and only feasible for small image datasets. Manual Segmentation is necessary as it provides the ground truth labeled images to further develop semi-automatic and fully automatic segmentation techniques.[9-10] **Thus the aim of this study was to assess volume of cystic jaw lesions using semiautomatic and manual image segmentation.**

MATERIALS AND METHODS

Thisretrospective using archived data was granted by the Research Ethics Committee (REC) of the faculty of dentistry, Minia University, under approval number 534 – 1/11/2021.All 36 images were taken using the same CBCT scanner (SCANORA® 3Dx, Helsinki, Finland), with 4-10 mA and 60-90 kV, 18- 34 seconds of exposure time, and focal spot 0.5 mm. The acquired data from the X-ray machine were exported using a specific type of file (Digital Imaging and Communication in Medicine (DICOM)). (DICOM) formatted images were created from axial slices 0.5 mm in thickness. Thereby generated data was extracted and further processed with the help of biomedical image processing software, for image segmentation purposes.

- 3D Volumetric Analysis from CBCT Data

This study compares Mimics and Invesalius which were compatible with the Windows operating system. Segmentations were performed according to each software manufacturer's recommendations and using the interactive threshold technique. This means that the operator selected the best threshold interval for visualizing the entirety of the anatomic boundaries of the cystic lesion.To investigate the reliability of the employed volume calculation procedure, 5 randomly selected patients were measured twice by 3 investigators to analyze inter-observer reliability. All readers were blinded to each other's results.**The sample was grouped into 3 categories, according to the cystic lesion' estimated volume and the treatment plane, into small, medium and large cyst.**

STATISTICAL ANALYSIS

Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed non-normal (non-parametric) distribution. Data were presented as median, range, mean, and standard deviation (SD) values. The inter-examiner agreement was assessed using Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC). Closer values of these coefficients to one indicate better inter-observer agreement.

Qualitative data were presented as frequencies and percentages. The significance level was set at $P \leq 0.05$. The analysis of the data was carried out using the IBM SPSS version 25 statistical package software and Med-calc version 12.The normality of the data was tested using the Shapiro-Wilk test.Data were expressed as mean ± SD and by median (IQR) for non-parametric quantitative data. Analyses were done between the two techniques in each group using the Wilcoxon signed rank test. Correlation between two techniques in each group wasdone using **Pearson's correlation** followed by **simple linear regression analysis**.Assessment of reliability between the two techniques was done using **Cronbach's alpha** and **interclass correlation.**The agreement between the two techniques in each group using the **Bland-Altman plot.The p value less than 0.05** was considered statistically significant.

RESULTS

1- The present study was conducted on 36 patients: 21 males (53.1%) and 15 females (46.9%). The most common type of cyst was radicular cyst (36.7%) followed by odontogenic keratocyst (20.4%). Almost half of the cysts (51%) were found in the lower arch and 49% were in the upper arch. The 2-softwareshowed very good inter-examiner agreement. The highest inter-examiner agreement for volume measurement was found with Invesalius (Cronbach's alpha = 0.992), followed by Mimics (Cronbach's alpha = 0.989). Pair-wise comparisons revealed that there was no statistically significant difference between Mimics and Invesalius software**(Figure 1).**

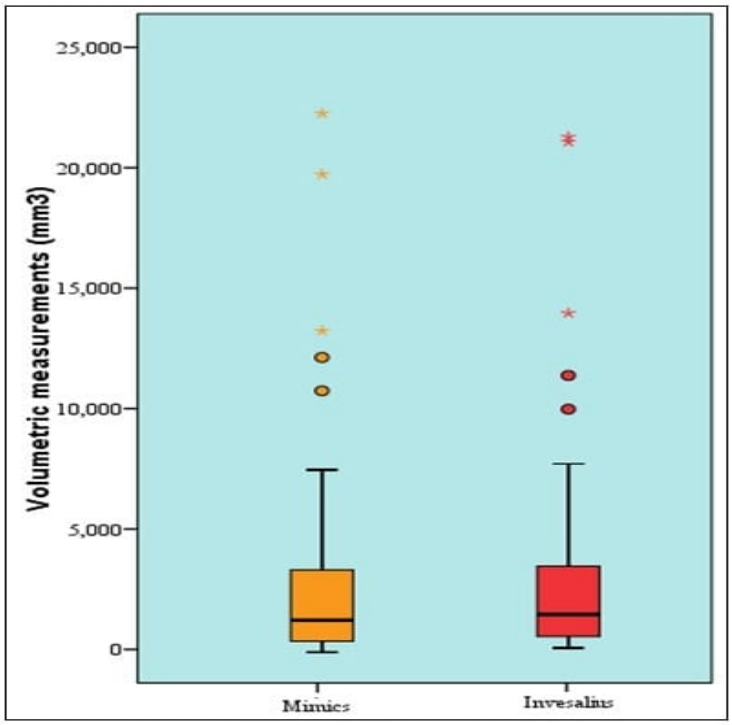


Figure (1). Box plot representing median and range values for volumetric measurements Mimics and Invesalius different software (Stars and circles represent outliers)

2- Results related to groups of cysts size

As regards the Bland Altman plot:The differences between the manual segmentation method and semiautomated segmentation method are plotted against the averagesof the two measurements (X-axis). The *green lines* illustrate the mean difference between both measurements, the *red lines* illustrate the 95% limits of agreement. The *dashed blue lines* represent the linear regression line with the difference as the dependent variable (criterion) and the mean as theindependent variable (predictor).Simple linear regression analyses for volume showed no statistically relevant p-value (0.051 and 0.087) for small and large-sized lesions respectively, therefore this parameter does not exhibit proportional bias. While showed a statistically relevant p-value (0.019) for medium-sized lesions, therefore this parameter exhibited proportional bias.

Pairwise comparisons between the two methods in different sized lesions

Group		Manual segmentation	Semiautomated segmentation	P value
Small sized (n=17)	Mean ± SD Median / IQR	444.6±240.8 383.9/ (227.9-628.9)	409.5±224.2 394.5/ (211-577.9)	***0.001****
Medium sized (n=9)	Mean ± SD Median / IQR	1442.6±228.6 1477.3/ (1237-1549.2)	1393.7±296.2 1336.1/ (1142.1-1530.1)	*0.110*
Large sized (n=10)	Mean ± SD Median / IQR	8544.3±5799.6 6326.4/ (4316.9-12076.2)	8766.6±6119.8 6257.6/ (4371.4-12615.7)	*0.575*

Wilcoxon signed rank test; *: Significant level at P value < 0.0

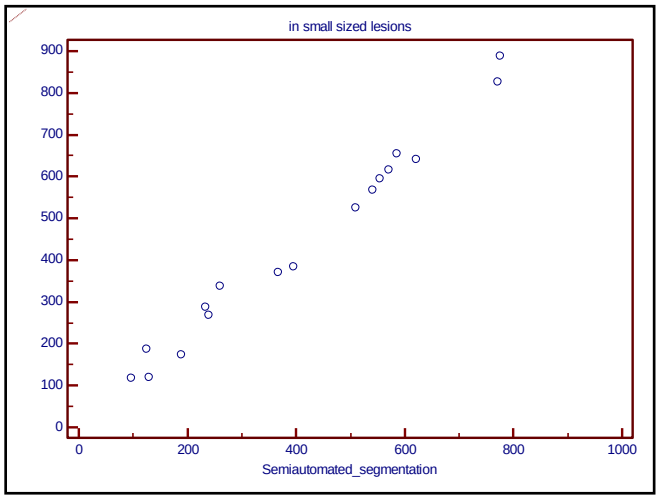
Correlation between the two methods in different sized lesions

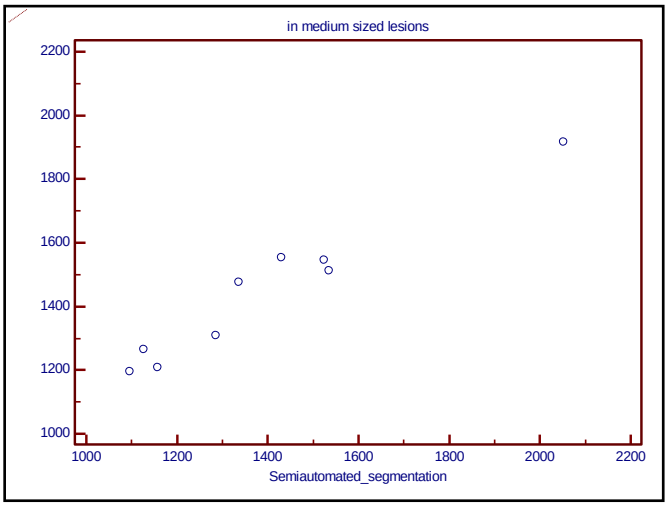
	Manual segmentation vs Semiautomated segmentation	
	R	**P value**
Small sized (n=17)	***0.991***	***<0.001****
Medium sized (n=9)	***0.974***	***<0.001****
Large sized (n=10)	***0.997***	***<0.001****

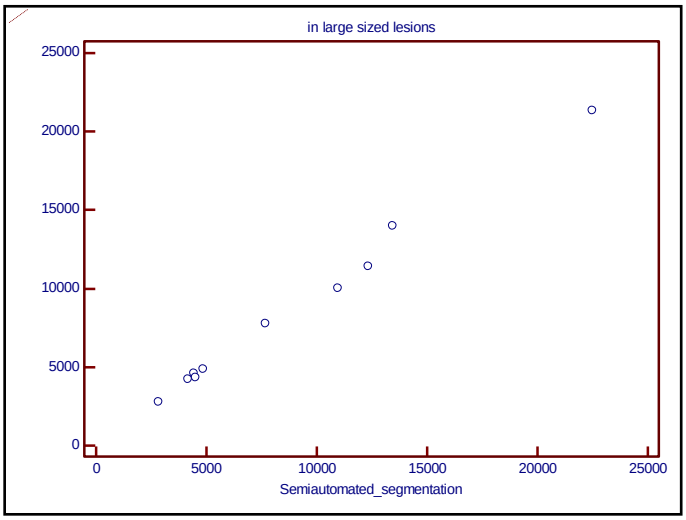
Simple linear regression analysis between the two methods in different sized lesions (Manual segmentation is the dependent variable)

Semiautomated segmentation	Constant	B	P value	R	R^2
Small sized	8.434	1.065	***<0.001****	*0.991*	*0.983*

Medium sized	395.155	0.752	***<0.001****	*0.974*	*0.948*
Large sized	261.829	0.945	***<0.001****	*0.997*	*0.994*





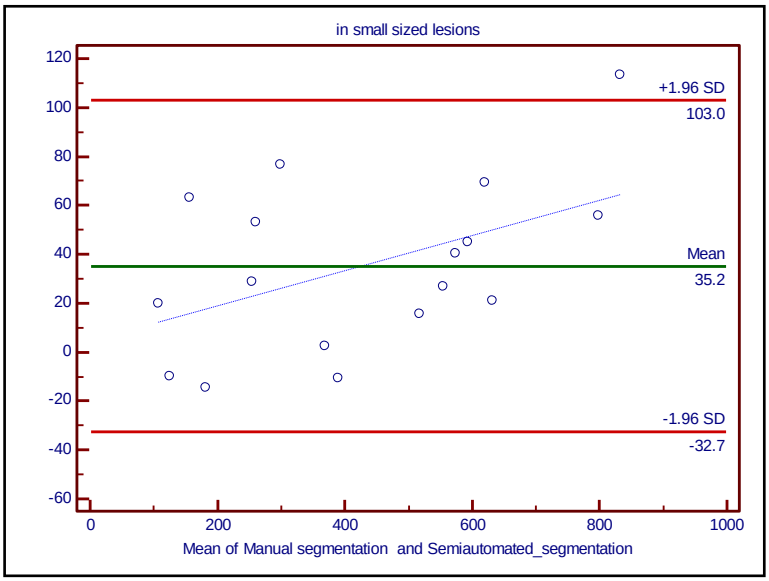


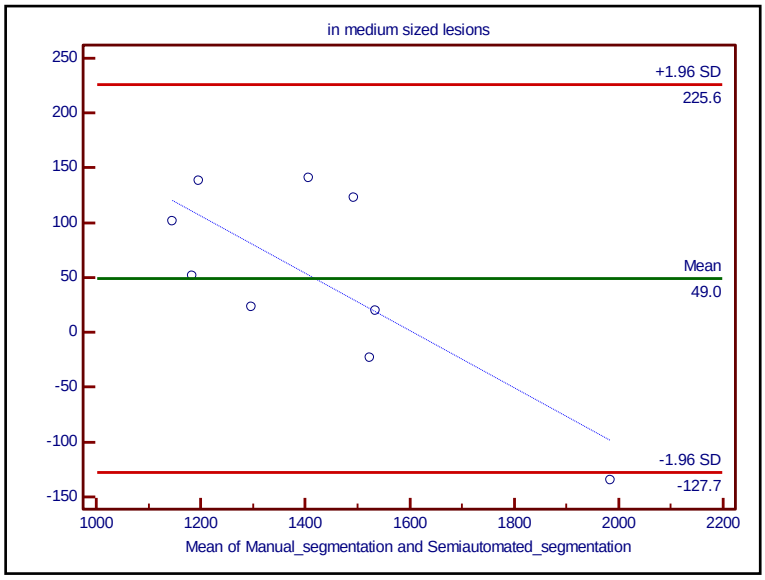
Reliability and interclass correlation between the two methods in different-sized lesions.

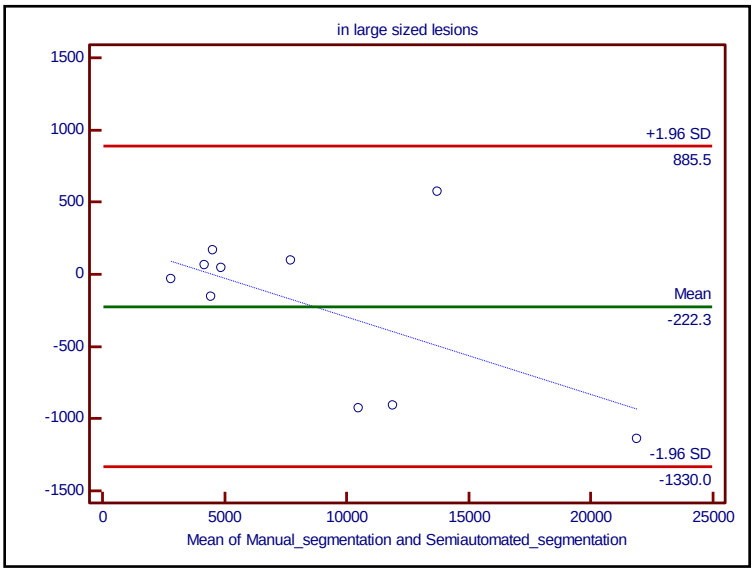
	Manual segmentation vs Semiautomated segmentation		
	Cronbach's alpha	**ICC**	**P value**
Small sized (n=17)	***0.994***	***0.989***	***<0.001****
Medium sized (n=9)	***0.970***	***0.942***	***<0.001****
Large sized (n=10)	***0.998***	***0.996***	***<0.001****

Bland-Altman plot analysis between the two methods in different-sized lesions

Manual segmentation vs Semiautomated segmentation	**Bland-Altman Plot**			
	Bias	**Limits of agreement**		**P value (linear regression)**
		Lower	**Upper**	
Small sized (n=17)	35.16	-32.73	103.05	*0.051*
Medium sized (n=9)	48.95	-127.66	225.57	***0.019****
Large sized (n=10)	-222.2	-1330	885.5	*0.087*


in small sized lesions
120
100
80
60
40
20
0
-20
-40
-60
+1.96 SD
103.0
Mean
35.2
-1.96 SD
-32.7
0
200
400
600
800
1000
Mean of Manual segmentation and Semiautomated_segmentation


in medium sized lesions
250
200
150
100
50
0
-50
-100
-150
+1.96 SD
225.6
Mean
49.0
-1.96 SD
-127.7
1000
1200
1400
1600
1800
2000
2200
Mean of Manual_segmentation and Semiautomated_segmentation



DISCUSSION

Cone Beam Computerized Tomography (CBCT) is a volumetric imaging modality used in the oral and maxillofacial field for diagnosis and treatment planning of both dental and non-dental pathologies including bone lesions. Bone lesions consist of cysts, benign and malignant tumors that may be clinically apparent or may be found incidentally on CBCT. [11]

In the current study, the DICOM data from CBCT scans were segmented using MIMICS, and InVesalius software. MIMICS software allows semiautomatic segmentation and interpolation between slices and detects the margins for saving time. InVesalius software provided manual segmentation and was included due to its easy availability for everybody on a free open-source basis.As in this study, many studies that evaluated the accuracy of different segmentation procedures have used manual segmentation as the gold standard.[12-14]

In this study, segmentation procedures were based on image thresholding. Since the segmentation process and the volume measurements are carried out in ideal conditions, the variability among the measurements may be attributed to the segmentation method itself and the threshold selection methods; semi-automatically using MIMICS and manually**.**

Concerning the operator-dependent reliability, manual and semi-automatic segmentation showed highinterexaminer agreement according to the ICC values and to the small volumetric differences found between the three recordings. **Weissheimer et al [15] also** compared the precision and accuracy of different imaging software programs including MIMICS and concluded thatthreshold adjustment is solely dependent on the operator; thus, checking theintegrity of the segmented object on 3 spatial planes is crucial.

Simple linear regression analyses for volume showed no statistically relevant p-value (0.051) for small and large-sized lesions respectively. While showed a statistically relevant p-value (0.019) for medium-sized

lesions. This can be explained by **Vallaeys K et al.**[14]who concluded thatcyst variability and the frequent absence of a strong grey gradient near their boundaries make the segmentation step difficult, which leads to an overextension of the segmentation beyond the limits of the lesion with the semi-automatic procedure. This leads to underestimation or overestimation of size. Even when utilizing the manual procedure, it is hard to segment accurately when boundaries are not sufficiently dense, robust, or discriminating.

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