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ACCURACY OF LINEAR MEASUREMENTS IN STITCHED CONE BEAM COMPUTED TOMOGRAPHIC IMAGES. AN IN-VITRO STUDY

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ABSTRACT

Introduction: Cone Beam Computed Tomography plays a major role in all specialties of maxillofacial region. This variability in applications necessitates variability in the available Field of View (FOV). However, large detector size might not be available in some machines. Stitching allows the fusion of 2 or more small volumes to form larger volumes. For that this study was carried out to evaluate the accuracy of linear measurements obtained from stitched CBCT images compared to direct real measurements.

Methodology: Twenty four skulls with mandibles were recruited from Anatomy Department, Faculty of Medicine, Cairo University. Two radiopaque gutta percha markers were glued on each skull and mandible at the nasion and mental ridge (at mid line) respectively. Each skull fixed to its mandible was placed on the CBCT machine Planmeca Pro Max 3D Mid® (Asentajankatu, Helsinki, Finland) in Oral and Maxillofacial Radiology Department at Faculty of Dentistry, Cairo University. For real measurements, the distance between the two markers was measured using digital caliper. The resultant images were evaluated using Planmeca Romexis Viewer version 4.4.0.R (Asentajankatu, Helsinki, Finland) and the CBCT measurements were performed by two blinded observers.

Results: The mean real measurement was 96.12 (±11.42) mm which was slightly greater than that of the CBCT measurement which is 95.43 (±11.39) mm. There was a good agreement between CBCT and real measurements. The level of inter-observer and intra-observer agreement is very strong regarding both real and CBCT measurements

Conclusion: Linear measurements driven from Stitched CBCT images are accurate and reliable for diagnostic purposes in maxillofacial region.

KEYWORDS: Linear measurements, Stitching, Stitched CBCT.

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INTRODUCTION

Cone Beam Computed Tomography (CBCT) plays a major role in maxillofacial region by assessing interested tissues in the three dimensions. This role is not limited to just reaching a proper diagnosis but also by sharing in treatment planning and assessing of different treatment outcomes[1,2,3].

The role of CBCT is not limited to implant planning and assessing pathological lesions. It extends to involve orthognathic surgery, orthodontics & endodontics[4,5]. This variability in applications necessitates variability in the available Field of View (FOV) (which is the volume to be included in the scan) and Resolution (voxel size)[6].

The dimension of FOV depends on the detector size, beam projection and the ability of beam collimation. As the manufacturing expense of the CBCT machine, great part of it, is from the cost of the detector, an approach is needed to allow scanning larger area of interest without the need for large detector size[7,8].

The solution of this problem was in stitching. Stitching is done through obtaining the raw data of 2 or more separate scans of small FOV and fusing them to form one volume of larger FOV [6,7].

Stitching can be performed in the vertical direction to increase the height of scanned volume or in horizontal direction to increase the width of scanned volume[7].

Stitching can be performed either manually by third party software as InVivo Dental, Anatomage (San Jose, CA, USA) or automatically by a special property in the CBCT system software as Romexis Stitching Program (Asentajankatu, Helsinki, Finland) in the vertical stitching and Kodak Dental Imaging Software (Carestream Dental, Atlanta, GA, USA) for horizontal stitching[1,7].

Stitching allows examination of larger volumes with higher resolution but it still suffers from some limitations as longer scan time which increases the possibility of motion artifact and doubling the exposures to the overlapped regions in the initial scans[1,6,7,9]

Accuracy of data obtained from 2D or 3D images, especially accuracy of linear measurements, is necessary for successful treatment planning. So linear measurements accuracy must be verified to stitched CBCT images but there is few studies that evaluate the accuracy of stitched FOV specially for vertical stitching[1].

So this study was aimed to evaluate the accuracy of linear measurements obtained from stitched CBCT images compared to direct real measurements.

Methodology

Twenty four skulls with mandibles were recruited from Anatomy Department, Faculty of Medicine, Cairo University. The selected skulls and mandibles were free from any fracture or abnormality that interferes with our study.

Two radiopaque gutta percha markers were glued on each skull and mandible at the nasion and mental ridge (at mid line) respectively. The skulls and mandibles were coated by a layer of pink wax of thickness 13–17mm[10] to simulate soft tissue in clinical situations of patients imaging. Then each skull was fixed to its related mandible using adhesive tape.

Each skull fixed with its mandible was placed on the CBCT machine Planmeca Pro Max 3D Mid® (Asentajankatu, Helsinki, Finland) in Oral and Maxillofacial Radiology Department at Faculty of Dentistry, Cairo University in a position simulating patient imaging and imaged using the following parameters: 90 kVp, 8 mA, resolution of 400 μm voxel and stitched field of view (FOV) (Ø20cm x 17 cm) from two FOV each of (Ø20cm x 10 cm), at an exposure time of 27 seconds.

After imaging of the skulls, the wax covering the two markers was removed carefully and the distance between the two markers was measured by two observers (each one was blinded to the other observer measurements) using digital caliper.

The resultant images were evaluated using Planmeca Romexis Viewer version 4.4.0.R (Asentajankatu, Helsinki, Finland) by two blinded observers (blinded to real measurements and to each other readings) after at least one month from real measurements in 2 separate sessions. One of the two observers repeated the measurements after 2 weeks of the first session.

For CBCT measurements: The slice thickness and slice gap were adjusted to be 1.2 mm. On the coronal image, the long axis of the sagittal cut was adjusted to pass through the two gutta percha markers. Then on the sagittal image, two tangential lines were drawn to the upper border of marker on nasion and to the lowest border of marker at mental ridge then the distance between both lines was measured (Figure 1).

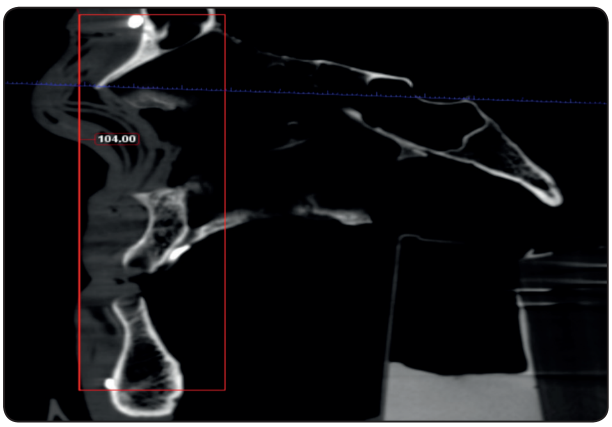

Fig. (1) On the sagittal image, two tangential lines to the upper border of marker on nasion and to the lowest border of marker at mental ridge were drawn and the distance between both lines was measured.

Statistical Analysis

1. Intra-observer and Inter-observer reliability scores:

Intra-class Correlation Coefficients were calculated to determine the level of agreement between:

(a) The first and second investigators records for both CBCT & real measurements

(b) The first investigator's dual CBCT records

Level of agreement is specified according to LeBreton and Senter (2008)[11] for inter-rater reliability coefficients. Coefficient ranges from 0.00 to 0.30 indicates lack of agreement and 0.31 to 0.50 as weak, 0.51 to 0.70 as moderate, 0.71 to 0.90 as strong, 0.91–0.100 as very strong agreement.

2. Descriptive analyses:

(a) Real and CBCT measurements were described in terms of mean, median, standard deviation (SD) and range.

(b) Bar charts representing means and standard deviations were used to graphically illustrate the comparison between Real and CBCT measurements.

3. Testing for normality:

To test for normality of the data, the Shapiro-Wilk test for normality was applied to choose the proper test for correlation and comparative analyses.

4. Comparative analysis:

(a) Mean difference (±standard deviation) between CBCT and real measurements was calculated.

(b) The non-parametric Mann-Whitney U test for paired data was used to assess the difference between real and CBCT measurements.

(c) Percentage difference (error) was calculated based on the following equation:

5. Assessing level of agreement between real and CBCT measurements:

Bland-Altman plots were used to demonstrate the level of agreement between the 2 techniques.

6. The significance level:

It was verified at $P<0.05$. The results are considered to be statistically significant if p-value was less than 0.05.

7. Statistical package used for this study:

R statistical package, version 3.3.1 (21-06-2016). Copyright (C) 2016. The R Foundation for Statistical Computing[12].

RESULTS

Descriptive and comparative analysis

- The mean real measurement was 96.12 (±11.42) mm which was slightly greater than that of the CBCT measurement which is 95.43 (±11.39) mm as shown in table (1).
- Although the mean real measurement was greater than that of the CBCT measurement by 0.69 (±1.45) mm, this difference was statistically insignificant (p-value = 0.05).

Assessment of the Level of Agreement

Most of the measurements were located between the upper and the lower limits of agreement (mean ± 1.96 SD). This indicates that the results of the CBCT and real measurements were not graphically different from each other and denoting good agreement between them. Given that the real measurements were higher than the CBCT measurements (line of mean difference above the zero.) (Figure 2).

Inter-observer and Intra-observer Reliability Assessment

The level of inter-observer and intra-observer agreement was very strong regarding both real and CBCT measurements [ICC > 0.99, p-value <0.0001] as shown in table (2).

TABLE (1) Descriptive analysis of the real and CBCT measurements (mm) - The means, medians, standard deviation (SD) and ranges – n= 24

	Mean	Median	SD	Range	
				Min	**Max**
Real measurement	96.12	98.9	11.42	71.95	118.35
CBCT measurement	95.43	98.07	11.39	71.33	118.8
Mean difference (SD)	**Mean Percentage difference (SD)**		**Mann-Whitney U test***		
			p-value**	**Interpretation**	
0.69 (±1.45)	0.72 (±1.42)		0.05	Statistically insignificant difference	

Results of the non-parametric Mann-Whitney U test for paired data.

*****Statistical significance at p-value <0.05.***

TABLE (2) Results of intra-observer reliability assessment – Intra-class Correlation Coefficient, 95% Confidence Interval (CI) and p-value.

	Intra-class Correlation Coefficient			Level of agreement
	ICC*	**95% CI**	**p-value****	
1st and 2nd observers' Real measurements	0.998	0.996 - 0.999	<0.0001	Very strong
1st observer's dual CBCT readings	0.999	0.997 – 1	<0.0001	Very strong
1st and 2nd observers' CBCT readings	0.999	0.998 – 1	<0.0001	Very strong

Intra-class Correlation Coefficient ranges from 0.00 to 0.30 indicates lack of agreement and 0.31 to 0.50 as weak, 0.51 to 0.70 as moderate, 0.71 to 0.90 as strong, 0.91–0.100 as very strong agreement. **Statistical significance at p-value < 0.05.

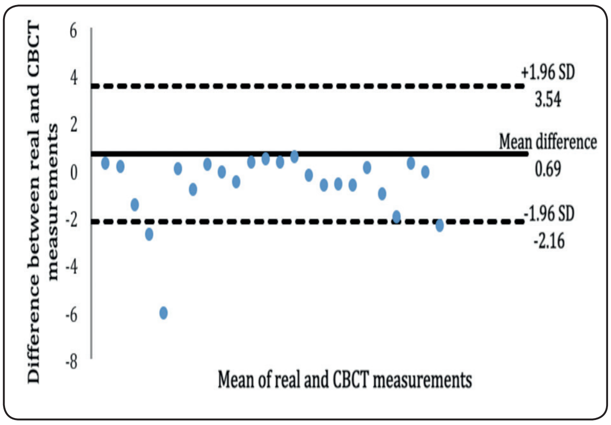

Figure (2): Assessing the degree of agreement between real and CBCT measurements - Bland-Altman plot

DISCUSSION

In our study, the mean real measurement was 96.12 (±11.42) mm which is slightly higher than that of the CBCT measurement which was 95.43 (±11.39) mm. This went with what of **Egbert et al 2015**[6] **& Baumgaertel et al 2009**[13] **who** found in their studies that CBCT measurements underestimated the real measurements.

While for the mean measurement difference which was 0.69 (±1.45) mm, it was in the same line with **Egbert et al 2015**[6] who found mean difference of 0.34 mm although that the distances measured in their study was much shorter (only intra-mandibular distance). According to **Tarazona-Álvarez et al 2014**[14]**,** using long measurements (100 mm), as in our study, increases the possibility of measurement error. In addition a 1-mm margin of error was considered clinically not significant in nearly all clinical dental procedures[6,15,16,17].

The results showed good agreement between stitched CBCT and real measurements. These results went with the result of **Srimawong et al 2012**[1] **& Kopp and Ottl 2010**[9] who found accurate agreement between real measurements and stitched CBCT measurements.

The level of inter-observer and intra-observer agreement is very strong regarding both real and CBCT measurements. This was in agreement with the results of **Srimawong et al 2012**[1] **& Kopp and Ottl 2010**[9] who found very strong intra-observer agreement in both real and CBCT measurements.

CONCLUSION

Linear measurements driven from Stitched CBCT images are accurate and reliable for diagnostic purposes in maxillofacial region.

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REFERENCES

1. Srimawong, P., Krisanachinda, A. & Chindasombatjaroen, J. Accuracy of Linear Measurements in Stitched Versus Non-Stitched Cone Beam Computed Tomography Images. in 6th Annual Scientific Meeting on Challenges of Quality Assurance in Radiation Medicine 46, 89–91 (2012).
2. Scarfe, W., Farman, G. & Sukovic, P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 72, 75–80 (2006).
3. Ahmad, M., Jenny, J. & Downie, M. Application of cone beam computed tomography in oral and maxillofacial surgery. Australian dental journal 57 Suppl 1, 82–94 (2012).
4. White, S. C. Cone-beam imaging in dentistry. Health Phys. 95, 628–637 (2008).
5. Miracle, A.C. & Mukherji, S.K. Conebeam CT of the head and neck, part 2: clinical applications. AJNR. Am. J. Neuroradiol. 30, 1285–1292 (2009).
6. Egbert, N., Cagna, D.R., Ahuja, S. & Wicks, R.A. Accuracy and reliability of stitched cone-beam computed tomography images. 41–47 (2015).
7. Scarfe, W.C., Li, Z., Aboelmaaty, W., Scott, S.A. & Farman, A.G. Maxillofacial cone beam computed tomography: essence, elements and steps to interpretation. Australian dental journal 57 Suppl 1, 46–60 (2012).

8. Scarfe, W. C. & Farman, A. G. What is Cone-Beam CT and How Does it Work? Dent. Clin. North Am. 52, 707–730 (2008).

9. Kopp, S. & Ottl, P. Dimensional stability in composite cone beam computed Tomography. Dentomaxillofacial Radiology 39, 512–516 (2010).

10. Schropp, L., Alyass, N. S., Wenzel, A. & Stavropoulos, A. Validity of wax and acrylic as soft-tissue simulation materials used in in vitro radiographic studies. Dentomaxillofacial Radiol. 41, 686–690 (2012).

11. LeBreton, J. M. & Senter, J. L. Answers to 20 Questions About Interrater Reliability and Interrater Agreement. Organizational Research Methods 11, 815–852 (2008).

12. R Core Team. R: A Language and Environment for Statistical Computing. (2016).

13. Baumgaertel, S., Palomo, J. M., Palomo, L. & Hans, M. G. Reliability and accuracy of cone-beam computed tomography dental measurements. American Journal of Orthodontics and Dentofacial Orthopedics 136, 19–25 (2009).

14. Tarazona-Álvarez, P. et al. Comparative study of mandibular linear measurements obtained by cone beam computed tomography and digital calipers. Journal of clinical and experimental dentistry 6, e271-4 (2014).

15. Wyatt, C. & Pharoah, M. Imaging techniques and image interpretation for dental implant treatment. The International journal of prosthodontics 11, 442 (1998).

16. Kobayashi, K., Shimoda, S., Nakagawa, Y. & Yamamoto, A. Accuracy in measurement of distance using limited cone-beam computerized tomography. The International journal of oral & maxillofacial implants 19, 228–232 (2004).

17. Torres, M. G. G., Campos, P. S. F., Segundo, N. P. N., Navarro, M. & Crusoe-Rebello, I. Accuracy of linear measurements in cone beam computed tomography with different voxel sizes. Implant dentistry 21, 150–155 (2012).