Accuracy Assessment of Linear Measurements Obtained by Cone Beam Computed Tomography at Different Voxel Resolutions: Comparative in-vitro Study

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Abstract

Purpose: To determine the accuracy of linear measurements (LM) at different voxel resolutions on various anatomic locations in cone beam computed tomography (CBCT).

Materials and Method: A total of 25 dried mandibles were used & 75 scans were performed in this study. 12 radiopaque markers were placed in the holes created by round carbide bur at different positions leading to 6 readings which were horizontal & longitudinal measurements in each mandible at various sites. The LM readings were taken first with the digital vernier calliper considering it as gold standard and later on CBCT at three different voxel resolutions i.e. 0.15mm, 0.30mm and 0.45mm by two observers blindly. FOV of the scan was 8 x 5 cm. The measurements were made between nearest points of radiopaque markers. ANOVA, post hoc test and intra class correlation was applied for comparison of the variables. P value < 0.05 was considered significant.

Results: On comparing the measurements taken by vernier calliper and at different voxel sizes of CBCT, no statistical significant different was found. Also, the post hoc analysis revealed no significant difference between measurements done by vernier calliper and CBCT at different voxel resolutions.

Conclusion: The measurements made on CBCT are strongly reliable even on changing the voxel size making it an efficient imaging tool in dentistry. LM made at higher voxel resolutions reduces patient exposure and are equally reliable.

Keywords: *Cone-Beam Computed Tomography, mandible, voxel, linear measurement.*

Introduction

Cone beam computed tomography (CBCT) has been proved to be a valuable diagnostic tool in craniofacial imaging not only because of its lower radiation exposure[1-5], but also for its short acquisition time, small physical size and moderate cost[6-8]. The treatment of various dental & maxillofacial diseases requires linear measurements (LM) between various anatomical landmarks and any measurement error may lead to significant consequences with likely treatment failure and patient morbidity. LM are useful in determining the proximity of impacted mandibular third molar with inferior alveolar canal or maxillary molars with floor of maxillary sinus, height and width of the bone needed for the implant placement, proximity of dento-maxillofacial pathology to vital structures and to determine growth pattern of cranio-facial structures in orthodontics.[9] LM made by CBCT are considered to be superior and accurate than 2D radiography which is unreliable.

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All the modern CBCT units have an option to alter resolution depending on the treatment planning. A reduction in image matrix size is desirable to increase spatial resolution and therefore provide greater image detail. Reducing the voxel size increases the spatial resolution of the images and arguably the accuracy of measurements in the image but it also increases patient's radiation exposure.[10]

In past, various studies[11-19] had been performed to study the effect of voxel size on accuracy of LM but has yielded different results. Patcas R et al[11] stated that voxel sizes affect the precision of measurements; and on the contrary Costa ALF[19] concluded that there is no effect of voxel size on LM accuracy.

Since, there is an inconsistency in the literature regarding the efficacy of CBCT and the influence of voxel size on the LM, our study aimed to determine the accuracy of LM at different voxel resolutions (0.15mm, 0.30mm & 0.45mm voxel) on various anatomic locations in CBCT.

As per the best of our knowledge and literature review, this study is one of a kind to determine the accuracy of LM made by CBCT on different sites and planes & at different voxel resolutions.

Materials and Method

The present study was conducted in the department of Oral Medicine & Radiology at ITS Dental College, Muradnagar, Ghaziabad, Uttar Pradesh. Ethical clearance was obtained from the institutional ethical committee prior to the study. A total of 25 dried mandibles were used.

In each mandible, holes were created with the help of round carbide bur. Gutta percha (radio-opaque marker), was subsequently placed in the space created. 12 radiopaque markers were placed at different position on each dried mandible leading to 6 readings in each mandible. The 12 radiopaque markers were placed as - 4 on right, 4 on left and 4 in anterior region of mandible. On the left side, 4 markers were placed in premolar – molar region in horizontal direction: - 2 on buccal side and 2 on lingual side; to make anterio-posterior measurements (fig. 1 a, b). On the right side, 4 markers were placed in premolar – molar region in vertical direction: – 2 on buccal side and 2 on lingual side; to make superio-inferior measurements (fig. 1 c, d). In the anterior segment, 4 markers were placed in symphysis region: 2 on buccal side and 2 on lingual side; to make anterio posterior & superio inferior measurements respectively; on buccal side lateral measurements were made by placing markers horizontally (fig. 1e) while on lingual side superio-inferior measurements were made by placing markers vertically (fig 1f).

The CBCT unit used in the present study was – NewTom GiANO with NNT software (New Net Technologies Ltd. Naples)

The Scans covered the mandibular anterior and posterior region till angle of the mandible bilaterally. During scan, the occlusal plane of the mandible was kept parallel to the floor by keeping the mandible in clear plastic jar which was half filled with water for soft tissue simulation. LM readings were taken by the two observer; first with the digital vernier calliper (Tiny Deal) considering it as a gold standard and then later the same was done on CBCT at three different voxel resolutions i.e. 0.15mm, 0.30mm and 0.45mm. The readings of LM of vernier calliper & CBCT at different voxel resolutions were kept blind while measuring.

On CBCT, superio-inferior measurements on anterior lingual aspect were made on sagittal section (fig. 2a); right superio-inferior buccal and lingual measurements were made on coronal section (fig. 2b); while anterior lateral measurements on buccal aspect and left anterio-posterior measurements on buccal and lingual aspect were made on axial section (fig. 2c) at all the voxel resolutions.

The measurements were made between nearest points of radiopaque markers.

The final Measurements made were:-

RSIB: Right Superio-inferior Buccal

RSIL: Right Superio-inferior Lingual

LAPB: Left Anterio-posterior Buccal

LAPL: Left Anterio-posterior Lingual

ALB: Anterior Lateral Buccal

ASIL: Anterior Superio-inferior Lingual

The statistical analysis was done by statistical software SPSS Version16.0. The mean values and standard deviation of different parameters were calculated. ANOVA and post hoc test were applied

for comparison between the groups. Inter-observer agreement was checked by Intraclass Correlation Coefficient (ICC). A p-value <0.05 was considered as significant.

Results

No statistical difference was found in between the LM made by vernier calliper and CBCT & strong reliability was found between the LM made on CBCT even after changing the voxel resolutions (fig 3a, 3b).

The intra-observer reliability evaluated using intraclass correlation coefficient [ICC] ranged between 0.99 - 1.0 for different measures.

Discussion

The advances in three-dimensional (3D) imaging such as CBCT offers significant advantages in both quantity and quality of data representing true anatomy. In dentistry LM play an important role in diagnosis and treatment planning. The discrepancies in LM may result in injury to nearby vital structures leading to treatment failure and morbidity. According to literature[20, 21] few authors had stated that CBCT underestimated the real distance between skull sites and others had stated[22, 23] that the measurements on CBCT are reliable and accurate.

In our study we have used 3 different sites i.e. right, left and anterior mandibular region & in each site both the buccal and lingual sides were considered. These sites were chosen as there are no studies in literature determining the linear accuracy at different sites. Also in our study both horizontal and longitudinal planes were taken into consideration as the published literature showed varied results. One study[24] claimed to overestimate the horizontal measurements whereas another study[25] claimed that distance in longitudinal directions (LD) are overestimated with CBCT.

The effect of factors such as system resolution and voxel size is undeniable on diagnostic accuracy of images, and a smaller voxel size is used to gain increased image resolution. By decreasing the voxel size image spatial resolution increases as there is a decrease in partial volume averaging.[26, 27] On the other hand, by decreasing the voxel size, the scan time increases, as does the probability of patient movement.[26] The matter of concern here is the increased patient dose which comes with increased resolution. This issue of increased radiation dose to children specifically for orthodontic purposes has been a major concern and source of discussion.[28]

Lascala et al[20] and Pablo et al[21] had stated in their studies that CBCT underestimated the real distances. These results are not in accordance to our study. In a study done by **Amir Reza et al[29]**, there was statistically significant difference between digital vernier calliper readings and CBCT readings which is not in accordance to our study.

Tustsumi et al[24] found that the measurements done in horizontal direction (HD) are overestimated with CBCT. On the contrary, **Yoshida et al[25]** found that the distance in the longitudinal direction (LD) was statistically overestimated from the actual length. These results are not in accordance to our study as we have measured longitudinal and horizontal dimensions as superio-inferior and anterio-posterior measurements respectively at three sites of mandible and we have not found any statistically significant difference between CBCT and actual LM in HD and LD.

Patcas R et al[11] found that the voxel sizes affects the precision of measurements. These results are not in accordance to our study. The studies done by F**ernandes et al,[13] Ehsan et al,[14] Ganguly R et al[16] and Yan Hui Sang et al[17]** have compared LM on different voxel sizes and found it to be statistically similar which is in accordance with our study.

Al Ekrish AA et al[30] found the accuracy of measurements to be more operator dependent with CBCT. This might be because most operators round off recorded measurements to the nearest 1 mm or 0.5 mm causing an error. In our study this error was avoided as the operators have measured the LM with an accuracy of 0.1mm and have not rounded off the measurements.

In conclusion, LM made by CBCT in our study are in consistence with that of vernier calliper which is considered as gold standard. The measurements made on CBCT are strongly reliable even on changing the voxel size, making the higher voxels more appropriate for LM. As per the best of our knowledge and literature review, this study is one of a kind to conclude that LM made by CBCT on different sites and planes & at different voxel resolutions are accurate. Further similar studies with larger sample size including maxilla and skull base are required. If those studies reflect findings similar to ours, CBCT may be considered as the gold standard imaging modality to determine the LM.

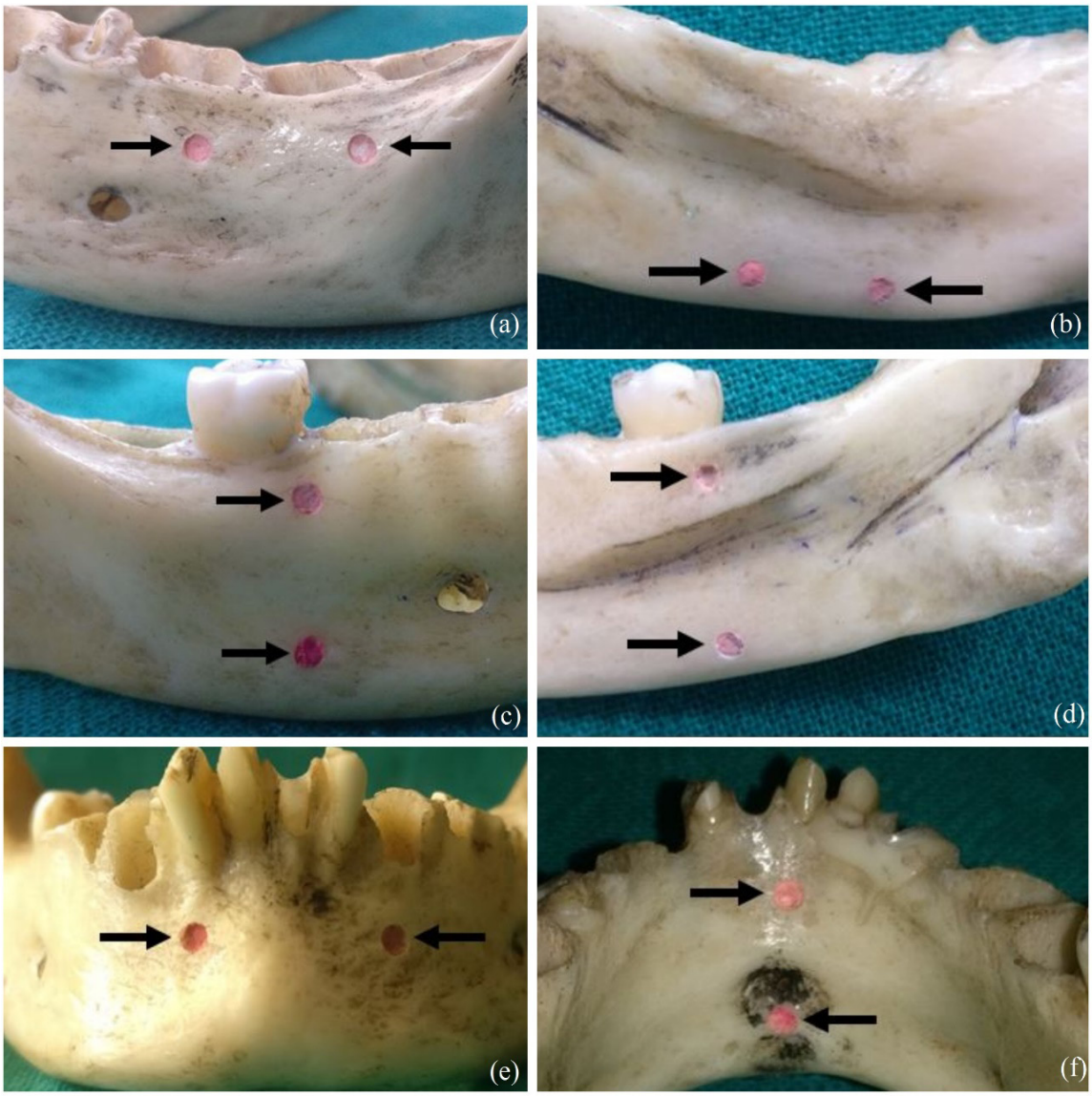

Figure 1: Radiopaque markers on mandible's (a) Left buccal side for anterio-posterior LM, (b) Left lingual side for anterio-posterior LM, (c) Right buccal side for superio-inferior LM, (d) Right lingual side for superio-inferior LM, (e) Anterior buccal side for anterio-posterior or lateral LM & (f) Anterior lingual side for superio-inferior LM.

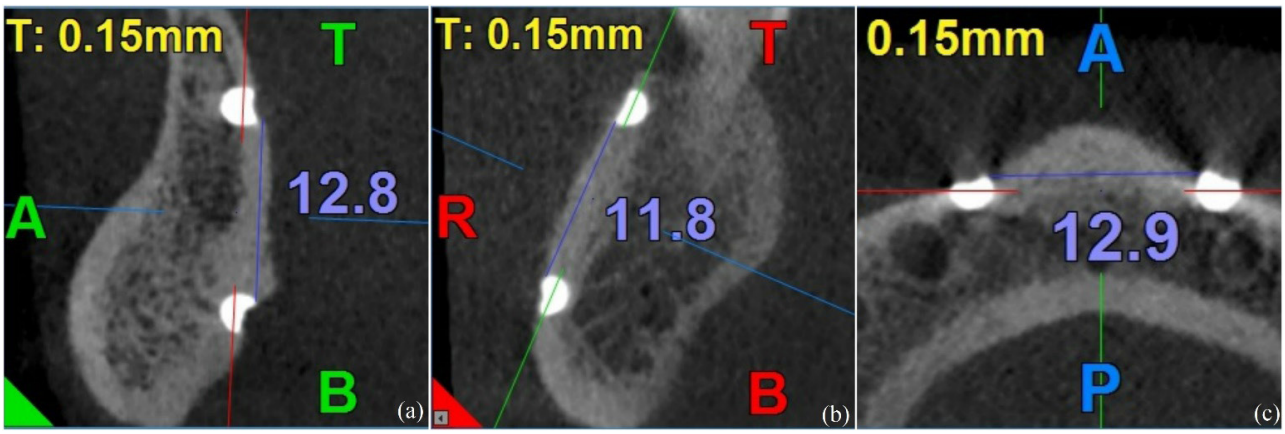

Figure 2: (a) ASIL measurement on sagittal section, (b) RSIB measurement on coronal section & (c) ALB measurement on axial section.

ALB					
	N	Mean	Standard Deviation	F value	P value
Vernier Calliper	25	13.628	2.7943	.005	1.000 (NS)
CBCT 0.15	25	13.528	2.7679		
CBCT 0.30	25	13.548	2.7671		
CBCT 0.45	25	13.576	2.7417		
CBCT Mean	25	13.552	2.7683		
ASIL					
Vernier Calliper	25	10.514	2.9798	.017	.999
CBCT 0.15	25	10.340	3.0130		
CBCT 0.30	25	10.328	2.9526		
CBCT 0.45	25	10.360	2.9925		
CBCT Mean	25	10.344	2.9919		
LAPB					
Vernier Calliper	25	11.308	2.6054	.021	.999
CBCT 0.15	25	11.152	2.4695		
CBCT 0.30	25	11.144	2.4624		
CBCT 0.45	25	11.144	2.4497		
CBCT Mean	25	11.156	2.4671		

Figure 3a: Mean and Standard Deviation of ALB, ASIL & LAPB measurements (mm) of different groups.

LAPL					
	N	Mean	Standard Deviation	F value	P value
Vernier Calliper	25	11.490	2.2519	.003	1.000 (NS)
CBCT 0.15	25	11.440	2.1894		
CBCT 0.30	25	11.468	2.2017		
CBCT 0.45	25	11.428	2.2343		
CBCT Mean	25	11.440	2.2108		
RSIB					
Vernier Calliper	25	13.371	2.4014	.014	1.000
CBCT 0.15	25	13.232	2.5215		
CBCT 0.30	25	13.252	2.4384		
CBCT 0.45	25	13.236	2.5786		
CBCT Mean	25	13.252	2.5118		
RSIL					
Vernier Calliper	25	14.931	2.7766	.022	.999
CBCT 0.15	25	14.720	2.7386		
CBCT 0.30	25	14.772	2.7578		
CBCT 0.45	25	14.768	2.7193		
CBCT Mean	25	14.752	2.7423		

Figure 3b: Mean and Standard Deviation of LAPL, RSIB & RSIL measurements (mm) of different groups.

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