Comparison of Hounsfield units between two CBCT units

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ABSTRACT

BACKGROUND
Cone-beam computerized tomography (CBCT) is a medical imaging acquisition system with a cone shaped X ray beam centered in a two dimensional detector. It allows the clinicians to analyse the craniofacial structures of jaw, bone and teeth in three dimensional resolution. It provides many advantages in dental treatments, planning with a lower radiation exposure.

AIM
The primary objective of our present study was to analyse and compare the hounsfield units between the two CBCT machines.

MATERIALS AND METHODS
A 3 dimensional radiographic phantom made up of poly methyl methacrylate (PMMA); clear acrylic. The length of the phantom measures about 4cm and width of 2.5 cm. This radiographic phantom contains four different materials : a lead foil, GP sticks, metal ball bearing and aluminium foil. The phantom was then scanned under two CBCT units : Kodak and Sirona at two different exposure parameters. The mean value of each density of materials was compared using a one way Anova test.

RESULTS
In our study, we analysed and compared the mean value of densities of 4 materials in radiographic phantom which was scanned at two different exposures. A pairwise multiple comparison was done using a one way Anova test. By comparing the densities between materials in the phantom, p value for each comparison was found to be < 0.05, hence it is statistically significant. Thus there is a significant difference in the hounsfield units (density) values of each material scanned under two different CBCT units with different exposure protocols but between units the values did not differ significantly ($p > 0.05$).

CONCLUSION
Within the limitations of the study, it was concluded that there is a significant difference in the densities of the material obtained between two CBCT units taken under two exposures using the phantom. It was found to be statistically insignificant. So, the pseudo hounsfield units in CBCT have to be used cautiously.

KEYWORDS
Bone density, Cone beam computed tomography, Hounsfield units, innovative technique

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INTRODUCTION

Cone-beam computerized tomography (CBCT) is a medical imaging acquisition system with a cone shaped X ray beam centered in a two dimensional detector. It allows the clinicians to analyse the craniofacial structures of jaw, bone and teeth in three dimensional resolution.[1] It provides many advantages in dental treatments, planning with a lower radiation exposure. It is one of the non-invasive methods of radiological evaluation of bone density that acts as an essential element for pre surgical implant planning.[2,3] For the successful implant treatment, it is necessary to analyse the bone quality and density with its height and width of bony structures. The specific density values obtained from the imaging system, termed as Hounsfield units (HU). These units are the standard measurement of density incorporated in relation to conventional CT units. It is more reliable in CT systems. As without these hounsfield units, it will be difficult to analyse the bone quality, internal structure of pathological lesions and to perform the scans through 2D and 3D images using DICOM software.[4] These hounsfield units provide us with an accurate bone density, for an implant placement and also to diagnose any lesions present in the anatomical structures.[5] There is a standard scheme used for scaling the renewable constriction coefficients in medical CT frameworks. Until this point of time, the producers of dental CBCT frameworks have not utilized a standard system for scaling the grey levels for representing the density values. Without such a framework, it is hard to decipher the grey levels of various CBCT machines.[6,7]

Digital Imaging and Communications in Medicine (DICOM), is software which provides the clinicians with conventional CT imaging. The images in two dimensional and three dimensional quality were used to assess bone density using the standard software.[8] Several studies have inferred that image artifacts and scattering ability will vary between the CBCT scanners, which can affect the accuracy of intensity values. This will provide images non eligible for assessing various bone density.[9] Despite the fact that CBCT is the modality of choice for bone analysis before the implant placement with an exact evaluation of bone and its anatomical structures.[10] Although CBCT shows some disadvantages such as beam hardening artefact with high radiation scattering effect.[11] It also has an ability to survey the bone thickness, and overall grayscale values which can be utilized for bone thickness assessment in dental procedures. However, many studies have illustrated that the bone density obtained by the grayscale in CBCT units has not yet been altered to analyse and conform the hounsfield units.[12,13] Previously our team has a rich experience in working on various research projects across multiple disciplines.[14-33] Now the growing trend in this area motivated us to pursue this project. An earlier study done by Katsumata et al recognised that CBCT imaging system was unable to provide an actual intensity value when compared to CT scans. The authors have found that estimated density obtained on a CBCT scan varied widely from a range of 21500 to over +3000 for different types of bone. Thus the study has concluded that the ability to perform and assess the density or quality of bone is restricted and in soft tissues, the HU seems to greatly differ.[34,35] An *in vitro* study performed with radiographic phantom, investigates the relationship between the grey levels and Hounsfield units present in dental CBCT scanners. It was found that there is a linear relationship between the grey levels and coefficients of each of the materials that exists with an "effective"energy.[36] The present study involves the acrylic radiographic phantom which is used to compare the density values of four materials between the two CBCT units. Thus the study aims to investigate and compare the density values obtained from the two different CBCT systems.

MATERIALS AND METHODS

A 3 dimensional radiographic phantom made up of transparent polymethyl methacrylate (PMMA); clear acrylic. The length of the phantom measures about 4 cm and width of 2.5 cm. This radiographic phantom consisted of four different materials: a lead foil, GP sticks, metal ball bearing and aluminium foil. These materials were located at the centre of the phantoms in a horizontal dimension of 1 cm (Figure 1). The phantom was scanned two times under two different CBCT units: Kodak and Sirona at two different exposure parameters. It was placed at the centre of the FOV, then the scout images were obtained. The data was reconstructed and transferred to the on Demand 3d Software. The artefacts with two different exposures were reduced under metal artifactual reduction algorithm (MAR) were noted. Then the mean value of each density of the material obtained was then statistically analysed using a one way anova test.

Figure 1. The Radiographic phantom consisting of lead foil, GP sticks, metal ball bearing, aluminum foil.

Our present study was performed using CBCT machines present in our University. A radiographic phantom containing four different materials was scanned under two different CBCT units: Kodak and Serena. CBCT analysis was performed and the phantom was scanned under two different exposures. Mean density value obtained for 4 different materials: 1) lead foil, 2) GP sticks, 3) Metal ball bearing 4) Aluminium foil. The Hounsfield units obtained from the DICOM software were tabulated. In table 1, the first column denotes the order of 4 different materials which was kept in the phantom. Second and third column represents the mean value of densities obtained for the materials under CBCT scans. The first exposure value kept under Kodak was about 120 kv / 6.3 ma, second exposure at 80 kv / mz. In Sirona, first exposure was at 85 kv/10 ma and second exposure at 85 kv / 7 ma. Mean density value for each material was tabulated and a pairwise multiple comparisons (Holm-Sidak method) were done to analyse the overall significance in the density values [Table 1]. By comparing the Hounsfield units between the materials, the difference in the mean was calculated. p value for each comparison was analysed by one way ANOVA. Here, the p value was found to be 0.15 which means it is statistically insignificant ($p > 0.05$) (Figure 1).

	CBCT MACHINES			
	KODAK		SIRONA	
MATERIALS IN PHANTOM	First exposure at 120 kv / 6.3 ma	Second exposure at 80 kv / 4 ma	First exposureat 85 kv / 10 ma	Second exposure at 85 kv/7 ma
1. Lead foil	993	1518	945	1450
2.GP sticks	1587	1732	1487	1632
3.Metal ball bearing	945	1450	1895	1675
4.Aluminium foil	316	516	415	315

Table 1. Comparison of derived Hounsfield units of materials in radiographic phantom

Thus our study has analysed that by comparing each densities of materials it is found to have significant differences in their mean values between different exposure protocols (Figure 2). In one way anova test, normality and equal variance analysis was done. It shows the differences in the mean value between the materials which is greater than would be expected by chance; there is a statistically significant difference (p value =< 0.05). When we compare the density values between units there was no statistically significant difference ($p > 0.05$). We observed that the density values of the materials were profoundly different when it was scanned under two CBCT machines. Likewise a study with similar findings, has illustrated that density values of soft tissues analysed using CBCT machines remain significantly different.[37] A previous study has compared and analysed HU and grey levels of CBCT, it was found that there is a strong correlation between CBCT and CT when soft tissues are scanned. These studies have revealed that there is a strong correlation between density values and grey levels in CBCT and CT, as it shows no significant variations in the results.[38] In our study we analysed and compared the radio density of materials at two different exposures. A similar comparative study done by Kim DG et al, evaluated the bone and soft tissues density which showed an accurate HUs and grey levels when kept at different kv/ma exposures.[39] A study done on the clinical applications of CBCT grey levels, have reported that CBCT scans taken under a fixed kvp value showed a poor correlation level when compared to other clinical studies.[40] Many studies have inferred that CT is considered as the modality of choice for bone density assessment for the implant placement with an approved accuracy. Recent studies also have reported that CBCT scans provide us with improved accuracy which is implemented in bone quality with lower radiation dosage.[41]

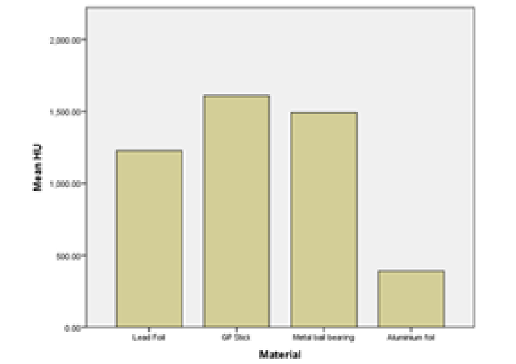

Figure 2. Bar graph showing the mean Hounsfield units for each of the material from the different exposure protocols.

DISCUSSION

Our institution is passionate about high quality evidence based research and has excelled in various fields.[42 - 51] A previousstudy with an opposing finding, estimated that grey levels in CBCT has not yet been clearly demonstrated as their correlation profoundly remains indefinite.[52] Our study has illustrated and compared the densities of 4 different materials which were scanned under two CBCT units (Kodak and Sirona) and it was found to have significant differences in their density values between different exposure protocols. A similar study done by Mah et al. stated that HUs and densities which were obtained from two different CBCT 1 and 2 are statistically found insignificant.[53] An earlier study reported by Reeves TE et al, illustrated that there are no significant differences between Hounsfield units of CBCT and CT estimated at different FOV.[54] In our study we found that two CBCT units are not same in terms of exposures, hardware and its reconstruction systems. Similar to our findings, a clinical study performed to analyse the high quality image acquisition with double exposures in dental cone beam computed tomography. It shows that density values obtained from certain CBCT models cannot be applied to other CBCT machines with different configurations.[55] However in our study the density values between two units were the same but the exposure protocols decided on the density values.

In our present we used a radiographic acrylic phantom comprising four materials, its density values obtained from 2 CBCT machines. A similar study has demonstrated the grey levels using NewTOM VG, 8 tissue phantom showed good correlation with grey levels of both CBCT and CT systems.[56] One study has been delineated that density values will differ from two CBCT units, so an utilization of calibrated phantom may give us an exact density assessment.[57] The present study had certain limitations as it is being performed within two CBCT machines, difference in the study methods, statistical analysis and scanner units. Thus the future extent of our study needs to be focused on developing the CBCT scanner units, as such to convert grey levels to Hounsfield units. This may provide us with an accurate density of the soft tissues and bones for implant placements and complex surgical procedures.

CONCLUSION

Within the limitations of our study, it was concluded that there is a significant difference in the densities of the material obtained between two CBCT units taken under two exposures using the radiographic phantom. It was found to be statistically insignificant. So, the pseudo Hounsfield units in CBCT have to be used cautiously.

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