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ULTRA-LOW-DOSE VERSUS NORMAL-DOSE SCAN PROTOCOL OF PLANMECA PROMAX 3 D MID CBCT MACHINE IN DETECTION OF SECOND MESIOBUCCAL ROOT CANAL IN MAXILLARY MOLARS: AN EX VIVO STUDY

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ABSTRACT

Objective: The aim of this study was to compare the ability of Normal and Ultra-Low-Dose protocols of Planmeca Promax 3 D Mid CBCT unit with different voxel sizes in detection of MB2 canal.

Materials and Methods: This study was conducted on 36 extracted human maxillary first and second molars. Six acrylic models were prepared and six molars were embedded in each model using Inlay wax. Each acrylic model was then placed in a plastic container filled with water. CBCT imaging of the acrylic models containing the extracted molars was taken by Planmeca ProMax 3D Mid machine (Helsinky, Finland). Each model was scanned with three different voxel sizes (0.075, 0.1, 0.2 mm) and two different exposure protocols, namely the Normal-Dose (ND) and the Ultra-Low-Dose (ULD) protocol. Assessment of the number of MB canals was carried out by two Oral and Maxillofacial Radiologists. To verify the number of root canals of the mesiobuccal root, these roots were sectioned and visually inspected. The data obtained were tabulated and subjected to statistical analysis.

Results: Transverse sections showed that 22 molars had two mesiobuccal root canals and 14 molars had only one mesiobuccal root canal. The results showed that the sensitivity and accuracy of CBCT images increase as the voxel size decrease. However, the results revealed no significant difference ($p>0.05$) between the (ND) and (ULD) protocol of the same voxel size used. Both intra and inter-observer reliability showed very good agreement (0.81–1).

Conclusions: ULD CBCT protocol can be applied for the detection of MB2 of maxillary molars. The smaller the voxel size, the higher the image resolution and image quality. The 0.075 mm voxel size of both protocols is accurate enough to be used as a gold standard in laboratory studies instead of the standard root sectioning technique.

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INTRODUCTION

Despite being physically small as compared to other tissues in the body, dental pulp may cause severe and intense pain if inflamed. Success of endodontic treatment depends on locating, mechanically preparing and obturating the root canals.[1] Because of their size and variable morphologies, root canal systems are often a challenge to both properly find and treat. Therefore, a thorough knowledge of the anatomy of root canal systems is crucial to avoid failure of endodontic treatment and recurrence of painful attacks to the patient. Particularly challenging for endodontists is the internal anatomy of the maxillary first and second molars.[2] The presence of second canal in the mesiobuccal root of maxillary molars has been the topic in numerous studies over the years.[3,4] In literature, this canal was named either second mesiobuccal canal (MB2) or mesiolingual canal.[2] Depending on the method of its detection, the frequency of MB2 canal ranges between 18.6% -96.1% .[5,4]

Finding this canal clinically is often not an easy procedure mainly due to the excess dentinal growth on its orifice.[6] Recently, adjunctive tools like magnifying loupes and dental operating microscopes have been increasingly used to facilitate the finding of these canals in clinical practice.[7] Although magnification improved the detection of extra root canals, these microsurgical tools did not show the complete length of those canals. Furthermore, the presence of water and improper access preparation may lead to failure of detection of MB2 canal.[8] Conventional radiographic techniques, although still most commonly used, showed less than 40% chance of locating MB2 canal.[9] Even digital techniques and improving film quality did not improve the detection ability of MB2 canal as the two-dimensional projection remains the main limiting factor of such techniques.[10] Lately, CBCT have attracted the attention in various dental fields.[11] Although the main applications of CBCT in dentistry are still in implant planning and surgical procedures[12,13], many other options are still under research and investigation. In endodontics, several applications of CBCT have been explored. These include evaluation of periapical pathosis, root fractures, root resorption, monitoring healing of apical lesions and assessment of tooth internal morphology.[1] The ability of CBCT to provide 3-dimensional reconstructions and to eliminate any superimposition of the internal tooth anatomy has proven to be very beneficial.[14]

It is important to mention that in CBCT, the selection of image resolution depends on the application it is used for. Generally, endodontic applications require high resolution and therefore small voxel sizes and consequently higher radiation dose. [1]

However, although the radiation dose of CBCT is dozens of times lower than conventional medical CT it is still higher than conventional 2 D methods.[15,16] Therefore, the benefits from using CBCT must outweigh the risk to the patients. Recently, Planmeca Promax 3D Mid added the Ultra-Low-Dose imaging protocol to its machine. Planmeca ULD can be used with all voxel sizes and in all imaging modes from normal to endodontic mode.

This imaging protocol is based on intelligent 3D algorithms. The mA-values, in particular, can be individually adjusted for each patient. When applied, the Planmeca ULD protocol will lower the current values and shorten the x-ray pulse needed for each frame. This will lower the patient dose and also shorten the rotation time making the scan less susceptible to motion artifacts. However, the ULD protocol does not take fewer frames or use a smaller rotation angle to decrease the patient's dose. For this reason, the ULD protocol can be used at any resolution and any field of view. Nowadays Planmeca ULD algorithm has an effective dose between 4 to 22 or 10 to 36 μSv. However, there are still no evidence-based criteria that determine the ideal CBCT scan parameters in demonstrating small anatomical structure such as MB2 canal.

Therefore, the aim of this study was to compare the ability of ND and ULD of Planmeca ProMax 3D Mid CBCT machine to detect MB2 canals in maxillary molars by 3 different voxel sizes.

MATERIALS AND METHODS

This study was conducted on 36 extracted human maxillary first and second molars. These molars were extracted for other treatment purposes and not for the purpose of this study. Molars recruited in the study were obtained from the outpatient clinic of the Oral Surgery Department, Faculty of Dentistry, Cairo University. The molars were stored in 5% sodium hypochlorite solution for at least 7 days for disinfection. Next, the teeth were left to dry air for 24 h.They were then carefully inspected and those with cracks, root fracture, improperly formed roots, root resorption, root and furcation caries and open apices were excluded. Six acrylic models were then prepared and six molars were embedded in Inlay wax (Inlay Wax 774 Veco Dent Co Italy) in each model for support. For identification, the acrylic models and the teeth were numbered with a black permanent marker.

CBCT imaging of the acrylic models containing the extracted molars was taken by Planmeca ProMax 3D Mid machine (Helsinky, Finland) in the outpatient clinic of the Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University. Each model was scanned with three different voxel sizes (0.075, 0.1, 0.2 mm) and two different exposure protocols, namely the Normal and the Ultra-Low-Dose protocol and each side with the three maxillary molars was scanned separately in order to obtain the smallest field of view with the smallest voxel size (0.075mm). In order to standardize the imaging technique, all scans were taken at 90 kVp and 50x40 mm (Tooth) (delete it) voxel size.

To simulate soft tissues during CBCT imaging, each acrylic model was placed in a plastic container filled with water. The plastic container was then placed on the machine by the aid of a plastic board of 1.5 cm height. The acrylic model was adjusted by the aid of the triple laser beam system in the machine.

The acquired images were processed with the Romexis software. The scans were analyzed in a PC running Microsoft Windows 10 (Microsoft Corp, Redmond, WA, USA). Assessment of the number of MB canals was carried out by two Oral and Maxillofacial Radiologists. The radiologists assessed the number of MB canals of the maxillary molars using Planmeca Romexis Viewer 4.5.0.R, on axial and corrected coronal cuts**.** The radiologists were free to adjust the brightness and contrast of image. In order to avoid bias, the radiologists were blinded from the scanning parameters during the assessment. The readings were repeated after two weeks interval for inter- and intra-observer agreement.

TABLE (1) DAP, CTDI and exposure time for each voxel size for ND and ULD protocol

Voxel size (mm)	0.2 (Normal Resolution)	0.1 (High Resolution)	0.075 (Endo mode)	0.2ULD (Normal Resolution	0.1ULD (High Resolution)	0.075ULD (Endo mode)
DAP(mGycm2)	339	529	661	79	127	159
CTDI (mGy)	5.8	9.2	11.4	1.3	2.2	2.7
Exposure time(s)	12	12	15	4	4	5

The observations were recorded as follows:

1 = MB2 was detected

0 = No MB2 was detected

To verify the number of root canals of the sample teeth, the mesiobuccal roots were sectioned at the laboratory of the Oral Pathology Department, Faculty of Dentistry, Cairo University. Each mesiobuccal root was resected and cut into two sections with Bronwill hard tissue microtome (Bronwill LBQ 094 VWR 77 machine). The first was made 3 mm coronal to the root apex, and the second cut was made 6 mm coronal to the apex. The number of root canals present in each section was confirmed by the use of an endodontic explorer, blue dye and a magnifying lens.

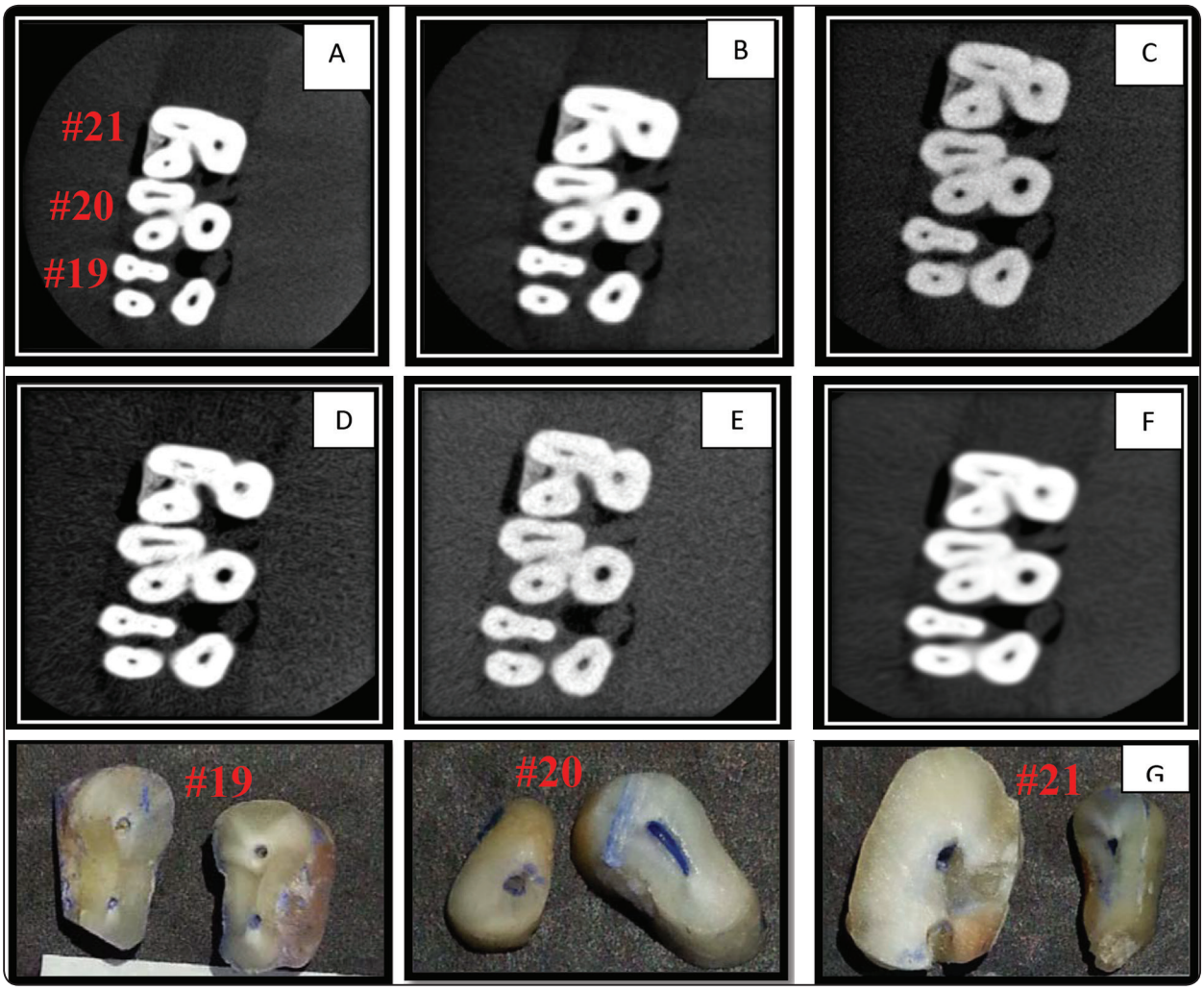

Fig. (1) Images of CBCT scans of the same teeth using different voxel sizes with ND and ULD protocol (A) 0.075 mm ND protocol (B) 0.1 mm ND protocol (C) 0.2 mm ND protocol (D) 0.075 mm ULD protocol (E) 0.1 mm ULD protocol (F) 0.2 mm ULD protocol. The MB2 canal was found on tooth (19) only (G) Transverse sections of the MB root of the same teeth

RESULTS AND STATISTICAL ANALYSIS

All Data were collected, tabulated and subjected to statistical analysis. Statistical analysis was performed by SPSS in general (version 17). Microsoft office Excel was also used for data handling and graphical presentation.

For diagnostic testing statistical analysis, sensitivity, specificity, positive predictive values, negative predictive values and test diagnostic accuracy were calculated with the 95% confidence limits for different voxel sizes. Statistical test of significance were carried out using z test for comparing two proportions.

For both inter and intra-observer reliability analysis, kappa measure of inter rater agreement was applied. Significance level was set at $P < 0.05$ and two tailed test assumption was applied all through the analysis.

In this study the transverse sections showed that 22 molars had two mesiobuccal root canals and 14 molars had only one mesiobuccal root canal.

For 0.075 mm (ND) & (ULD), the results obtained by the two observers in two readings were identical to the gold standard. Both sensitivity and test accuracy were 100%. For 0.1mm (ND), the sensitivity ranged from (95.5-100%) and the test accuracy ranged from (97.2-100%). However, for 0.1mm (ULD) the sensitivity ranged from (90.9-95.5%) and the test accuracy ranged from (94.4-97.2%). For the 0.2mm, ND and ULD protocol, both sensitivity and test accuracy showed lower values than the previous results. The sensitivity of the 0.2mm ND ranged from (86.4-90.9%) while the test accuracy ranged from (91.7-94.4%). The least values were obtained by the 0.2mm (ULD) in which the sensitivity ranged from (81.8-86.4%) and the test accuracy (88.9-91.7%). These results showed that there was a statistically significant difference in the sensitivity between the different voxel sizes of both protocols. Regarding the test accuracy, there was also a statistically significant difference between all used voxel sizes of both protocols but with the exception that there was no statistically significant difference between 0.075 and 0.1 mm ND and 0.1 and 0.2 mm ULD protocols. The specificity of all used voxel sizes with both protocols showed a 100% value which means that they are all equally specific.

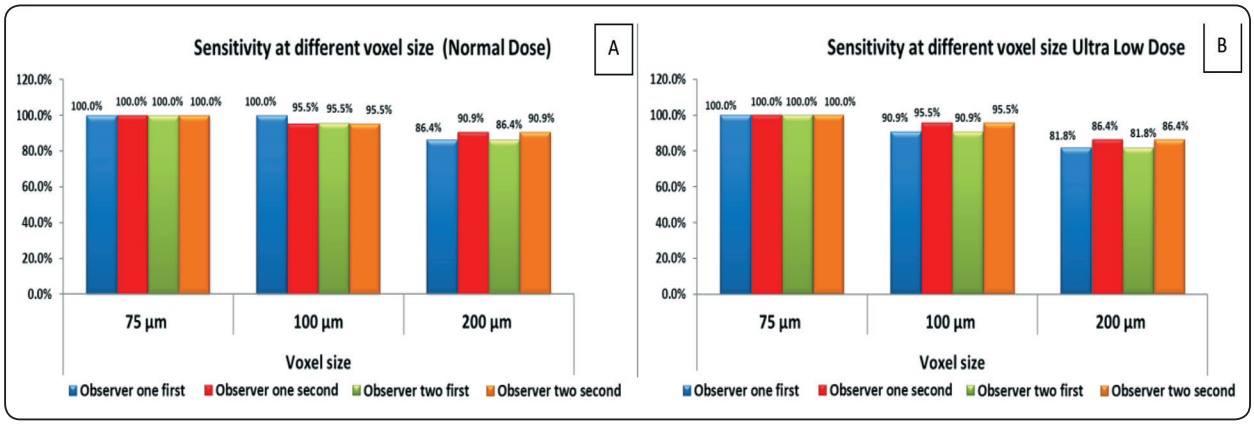

Fig. (2) Bar chart showing the sensitivity of the different voxel sizes for A) Normal and B) ULD protocol

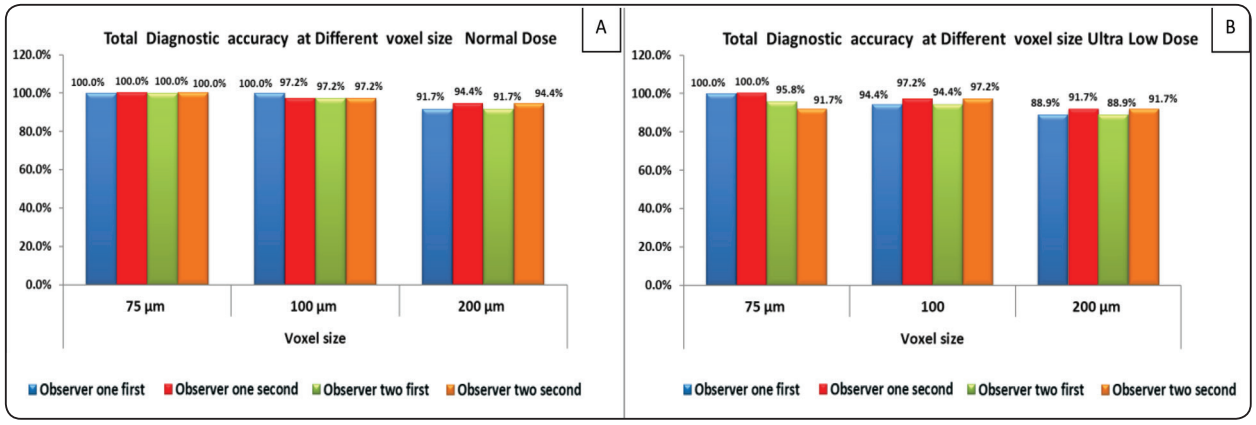

Fig. (3) Bar chart showing the test accuracy of the different voxel sizes for A) Normal and B) ULD protocol

On the other hand, the results of this study showed no significant difference ($p>0.05$) in the sensitivity and test accuracy between ND & ULD protocol for the same voxel sizes used.

For Inter- and Intra-observer Reliability, the weighted Kappa coefficient test was used to assess inter-and intra-observer agreement. Both showed very good agreement (0.81–1) in the detection of MB2 canal in maxillary molars.

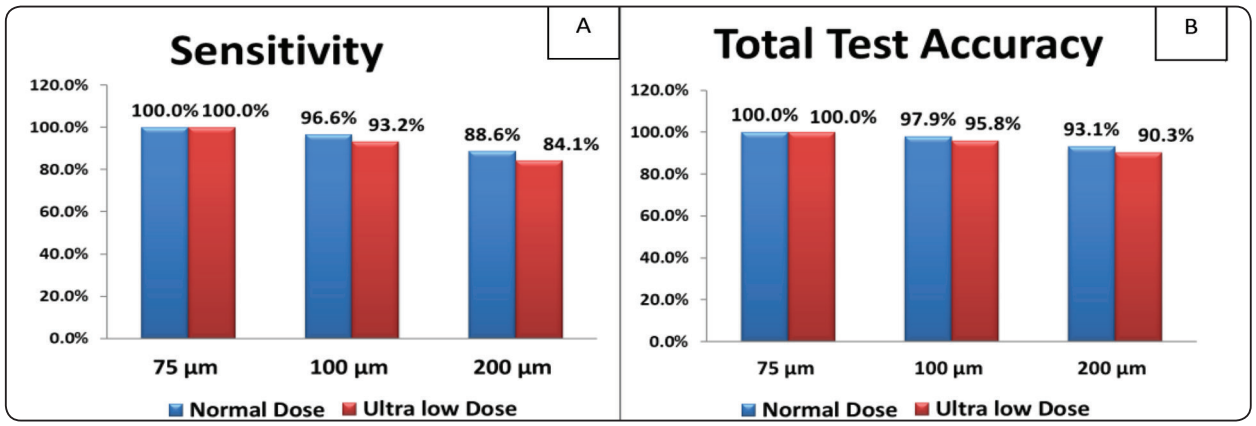

Fig. (4) A) Bar chart showing a comparison between the sensitivity of both protocols for all used voxel sizes. B) Bar chart showing a comparison between the test accuracy of both protocols for all used voxel sizes.

DISCUSSION

The identification of a second mesiobuccal root canal in maxillary molars has been probed in many studies using different techniques. Those studies included intraoral radiographs, magnification tools, dye injection and even the use of scanning electron microscope.[16, 17] However; all these techniques showed some limitations in locating the MB2 canal.

During the past few years CBCT has attracted the attention in different fields of dentistry, but only recently CBCT became a feasible option in endodontics.[1] CBCT allows accurate high resolution three dimensional observation of the internal tooth anatomy without any superimpositions.[14] Therefore, CBCT imaging prior to complex root canal treatment may help to increase the success rate of

its endodontic treatment. The CBCT radiation dose however; although much less than conventional CT scans; is still higher than intraoral radiographic techniques. According to the ALARA (As Low as Reasonably Achievable) concept, any radiographic examination must provide the diagnostic ability at minimum radiation exposure to the patient. Even though CBCT is considered reasonable for evaluating the presence of MB2 according to the basic principles of justification of means and aims; reducing the radiation dose should be considered. The risk of radiation induced cancer is definitely greater from CBCT scans than conventional intraoral radiographic techniques. [18] Planmeca recently added the ULD protocol to its CBCT machines. This protocol significantly reduces the exposure to the patients. According to Planmeca, ULD protocol can be used with all voxel sizes and in all imaging modes from Normal to Endodontic mode. They added that this protocol reduces the effective patient dose by an average of 77% without a statistical reduction in image quality. Planmeca also reported that the radiation dose of the ULD protocol is less than the radiation dose of panoramic radiography. However, selection of the optimal protocol and exposure factors is highly recommended for dose optimization for different diagnostic tasks. [19, 20] Therefore, evaluation of the ULD protocol image quality for different dental applications must be evaluated before the recommendation of its use. In this study, we evaluated the ULD protocol in the detection of the MB2 canal in extracted maxillary molars.

Katsumata et al., 2007 reported that CBCT image quality is affected by the scanning protocol used. [21] They reported that voxel size, exposure settings, field of view (FOV), and detector type, all affected the detection accuracy of CBCT machines. Scarf et al., 2009 noticed the advantages of using small FOV in different endodontic applications.[1] They explained that images obtained from small FOV have higher spatial resolution because of the smaller voxel sizes that can be obtained.

On the other hand, the radiation dose of CBCT depends on several factors which include voxel size. Small voxel size requires more acquisition time, which increases the radiation dose to the patient. [22] However, for the same voxel size the ULD protocol significantly reduces the radiation dose.

In this study we used the smallest FOV (50×40mm) of Planmeca ProMax 3D Mid CBCT unit in order to scan the acrylic models with the smallest voxel size (0.075 mm endodontic resolution). The acrylic models were also scanned with (0.1 mm, 0.2 mm) voxel sizes which have acceptable resolution but offer lower radiation dose.

For ND Protocol, the scanning time was 15s for the 0.075mm voxel size, 12sec for both 0.1 and 0.2 mm voxel sizes. On the other hand, the scanning time for the ULD protocol was 5 sec for 0.075mm voxel size and 4 sec for both 0.1 and 0.2 mm voxel sizes. The DAP of the ULD protocol was much lower than that of ND protocol as seen in Table (1). Based on the results of this study the sensitivity and the accuracy of both CBCT protocols for the same voxel size showed no statistically significant difference (p-value > 0.05). However, there was a statistically significant difference in the sensitivity between the results of 0.075mm, 0.1mm and 0.2mm voxel size of the ULD protocol which showed 100%, 93.2% and 84.1% respectively. The results of this study came not much different from those of Liljeholm et al who stated that the image quality of the ultra-low dose high definition (UL-HD) and the ultra-low dose medium definition (UL-MD) protocols were comparable in a lot of situations.[23] They added that the improved geometric accuracy with UL-HD comes at the expense of almost a 25% increase in dose. They advised that when geometric accuracy is not critical for correct diagnosis, the UL-MD protocol may be recommended.

Regarding the CBCT assessment of the MB2 canal, the 0.075mm voxel size for both Normal and ULD protocol showed 100% sensitivity as compared to the clinical sectioning. Therefore,

the ULD protocol can be employed to detect the MB2 canal because it is with acceptable diagnostic accuracy and reduced radiation exposure.

However, the current study showed that increasing the acquisition resolution of CBCT for both ND and ULD protocols improves the detection of the MB2 canals of maxillary molars. These results come in agreement with Bauman et al., 2011 who also used CBCT (iCAT_Classic Imaging Sciences International, Hatfield, PA, USA) with different voxel sizes to detect the MB2 canal.[10] In their study, although they used 0.4, 0.3, 0.2 and 0.125 mm voxel sizes, they similarly found that the accuracy of CBCT scans in detection of MB2 canal increases as the voxel size decreases. Furthermore, Vizzotto et al., 2013 compared CBCT with different voxel sizes (0.2, 0.25, and 0.3 mm) and conventional periapical radiographs in detection of second mesiobuccal canal in maxillary molars when the MB1 canal was unprepared, filled, and when filling was removed and canal was reprepared.[24] They concluded that the MB1 root canal condition did not influence MB2 canal detection accuracy in 0.2 mm voxel size. However, the presence of root canal fillings in the MB1 canals reduced the detection accuracy of MB2 canals in the 0.25 and 0.3 mm voxel sizes. These results were in agreement with the current study in which the smaller voxel sizes showed higher image accuracy.

From the above mentioned results we can recommend the use of 0.075 mm voxel size of both protocols as the gold standard when evaluating the MB2 canals in ex vivo studies as it showed 100% sensitivity in detection of MB2. Again, it's important to mention that the DAP of the ULD protocol for the 0.075mm voxel size was significantly lower (76%) than that of the 0.075mm voxel size ND protocol. However, it is worth mentioning that ex vivo studies offer the advantage to exclude other factors that might affect the image quality. Therefore, it should be noted that in clinical situations, the image quality may be reduced by metallic and/or motion artifacts.[25,26]

In this study the prevalence of MB2 canal was found to be 61.1% of the included maxillary molars. This prevalence was very similar to that of Filho et al and Smadi and Khraisat who found the MB2 canal in 67.14 % and 63.9% respectively.[12, 16] In this study both magnification and brightness tools of the viewing software improved the detection of the MB2 canal. This comes in agreement with other studies which also showed that magnification increased the ability to detect root canals. [27, 26]

Furthermore, it is also important to report that although the results of this study are promising regarding the application of ULD in detection of MB2 canal, the ULD protocol is still a relatively new addition and that only few studies were performed to evaluate its applications.

CONCLUSIONS

ULD CBCT protocol can be applied for the detection of MB2 of maxillary molars in ex vivo studies. The smaller the voxel size used, the higher the image resolution and image quality. Although the image quality was reduced as compared to the ND protocol, there was no statistical significant difference between the two protocols for the same voxel size. In addition, the high resolution0.075 (mm voxel size) of both protocols is accurate enough to be used as a gold standard in laboratory studies instead of the standard root sectioning technique. As the ULD protocol is still a new update, further studies are needed to explore its applications especially in clinical situations as it offers a much lower radiation dose.

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