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Cone-beam computed tomographic reconstructions in the evaluation of maxillary impacted canines

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ABSTRACT

Purpose: Prior to cone-beam computed tomography (CBCT), orthodontic competence included radiological interpretation. Nevertheless, maxillary impacted canines (MICs), because of their position and adjacent complex anatomy, have been challenging to interpret, particularly with regard to root resorption. Although CBCT cross-sectional reconstructions of MICs yielded clearer insights into its diagnosis and treatment planning, the value of simultaneously using 2 different cross-sectional or multiplanar reconstructions of the CBCT datasets - orthogonal and curved/panoramic multiplanar reconstructions - has hitherto not been considered.

Materials and Methods: Both orthogonal and curved/panoramic multiplanar reconstruction series of 5 screenshots were each reconstructed from the 5 cm × 5 cm CBCT datasets of 15 separate MICs. Fifteen credentialled and experienced orthodontist volunteers reviewed 2 separate PowerPoints of 15 randomized series each, 1 week apart. Their review considered 6 factors that could affect treatment: the position and level of the MIC, the presence or absence of root resorption, ankylosis, cysts, and dilaceration.

Results: All 15 orthodontists were statistically similar regarding overall years of experience and of CBCT use. Although either reconstruction alone allowed the orthodontists to determine whether ankylosis and, to a lesser extent, most of the other features were present or absent in the MIC, reviewing both reconstructions together was necessary to determine whether root resorption was present or absent in the adjacent tooth.

Conclusion: Reviewing both orthogonal and curved/panoramic multiplanar reconstructions was necessary to evaluate the presence or absence of root resorption in the teeth adjacent to MICs and that of many other features. ***(Imaging Sci Dent 2023; 53: 145-51)***

KEY WORDS: Tooth, Impacted; Root Resorption; Cone-beam Computed Tomography; Tooth Ankylosis

Introduction

Maxillary canines are among the most frequently impacted maxillary teeth due to their high developmental position within the maxilla and their long eruption pathway, the longest of any tooth; therefore, the diagnosis of maxillary impacted canines is essential to achieve optimum functional occlusion and aesthetics.[1] Furthermore, maxillary impacted canines are located at the "corner" (hence its name translated as "corner tooth" in German and Nordic languages) between the almost sagittally directed posterior sextant and coronally directed anterior sextant of the dental arch, which makes their radiological visualization challenging. When cone-beam computed tomography (CBCT) debuted in 1999, the principal modality used in orthodontics was conventional radiography;[2] this was prescribed and interpreted by orthodontists alone. Studies comparing conventional radiography and CBCT revealed that they not only produce different diagnoses and treatment plans for maxillary impacted canines,[3-9] but also different treatment outcomes; CBCT reduced the treatment time by an average of 4 months.[10]

The 2 basic reconstructions of a CBCT dataset are 3-dimensional (3D) (volumetric reconstruction) (Fig. 1) and cross-sectional imaging. Although the volumetric recon-

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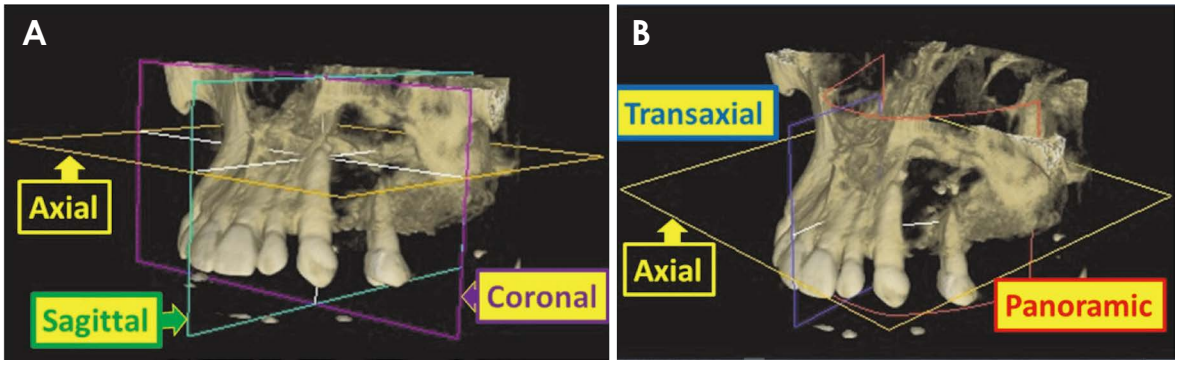

Fig. 1. An 8 cm × 8 cm field-of-view of cone-beam computed tomography of a lesion (not found in this study). A. The orthogonal MPR displays the axial (yellow), coronal (purple) and sagittal (green) planes. B. The panoramic plane (red) is constructed by the operator from the axial plane (yellow). The trans-axial plane (blue) is automatically produced perpendicularly from the panoramic plane. MPR: multiplanar reconstruction.

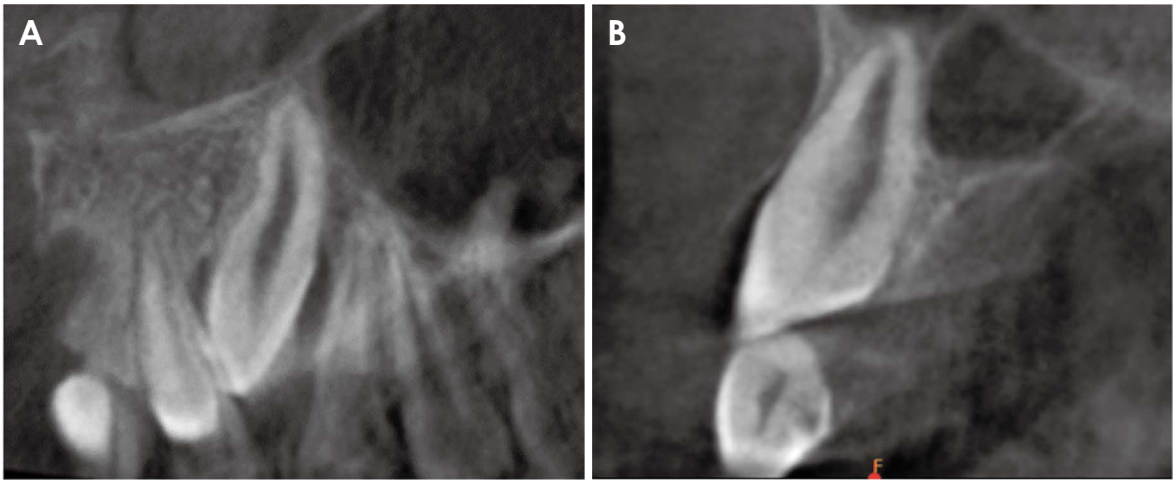

Fig. 2. Both multiplanar reconstructions (MPRs) are reconstructed from the same dataset of a case displaying root resorption of the tooth adjacent to the maxillary impacted canine. A. Orthogonal MPR. B. Curved/panoramic MPR.

struction features prominently in medical radiological literature, it appears only occasionally in the dental literature, such as in a case of Monckeberg's atherosclerosis of the external carotid artery and its branches.[11,12] Standard cross-sectional imaging (multiplanar reconstructions; MPRs) includes the orthogonal MPR, which displays the traditional anatomical planes (axial or transverse, coronal, and sagittal Fig. 1A), which are perpendicular to each other. This reconstruction has been used in most of the aforementioned reports.[3,6-8] Others used the "curved" or "panoramic" MPR.[5,9,10] Prior to the advent of CBCT, the curved/panoramic MPR was initially created for medical computed tomography as Dentascan[13,14] to assist dental implantologists.[13] Unlike the orthogonal MPR, which is generated spontaneously upon opening the dataset, the curved/panoramic MPR requires the operator to plot out the dental arch on the axial reconstruction (yellow plane in Fig. 1B) from which the panoramic reconstruction (curved red plane in Fig. 1B) is generated by the software. At the same time, the trans-axial image (blue plane in Fig. 1B) is created, exactly perpendicular to the panoramic reconstruction. Although almost all studies have used either orthogonal or curved/panoramic MPRs, revealing that CBCT was superior to conventional radiography in the evaluation of maxillary impacted canines,[3,5-10] no study has used both.

Although the literature is replete with publications on orthodontic criteria for prescribing CBCT,[15-17] there is little with regard to the specific features to be looked for, other than root resorption of the tooth adjacent to the maxillary impacted canine (Fig. 2B).[15,18] In addition to root resorption, dilaceration (Fig. 3A), and potential cystic formation on the maxillary impacted canine (Fig. 3A), CBCT can

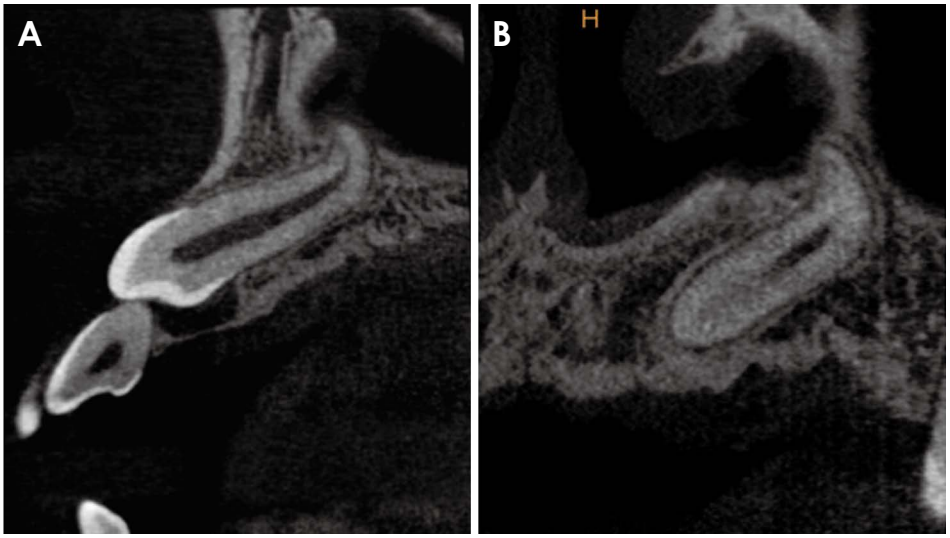

Fig. 3. Both multiplanar reconstructions (MPRs) are reconstructed from the same dataset of a case displaying dilaceration of a maxillary impacted canine. A. Orthogonal MPR displaying potential cyst formation. B. Curved/panoramic MPR.

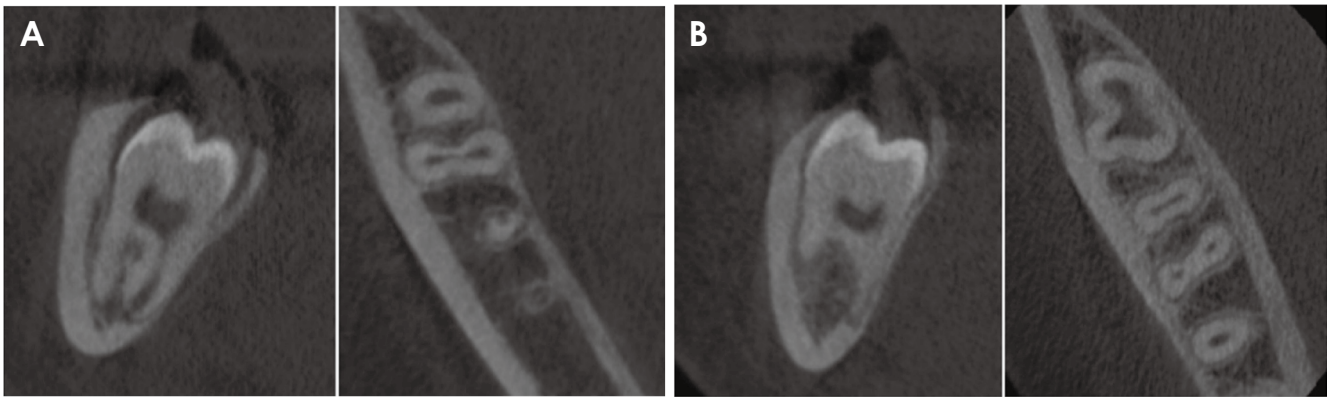

Fig. 4. Both multiplanar reconstructions (MPRs) were reconstructed from the same dataset for a case displaying ankylosis of a root. A. Coronal and axial of an orthogonal MPR. B. Trans-axial and axial of a curved/panoramic MPR.

also reveal ankylosis of the impacted tooth (Fig. 4). Figure 5 exhibits fusion of the impacted tooth to the adjacent tooth. Although Figures 4 and 5 display teeth other than the maxillary impacted canines, as these phenomena also affect treatment planning for impacted teeth *per se*, they were considered for inclusion as features to be studied in the report; only ankylosis was included, as it occurred as frequently as 7% in a recent report on maxillary impacted canines.[19]

Since the installation of the CS 9000 and CS 9300 CBCT units (Carestream Dental LLC, Atlanta, GA, USA) at the authors' institution, both reconstructions have been used routinely. The curved/panoramic MPR reconstructions were noted during the execution of a recent endodontic study.[20] The experience acquired from that study suggested that due to the maxillary canine's length (the longest tooth) and its site at the "corner" of the upper dental arch, both orthogonal and curved/panoramic MPR reconstructions of the same dataset should be reviewed.

The purpose of this study was to determine agreement between 2 reconstructions of the same datasets when 6 features potentially pertaining to maxillary impacted canines were assessed by credentialled orthodontists.

Materials and Methods

The 5 cm × 5 cm CBCT datasets of 15 cases of maxillary impacted canines made on the 2 aforementioned Carestream units were reviewed by 15 credentialled and experienced orthodontists. Ethics permission was granted (certificate numbers: H18-00271 and H18-01660).

A pilot study was performed to ascertain the optimum method that would clinically allow each of the 15 reviewers to complete the 2 required sessions, without having been

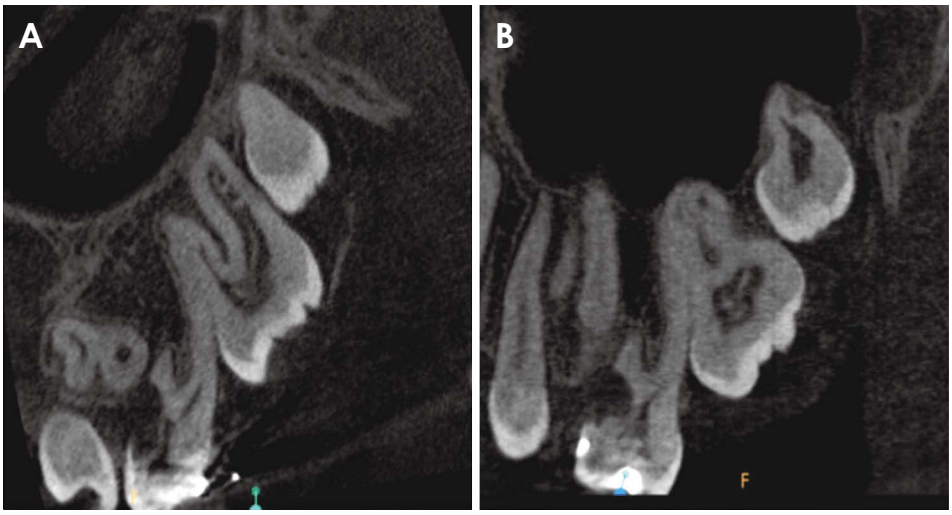

Fig. 5. Both multiplanar reconstructions (MPRs) are reconstructed from the same dataset for a case displaying fusion between 2 teeth. A. Sagittal view of an orthogonal MPR. B. Panoramic view of a curved/panoramic MPR. Both MPRs display cervical root resorption and calcified pulps.

discouraged from the whole enterprise by a negative experience in the first session. The latter was crucial as we had only a limited pool of credentialled orthodontists who were eligible to participate. The subject of the pilot study was 1 of the authors, a credentialled and experienced orthodontist who led teaching in the graduate program. This pilot study revealed that in order to allow each reviewer to use the whole dataset volume, they would have had to spend up to 1 hour to study the whole volume of each case for each reconstruction, which would be impractically long, thus setting the study up for failure. Therefore, a decision was made to take a representative sequence of screenshots arrayed in sequence for each reconstruction, thus both eliminating the software learning process and reducing the time needed to conduct the study. A representative image of 5 screenshots was produced for each of the 2 reconstructions (orthogonal and curved/panoramic MPRs) for each of the 15 cases. The resultant 30 sets (15 sets of orthogonal MPRs and 15 sets of curved/panoramic MPRs) were combined, randomized, and divided into 2 mixed sets of 15 reconstructions. Each set was assigned to one of the 2 sessions to be reviewed separated by at least a week.

Fifteen out of the 23 instructors, who were credentialed orthodontists (65%), volunteered. Reasons for declining included not having time to participate in the study and/or the absence of experience in reviewing CBCT datasets (for 3 instructors).

The 6 features considered were 1) the buccolingual position of the impacted tooth, 2) the vertical level of impaction of the impacted tooth, 3) the presence or absence of root resorption of an adjacent tooth (Fig. 2B), 4) the presence of dilaceration of the root of the impacted tooth (Fig. 3), 5) presence of a cyst in the impacted tooth (Fig. 3A), and 6) ankylosis (Fig. 4). A potential dentigerous cyst was defined as the follicular space exceeding 2 mm.

Each reviewer completed a questionnaire concerning their years of practice as a credentialed orthodontist and experience using CBCT software. Mean differences in continuous variables such as years of practice and experience were tested by the independent sample t-test or its non-parametric equivalent (Mann Whitney U test). Two-tailed tests were employed and the threshold for significance was set at $P<0.05$. Inter-examiner reliability for each of the 2 sessions was displayed for each of the 6 features by box-and-whisker plots.

Results

No statistically significant sex differences were found with regard to years in orthodontic practice (6 women: 15.5 ± 11.5 years; 9 men: 26.4 ± 14.3 years; $P=0.142$) nor with regard to their experience with either type of CBCT reconstruction (orthogonal MPR: 5.8 ± 4.0 years vs. 6.9 ± 4.0 years; $P=0.627$, and curved/panoramic MPR: 1.7 ± 3.2 vs. 3.7 ± 3.9 years: $P=0.301$ respectively). The inter-examiner reliability for each feature in each of the 2 sessions is displayed in Figure 6. While the medians were similar for each feature in both sessions, the median for the presence or absence of a cyst in the maxillary impacted canine was higher in the first session. The boxes in Figure 6, which represent the middle 50% of the data for the level of impaction, are similar in size and placement, indicating certainty by these credentialled orthodontists of this feature in each session. The size and placement of the boxes between the sessions differed most markedly for the presence and absence of root resorption, and the box from the first session

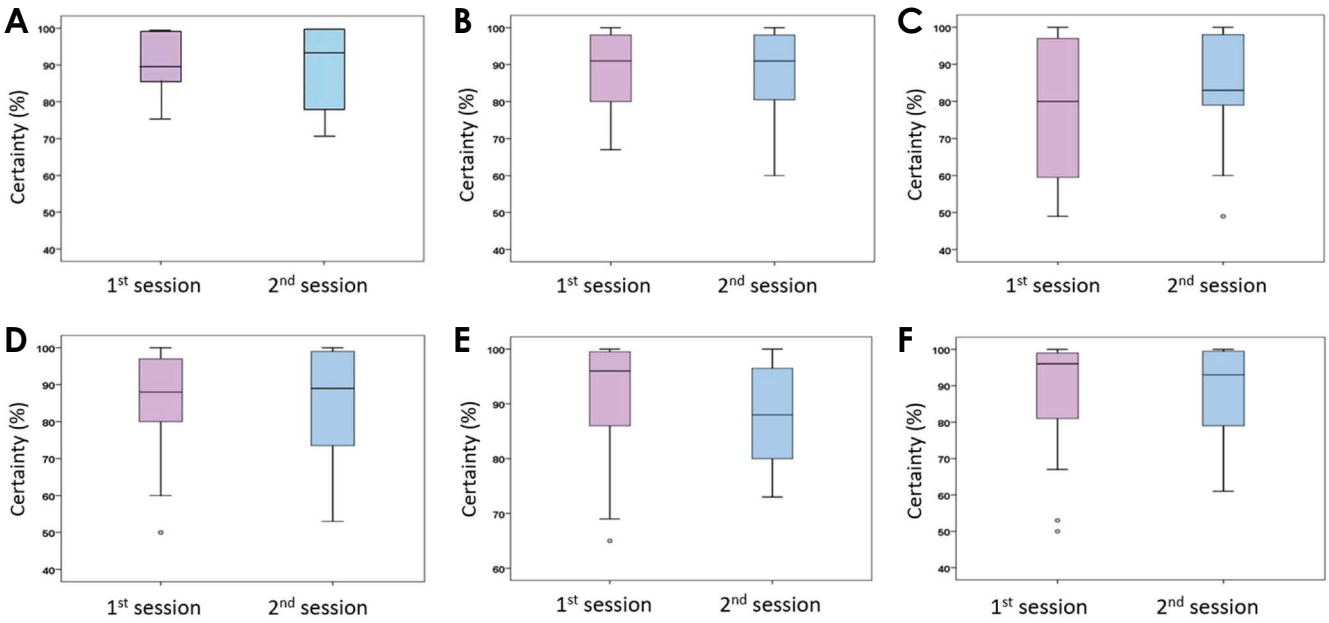

Fig. 6. Inter-examiner reliability for the 6 features in each of the 2 sessions. The box and whisker plot displays the median (horizontal line in the box) and the middle 50% (the box). The upper whisker represents the uppermost 25% and the lower whisker represents the lowest 25%. The dots outside the plot represent outliers. A. Position of the impacted maxillary canine. B. Level of impaction of the maxillary canine. C. Presence/absence of root resorption of the adjacent tooth. D. Presence/absence of dilaceration of the impacted canine. E. Presence/absence of a cyst of the impacted canine. F. Presence/absence of ankylosis of the impacted canine.

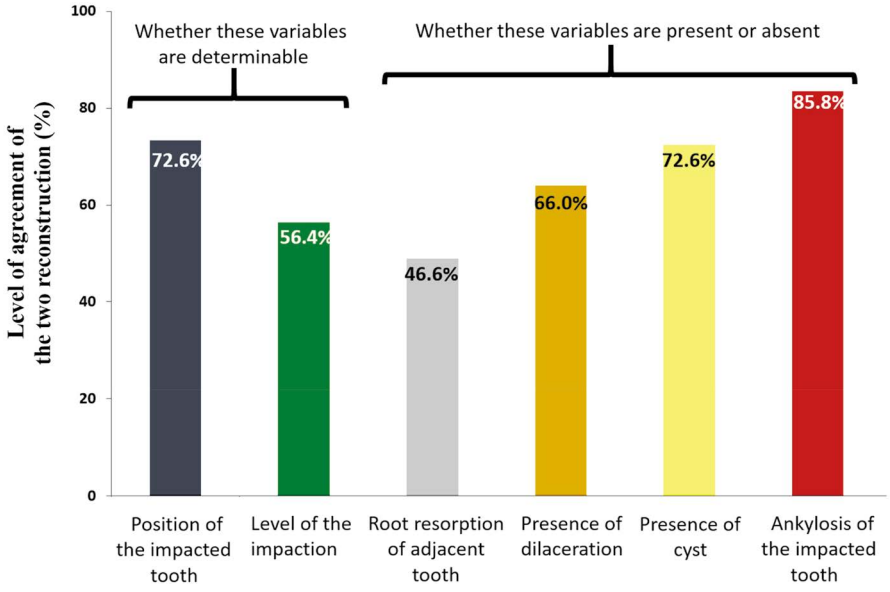

Fig. 7. A bar graph showing a comparison of the level of agreement between the 2 reconstructions in regard to 6 variables. These are shown as percentages superimposed at the top of each of the 6 bars. The best agreement between the 2 reconstructions was for ankylosis of the impacted tooth and the worst for root resorption of the adjacent tooth. The other 4 features exhibited intermediate agreement.

was larger. The positions of the medians and boxes (between 80 to 100% certainty) for 5 of the 6 features indicated that the majority of participants were comfortable in their decisions, except for root resorption in the first session.

The results of the overall agreement between the 2 reconstructions for each of the 6 variables, which were either determinable or were present or absent, are shown in Figure 7. Either reconstruction alone was likely to be sufficient to

determine the presence or absence of ankylosis of the impacted teeth (85.8%), whereas both reconstructions had to be reviewed in order to visualize the presence or absence of root resorption in the adjacent tooth (46.6%). In the case presented in Figure 2, root resorption is more clearly displayed in Figure 2B in the curved/panoramic reconstruction. To determine the other 4 features - the position of the impacted tooth, level of impaction, and the presence or absence of a dilaceration or a cyst - a review of both reconstructions was beneficial.

Discussion

As orthodontists are the primary diagnosticians and directors of treatment for derangement of the dento-alveolar apparatus,[6] there is a need to re-equip them with an understanding of how CBCT can complement the assessment of maxillary impacted canines. Although a previous publication expressed this need to re-equip orthodontists,[17] it did not consider the value of the concurrent use of different MPR reconstructions.

The difficulty of reviewing a CBCT dataset of a maxillary impacted canine can be appreciated by comparing the relatively easier task of reviewing the posterior sextant. Figure 5 reveals that although the sagittal plane of the orthogonal MPR is broadly similar to the panoramic plane of the curved/panoramic MPR, the latter passes through the posterior teeth in a more mesio-distal manner, whereas the former passes through them obliquely. This difference is more pronounced for the maxillary canine's position at the "corner" of the upper arch in Figure 2.

An advantage of the present study is the recruitment of 15 credentialled and experienced orthodontists, which is considerably larger than the only other study dedicated to orthodontist reviewers, which used only 4.[8] Additionally, all datasets reviewed were 5 cm × 5 cm, made at the same institution and reviewed on the same software, which was produced by the manufacturer of the CBCT units used. The main limitation was the limited time available to the reviewers, which compelled them to review PowerPoints rather than the full individual datasets for each case.

The present study indicates that both MPR reconstructions should be reviewed to determine whether root resorption is present or absent, as this determination may not be achieved if only 1 MPR reconstruction is used. This could reflect the difficulty in observing root resorption when it occurs in one MPR, but not in the other. Root resorption of the lateral incisor generally occurs in the middle third of the root.[21] This difficulty may be particularly pronounced if the root resorption is not severe. The purpose of CBCT in such cases is to identify early cases to facilitate early and appropriate treatment. This, in turn, would contribute to the significantly shorter treatment time in cases where CBCT has been used.[10]

The risk of root resorption may be increased by an enlarged follicle in the maxillary impacted canine. The similarity of the median values in Figure 6 between each session indicated that most of the features were similarly perceived in both sessions. The difference between the median values for the presence or absence of a cyst arising on the maxillary impacted canine, might have arisen from the consideration of an enlarged follicle as a cyst in one session and as an enlarged follicle in another session. Generally, once the impacted tooth is no longer in contact with the tooth undergoing resorption, the resorption stops. Therefore, even if the resorption is minor, any appropriate action taken to stop it will be beneficial to the patient.[21]

Although dilaceration is prevalent in maxillary impacted canines, it should also be looked for in teeth adjacent to them, including the premolars,[22] which will also be captured in a small field of view, as used in this study.

Ankylosis of a maxillary impacted canine should be considered, particularly if the tooth is intruding.[23] Although Figure 5 prompted consideration of fusion of the root of the maxillary impacted canine with that of an adjacent tooth, the absence of this phenomenon in the literature led to its exclusion as a feature in this study.

A recent multi-national survey on CBCT prescription criteria employed by orthodontists[17] advised CBCT education and training in order to enhance CBCT analysis and interpretation, and thereby treatment outcomes.[10,24] This training should include awareness of the different reconstructions and the need to use them together to optimize the value of CBCT investigations, particularly for maxillary impacted canines. Not only is this optimization achieved without further irradiation to the patient, but maximizing the use of the data already acquired may enhance the quality of the diagnosis and thereby the treatment of that patient. Indeed, this may be seen simply as an extension of the clinician's duty to review all images and datasets for incidental findings.[25,26] Figure 5 presents the incidental findings of calcified pulps that should be identified prior to orthodontic treatment since they could cause changes in the pulp, including calcification.[27]

Conflicts of Interest: None

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