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FEATURES SECTION

Cone beam computed tomography: a useful tool in orthodontic diagnosis and treatment planning

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The aim of this article is to make clinicians aware of the use of cone beam computed tomography (CBCT) within the field of orthodontics. The paper describes five cases each one illustrating the improved diagnostic yield using CBCT over conventional radiography thus facilitating the appropriate treatment planning of patients.

Key words: Cone beam CT, orthodontics, resorption, ectopic teeth, imaging, impacted molars

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Introduction

Cone beam computed tomography (CBCT) has been used in dentistry since the mid 1990s. As the name implies, it uses a cone shaped X-ray beam which rotates around the patient to acquire a volumetric data set of the region of interest with a single rotation of the patient.[1,2] The CBCT volumetric data set comprises a three-dimensional (3D) block of cuboid structures known as voxels, where each voxel represents a specific degree of X-ray beam absorption.[3] Image reconstruction is achieved using computer algorithms ultimately producing 3D images at high resolution.

The main advantage of CBCT is that the radiation dosage is considerably less than conventional CT scanning.[4–7] In addition with most units the patient is scanned in the upright position, and so there is less distortion of the soft tissues in comparison to conventional CT where the patient is supine. This is particularly useful if the facial soft tissues are reconstructed.

The literature is replete in clinical applications of CBCT.[8] Within the orthodontic specialty useful applications include imaging of impacted teeth[9,10] and dental abnormalities, assessment of alveolar bone heights and bone volume,[11,12] investigation of the temporomandibular joint[13] and airway analysis.[14] The use of CBCT in the field of endodontics has also been described as it is useful for diagnosing canal morphology, assessing root and alveolar fractures, analysis of resorptive lesions and identification of pathology.[15,16]

This paper reports on five cases where conventional radiographs suggested the need for a CBCT which yielded additional diagnostic information to allow the clinician to carry out the treatment planning process. In all cases, CBCT imaging was carried out using the Classic i-CAT (Imaging Sciences International, Hatfield, PA, USA). These data were then exported into Simplant (Materialise, Leuven, Belgium) to carry out the 3D reconstructions. The exporting of data and 3D construction of images takes additional time and resources.

Case 1

A 13-year-old Caucasian male was referred to the Orthodontic department for an opinion. The patient had avulsed the UL1 and subluxed the UR1 due to trauma 24 months previously. Both central incisors were non vital and had been dressed with calcium hydroxide. The patient presented in the mixed dentition with Class I incisors on a Skeletal 1 base complicated by a developmentally absent UR2 and diminutive UL2. The UR3 was palpable buccally but the UL3 was not palpable. Conventional radiographs (Figures 1 and 2) confirmed the absence of the UR2 and marked resorption of the URB and URC with the canine favourably positioned. On the periapical radiograph the UL3 was superimposed on the UL1 and there was marked resorption of the UL1. The apical tissues of the UR1 were normal.

In view of the history and the radiographic findings, CBCT of the maxilla was performed. The whole maxilla was scanned as it is not possible to limit the radiation field to specific regions within the jaw using the i-CAT CBCT unit. This examination showed marked external root

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Figure 1 Periapical radiograph suggesting that the resorption associated with the UL1 is caused by the ectopic UL3

resorption of the UL1 (Figure 3) which communicated with the pulp. This resorption is probably as a result of the previous avulsion of the UL1 and not due to the ectopic UL3 which the conventional periapical film suggests. The UL3 was palatally positioned and had caused marked resorption of the UL2 with only 4.4 mm of labial root length remaining (Figure 4). The 3D reconstruction of maxillary dentition showed the proximity of the unerupted canine to the incisors (Figure 5), and ultimately helped in the treatment planning of the patient.

Based on the results of the scan it was decided to extract the UL2 and ULC and expose and bond the UL3. Had the scan not been available then it is likely that the patient would have been treatment planned for

Figure 2 Cropped panoramic radiograph showing patient in the mixed dentition with ectopic UL3, missing UR2 and resorption of the UL1

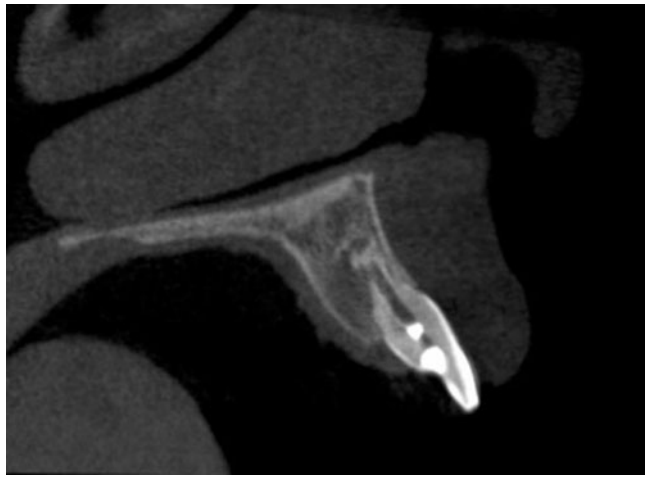


Figure 3 Sagittal CBCT section through the UL1 demonstrating the external resorption

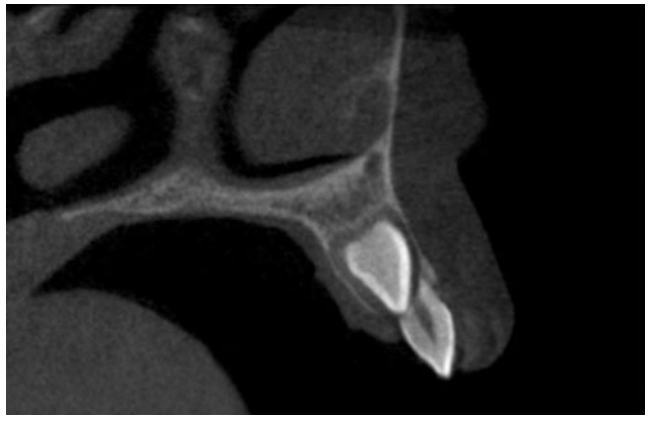


Figure 4 Sagittal CBCT section through the unerupted UL3 illustrating the extent of resorption of the UL2

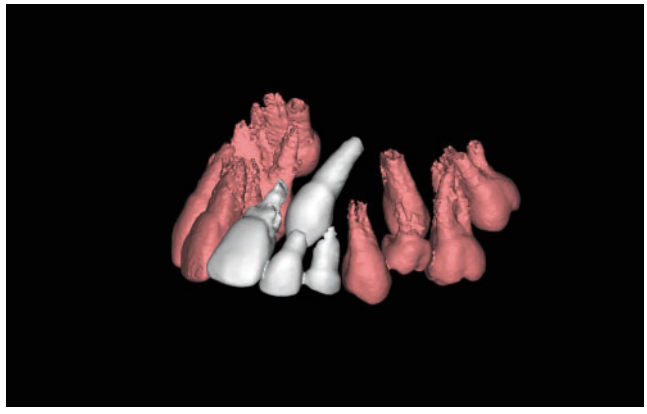


Figure 5 Three-dimensional reconstruction of the maxillary dentition showing the relationship of the unerupted UL3 to the erupted dentition

Figure 6 Cropped image of a lateral cephalometric radiograph showing the buccal position of the UR3

extraction of the UL1. The UL2 would have been moved into its position and the maxillary canines masked as lateral incisors. With the severely compromised root length of the UL2 the risk of further root resorption would be high. Despite the external resorption on the UL1 following avulsion, it was decided to leave this tooth *in situ* and the patient and parents were warned of its poor long term prognosis.

Case 2

A 10-year-old Caucasian female was referred to the Orthodontic department by her general dental practitioner (GDP) regarding the unerupted UR1. She presented in the mixed dentition stage with Class I incisors on a Skeletal 1 base complicated by previous trauma to the URA and potential upper and lower arch crowding. The UL3 was palpable buccally. A lateral cephalometric radiograph (Figure 6) and panoramic radiograph (Figure 7) showed the ectopic position of the UR3. The central incisor was at an average angulation with the canine tooth positioned buccally.

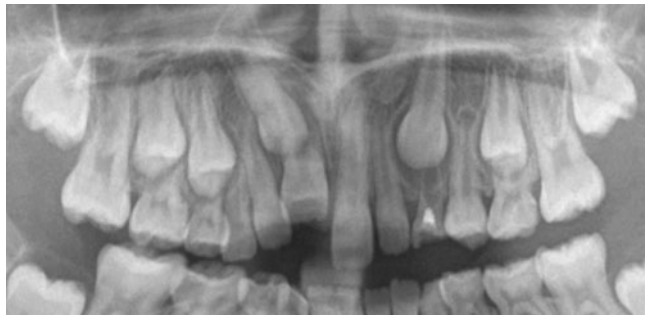


Figure 7 Cropped panoramic radiograph showing the ectopic position of the UR3 with loss of apical definition of the UR1

The original treatment plan was to extract the UR1 and to align the UR3 masking it as a central incisor. However, it was decided to perform a maxillary CBCT in order to assess the precise position of the UR3 and the root morphology of the UR1.

CBCT examination confirmed that the UR3 was buccal to the central incisor. The incisor was mildly dilacerated and there was a small amount of resorption present at the aberrant buccal contact area between the two teeth (Figure 8). There was little buccal bone support due to the position of the canine tooth (Figure 9).

As a result of the scan it was decided to extract the buccally positioned canine and URC and to use an upper fixed appliance to align the central incisor into its correct position. This case illustrates the uses of CBCT to supplement standard orthodontic plain film radiographs. These give only two-dimensional information whereas CBCT provided enhanced diagnostic information which resulting in a more suitable orthodontic treatment plan.

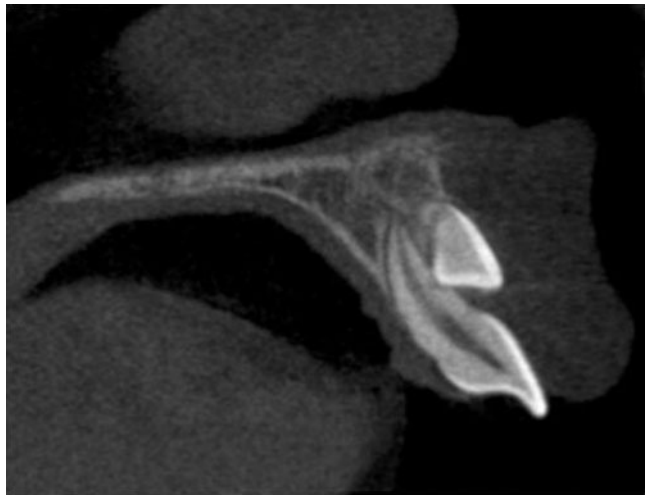


Figure 8 Sagittal CBCT section through the UR1 showing the canine to be buccally positioned with a small amount of resorption on the labial surface of the incisor

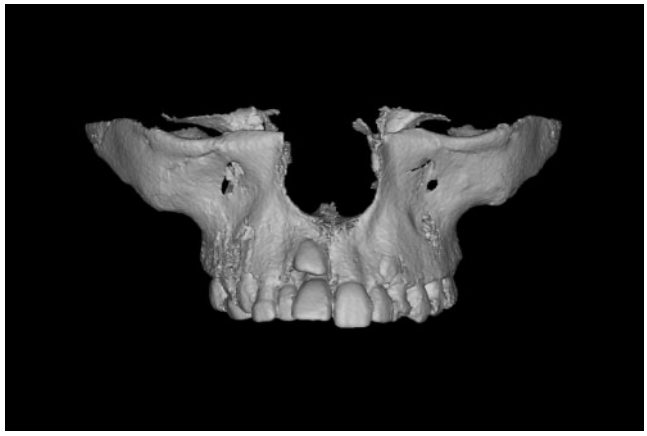


Figure 9 Three-dimensional reconstruction illustrating the close proximity of the UR3 with the UR1 and the absence of buccal bone

Case 3

A 17-year-old Asian male was referred to the Orthodontic department regarding unerupted maxillary canines and crowding. He presented with idiopathic infantile arterial calcification which is a rare disease characterized by extensive depositions of hydroxyapatite in the internal elastic lamina of medium-sized and large arteries, frequently accompanied by periarticular calcifications,[17] and hypophosphatasia. He had a Class III malocclusion on a Class I skeletal base with ectopic maxillary canines, unerupted LL5 and severe upper and lower arch crowding. Plain radiographs (Figure 10) showed the patient in the permanent dentition with ectopic maxillary canines and impacted LL5. Vertical parallax was performed using the panoramic radiograph (Figure 10) and the upper standard occlusal film (USO) (Figure 11) and this indicated that the canines were palatally positioned, with resorption of the UR1. However, the USO radiograph was not ideal as it had a movement artefact. Due to the complexity of the case and the need to assess the prognosis of the UR1 CBCT was performed.

Cone beam CT images showed there was marked resorption of the right central incisor by the canine and this involved the pulp chamber of the tooth (Figure 12). In addition the pulp chambers of the upper incisor teeth extended almost to the incisal edge which is feature of hypophosphatasia.[18] There was apical resorption of the UR1 due to the palatally ectopic position of the UR3. The roots of the two central incisors were short and blunted, but there was no history of trauma so this finding may be related to the hypophosphatasia (Figure 13a, b). Treatment involved extraction of lower second premolars, surgical removal of the UL3 which had a poor prognosis, and extraction of the UR1. An attachment was placed on the UR3 to align it in the

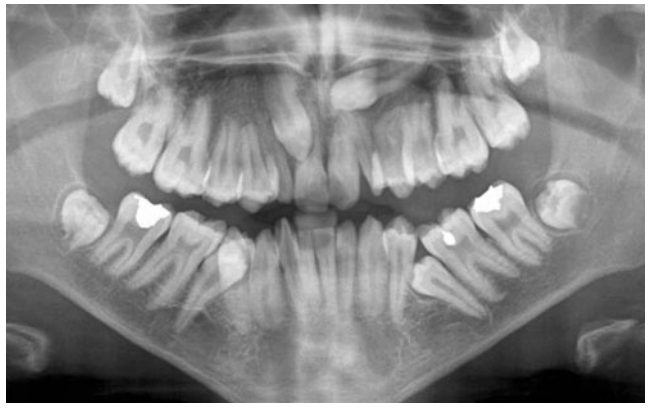


Figure 10 Panoramic radiograph demonstrating the ectopic maxillary canines, caries and impacted LL5

position of the central incisor. As a result of the 3D imaging the orthodontist, clinician and patient were able to see the unerupted teeth and incisor root resorption. This assisted the treatment planning process and informed consent. This case highlights the high diagnostic yield of the CBCT including tooth morphology, position and the anatomy of the pulp chambers.

Case 4

A 17-year-old Asian female was referred to the Orthodontic department by her GDP regarding unerupted teeth. She presented with a Class III malocclusion

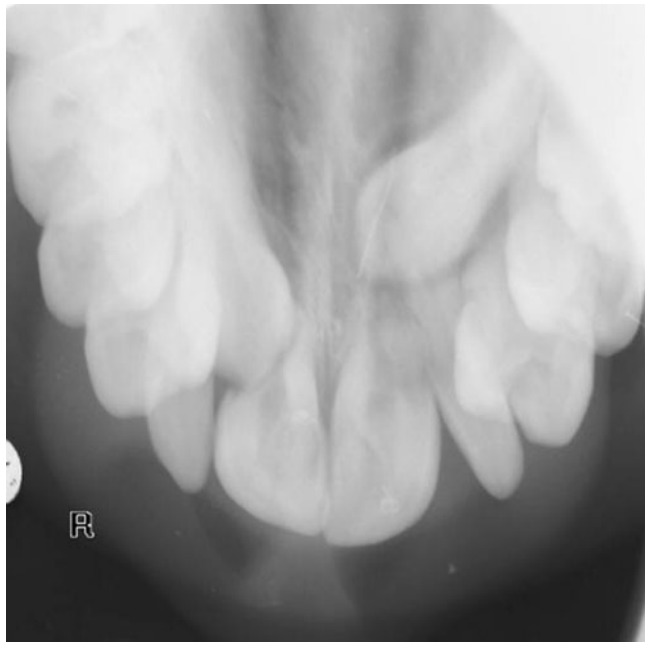


Figure 11 Upper standard occlusal radiograph demonstrating the unerupted canine teeth and the central incisor roots

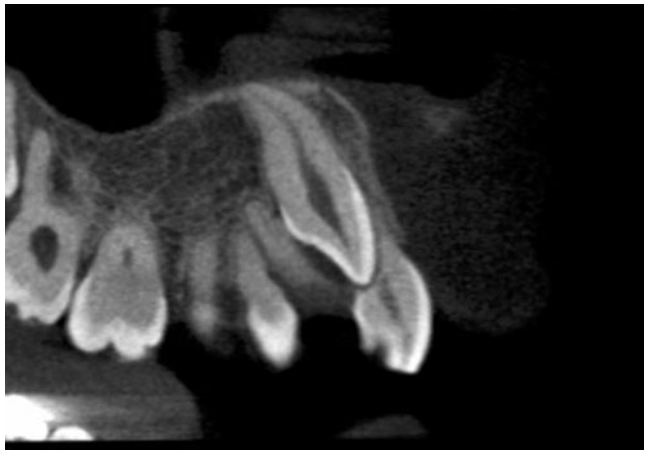


Figure 12 Sagittal CBCT section demonstrating the marked resorption of the UR1 by the canine tooth

on a Class I skeletal base complicated by several carious molars and retained maxillary deciduous incisors and canine.

Radiographic examination (Figures 14 and 15) revealed extensive caries in UR7, UL6, LR6, and LL6 with associated apical pathology of the lower first molars. There was a complex mass of calcified tissue in the left anterior maxilla associated with possibly the unerupted UL1 and UL2. To gain more information on this region CBCT was performed.

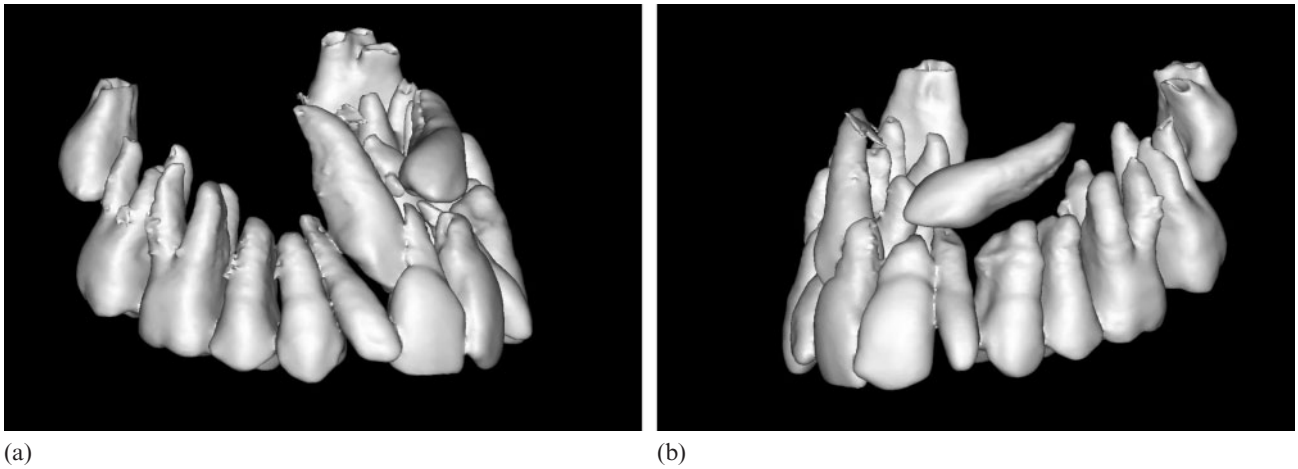
The CBCT images showed the UL1 was vertically positioned with a fully formed curved root (Figure 16). The UL2 was horizontally positioned in the hard palate (Figure 17a, b). There was no root resorption of the erupted permanent teeth. Within the left maxilla was a large complex odontome made up of several irregular masses of haphazardly arranged tooth substance. Due to the age of the patient and the unfavourable position of

Figure 14 Panoramic radiograph demonstrating the carious posterior teeth and the odontome in the left maxilla with ectopic UL1 and UL2

the UL1 and UL2 the treatment plan was to extract the UL1, UL2 and the odontome along with the remaining maxillary deciduous teeth. In addition due to the poor prognosis of the remaining first molars extraction of these teeth was also necessary and the patient was referred for endodontic treatment of the UR7. Following the extractions and endodontic treatment the patient was planned for fixed appliance treatment for alignment and space closure in the upper right quadrant. Following completion of fixed appliance treatment implants were planned to replace the UL1 and UL2.

Case 5

A 12-year-old Caucasian male was referred to the Orthodontic department by a local orthodontic specialist regarding upper second molars that had failed to erupt following a previous course of orthodontic treatment. The patient presented with a Class I malocclusion on a mild Class II skeletal base with previous loss of upper first premolars. A panoramic radiograph (Figure 18) showed



(a) (b)

Figure 13 Three-dimensional reconstruction showing (a) the maxilla from the right side and (b) maxilla from the left side

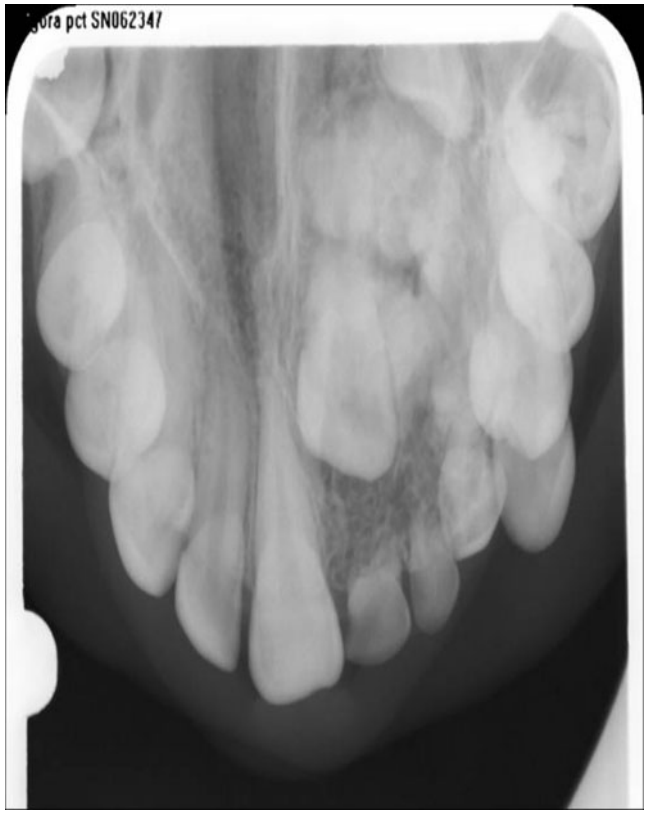
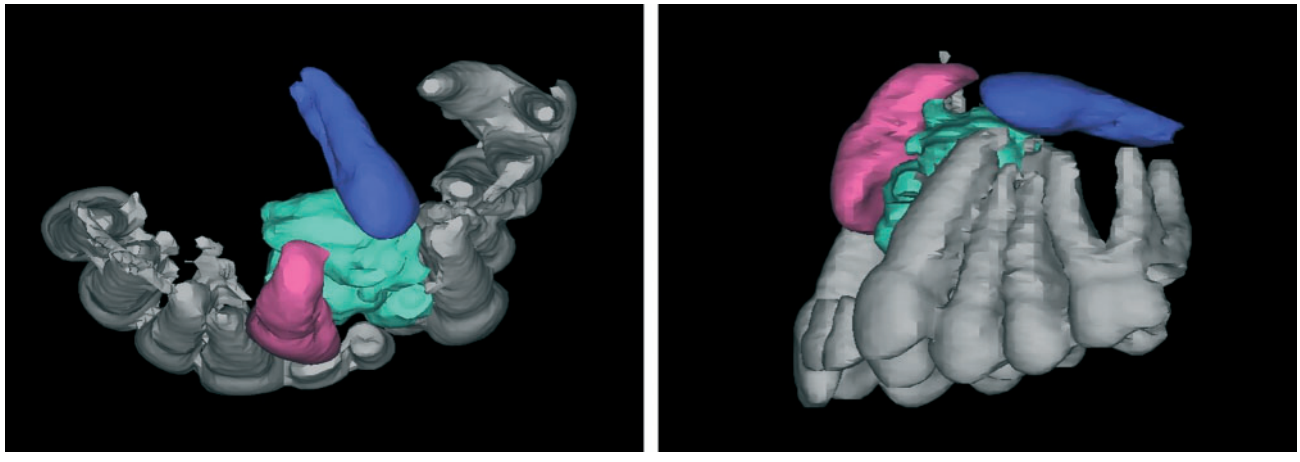


Figure 15 Upper standard occlusal demonstrating the radio opaque mass associated with the UL2 and UL3

developing lower third permanent molars with posterior stacking of the upper second and third molars. The crowns of the upper second molars were in close proximity to the distal roots of the upper first molars. Due to the proximity of the unerupted teeth to the roots of the upper first molars and to assess the relationship of the unerupted molar teeth CBCT was carried out.

Figure 16 Sagittal CBCT section showing the position of the UL1 and odontome mass

The CBCT image showed the UL7 was vertically impacted with the crown contacting the distobuccal root of the UL6 which showed a small area of resorption (Figure 19). The eruption path was blocked by the unerupted UL8 (Figure 20). The UR7 was vertically impacted in close proximity with the distobuccal root of the UR6, but no pathological resorption was present (Figure 21) and the eruption path was blocked by the UR8 (Figure 22). As a result of the CBCT findings it was decided to extract the maxillary third molars to facilitate eruption of the second molars.



(a) (b)

Figure 17 Three-dimensional reconstruction showing the position of the odontome and unerupted teeth: (a) view from above; (b) view from the left side

Figure 18 Panoramic radiograph demonstrating posterior molar stacking of the maxillary second and third molars

Discussion

Diagnostic information is essential in influencing clinical decision making. Accurate imaging leads to better treatment planning decisions and potentially more predictable outcomes. CBCT is an emerging imaging modality that can offer the clinician information above that obtained from conventional radiographs.

A common problem in orthodontics is underestimating the degree of resorption associated with unerupted teeth especially maxillary canines. Ericson and Kurol investigated the extent of incisor resorption from ectopic maxillary canines using conventional CT.[19] They found that 38% of lateral incisors and 9% of central incisors

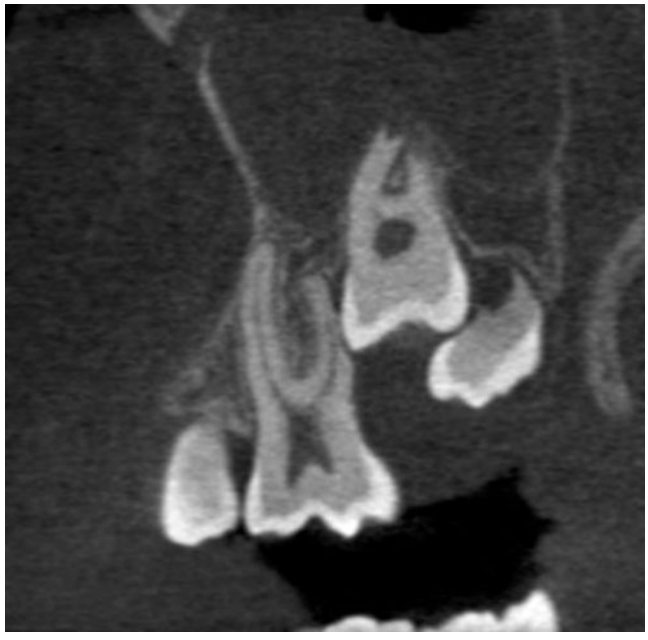


Figure 19 Sagittal CBCT section through the unerupted UL7 and UL8 demonstrating the resorption to the distal root of the UL6

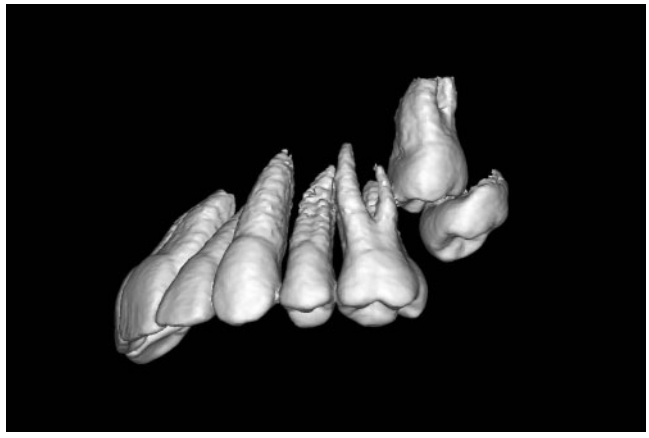


Figure 20 Three-dimensional reconstruction demonstrating the position of the left molar teeth

Figure 21 Sagittal CBCT section through the unerupted UR7

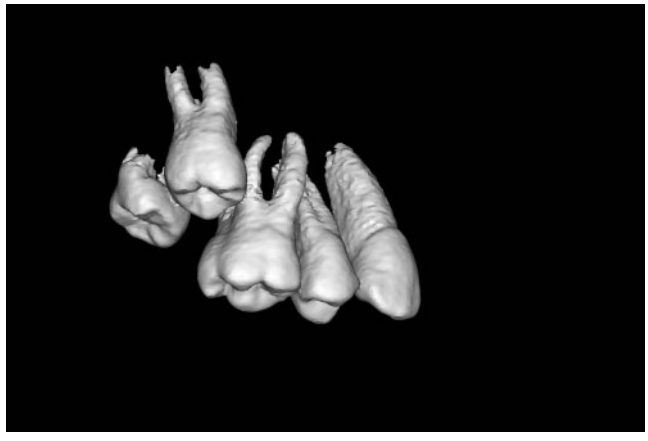


Figure 22 Three-dimensional reconstruction of the right maxillary molars demonstrating the position of the molar teeth

showed evidence of resorption. Walker and co-workers found that incisor resorption adjacent to the impacted canine was present in 66.7% of the lateral incisors and 11.1% of the central incisors when assessed using CBCT.[20]

Location of unerupted teeth is an essential part of orthodontic diagnosis and treatment planning and can be assessed using different methods. Using panoramic radiographs the position of the unerupted teeth can be assessed by looking at the magnification of the canine relative to the surrounding dentition or the contra lateral canine, this magnification technique is sometimes difficult to apply especially if the canine is in close proximity to an incisor root.[21] A panoramic radiograph can also be used in conjunction with a lateral cephalograms for localizing unerupted teeth.[22] However, a more commonly used method for canine localization is the parallax technique.[23,24] Armstrong and co-workers compared the use of horizontal and vertical parallax to localize ectopic maxillary canines.[24] Results showed that the diagnostic sensitivity for palatally placed canines was significantly greater for horizontal parallax (88%) than for vertical parallax (69%). CBCT eliminates potential problems with magnification and superimposition which in some cases make radiographic interpretation particularly challenging.

Cases 1, 2 and 3 highlight the advantages of CBCT images which give the clinician the ability to assess the precise position of the ectopic tooth and to assess the degree of root resorption of adjacent roots. They provide information about the amount of alveolar bone coverage, the three dimensional proximity and resorption of the roots of adjacent teeth, local anatomical considerations and overall stage of tooth development. In selected cases CBCT provides information that is advantageous with the management of ectopic teeth.

Case 4 illustrates the benefit of the CBCT allowing the surgeon and orthodontist to accurately locate the precise position and structure of the odontome prior to its surgical removal, and ascertain the proximity of anatomical structures. The 3D images mean that there is no superimposition of structures which can cause difficulties in interpreting conventional radiographs.[24]

Treatment of impacted maxillary second molars consists of the removal of any possible barrier.[25,26] The review by Salentijn on treatment of patients with impacted upper second molars, due to overlying third molars,[26] suggested that upper third molars when causing impaction of upper second molars should be extracted between the ages of 11–14. In order to remove the tooth causing the obstruction it is important to determine the best surgical approach causing the least harm to adjacent tooth roots. When using conventional radiographs to make these decisions, it is difficult to determine the exact buccolingual relationships of the teeth and surrounding structures.

Case 5 illustrates the benefits of the CBCT image to accurately locate the position of the unerupted molars. This facilitates the clinician in determining the extraction pattern and enables them to arrange for the removal of the tooth with the poorest prognosis.

The Ionising radiation (Medical Exposure) Regulations[27] do not explicitly state whose responsibility it is to report radiographs, it is generally regarded that this is an 'operator role'. Therefore, any person who is involved in the reporting of CBCT scans should have appropriate training, to be able to interpret all the image data including those areas outside the jaws, since any occult pathology or abnormalities found on the scans must be reported on, and if necessary referred for further management.[28] The classic i-CAT has a large field of view extending beyond the jaws. General and maxillofacial radiologists will have received extensive training in interpretation of these regions as part of their specialist training. However, it raises the question as to whether general practitioners and dental specialists have the necessary training to be able to adequately report on all the images generated from these scans[2]

The advantages of CBCT in maximizing diagnostic yield and reduced radiation exposure have been well documented.[1] It is essential that these images are requested appropriately and in order to maximize diagnostic yield for the patient all images should be analyzed and reported on.[2] Currently there are no published referral criteria for CBCT. The British orthodontic Society Orthodontic Radiographs guidelines[29] state that the CBCT should be used with caution and the clinician should always ask whether the question for which the imaging is requested could be answered by conventional radiography. There are currently no formalized selection criteria for CBCT in Orthodontics, and that more evidence based research is necessary in this area.

Conclusions

Orthodontic clinicians have a responsibility to their patients to ensure that they request radiographic images that maximize diagnostic yield. This is especially true when the information will be used to plan surgical and orthodontic intervention. CBCT allows the clinician to have an accurate 3D picture of the position of teeth/areas of interest which facilitates planning for both the orthodontist and surgeon. It must be remembered that although CBCT is a useful tool in the orthodontist's

armamentarium, it is essential that they are only used when conventional radiography has failed to give or is unlikely to give the necessary diagnostic information.

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