Dentistry Clinical

The future of endodontic diagnosis and treatment planning

Richard Kahan looks at the benefits and practicalities of incorporating micro CT in a specialist endodontic practice

The limitations of the use of standard radiography in the practice of endodontics is well known and documented (Tidmarsh,1987; Mol & van der Stelt, 1992; Rohlin & Akerblom, 1992; Molander et al, 1995), with the ability to detect periradicular disease (sensitivity) and lack of disease (specificity), significantly lower than a practitioner would wish for (Bohay, 2000). Periapical pathology can only be seen on a radiograph once the adjacent cortical plate has started to be eroded, and therefore diagnosis can be a lottery in the positioning of the root apex, with sometimes even bone damage from a pulpitis visible, but a very large lesion undetectable (Bender, 1997).

However, as the periapical radiograph has been the only way to accurately visualise unseen tooth and root anatomy with associated hard tissue pathology, it is considered mandatory before any endodontic procedure is carried out (European Society of Endodontology, 2006). As it is only a two dimensional representation of a complex layered composite of calcific materials, a practitioner will need to use all available diagnostic tests, a fair amount of intelligence and sometimes luck, to establish effective diagnosis and treatment planning.

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As an endodontist, I am continually frustrated to be dependent on poor quality subjective clinical tests (percussion, palpation, thermal and electrical), with the only objective diagnostic test, a periapical radiograph. I frequently hear of patients with pulpal and periapical disease being told by their dentists that there is 'nothing wrong' from the X-ray. There is frequently something wrong, it is just a failing in the sensitivity of the diagnostic test and the dentist's over-dependency on a limited medium.

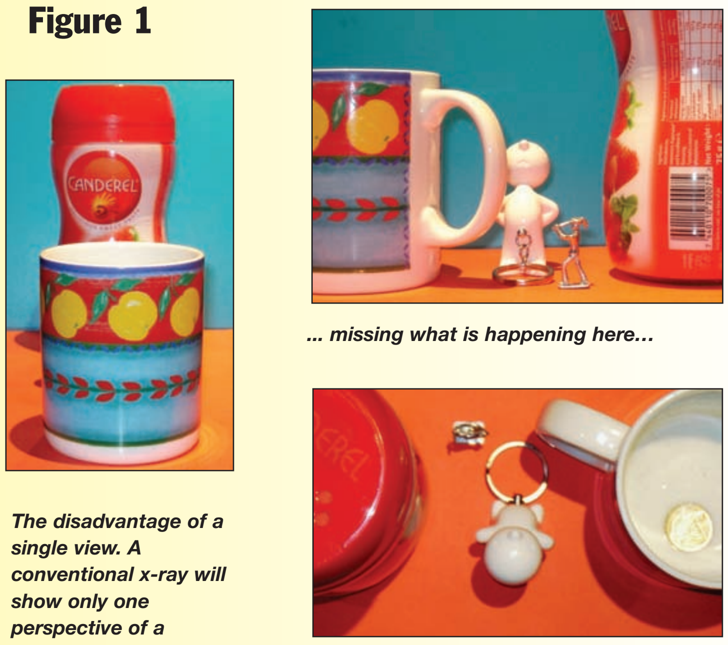
Computed tomography (CT) is a medical imaging method employing tomography where digital geometry processing is used to generate a three-dimensional image of the internals of an object, from a large series of two-dimensional X-ray images taken around a single axis of rotation. Since its introduction in the 1970's, CT has become an important tool in medical imaging to supplement X-rays and medical ultrasonography. It is now the gold standard in the diagnosis of a large number of different disease entities. In the late 1990's scanners specifically for maxillo-facial use were developed producing a cylinder shaped volume of radiographic data in a single rotation called cone beam computed tomography (CBCT). Thanks to readily available powerful personal computers, the data in the cylinder can now be processed rapidly and reconstructed by software into multiplanar radiographic reconstructions with relatively good resolution. Dental anatomy can be visualized in slices in any plane, rather than the composite view afforded by standard intra-oral radiography (Figure 1).

Limited volume CBCT scanners capture small volumes of data that can include just two or three individual teeth and this was first seen in the Accuitomo 3D scanner launched by Morita in 2001. Recently, Morita has upgraded its OPG machine to include the advanced technology found in the Accuitomo, producing the Veraviewepocs 3D. This 'small footprint' scanner is particularly attractive to endodontists as the combination of a small field of radiation with advanced digital processing reduces the effective dose of radiation to that of 5-6 standard periapical radiograph exposures (Table 1). The information gathered in such a scan dramatically increases diagnostic sensitivity, reducing the need for invasive investigation, as well as providing vital information on the anatomy of the roots, root canals and surrounding tissues, for treatment planning.

Two months of routine use of the scanner has revolutionised my practice of endodontics. I believe it has the same potential to change the face of the speciality as the introduction of the operating microscopes and nickel titanium files. Previously invisible periapical pathology under the distal root of a lower molar, reacting positively to an electric pulp test, was discovered and allowed treatment of unexplained pain (Figure 2). Vertical crown fractures of vital teeth extending into roots can be seen in the reactive bone loss and therefore a diagnosis and prognosis can be established (Figure 3). The extent of areas of internal and external resorption can be correctly gauged and treatment planned (Figure 5). Hidden post or pin perforations, apical transportations and missed canal in the plane of the X-ray beam can be seen through z- and y-plane analysis (Figures 4 & 6). Canal anatomy can be confirmed so time is not wasted looking for possible extra canals. Effective pre-apical surgery planning can be carried out locating anatomical structures such as the maxillary sinus or ID canal for safety, the position of the root apices relative to the surgical access, and the size of the lesion and its association with the apices of adjacent teeth so that damage can be avoided to their apical vessels (Figure 7). Even the effect of toxins from an irreversible pulpitis can be seen in damage to the periapical bone (Figure 8).

However, there are limitations in the use of CBCT scanners for endodontics. Frequently, judgements have to made on the quality of

Figure 1



The disadvantage of a single view. A conventional x-ray will show only one perspective of a composite image...

... missing what is happening here...

... nor appreciating what is going on here!

Case history – instant gratification!

This case presented in the first week of scanner use. The patient complained of pain in the lower right jaw but could not locate the source. The conventional (enhanced digital) X-ray taken suggested a problem with the back tooth, but no reason could be found for any disease with this tooth by the referring dentist.

The scanner clearly showed the problem to be at the LR6 with a lesion at the distal root. This could not be seen on the conventional X-ray as the thickness of bone in these regions obscured the changes. Non destructive vitality testing with a full crown present was not possible. The slices created by the scanner were absolutely clear though. Note also the appearance of a furcation lesion at the LR6. This however is artefact caused by the adjacent implant.

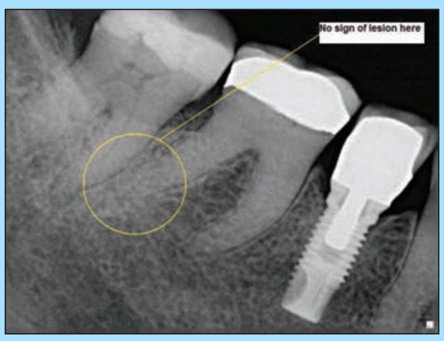


Figure 2a: Conventional digital x-ray

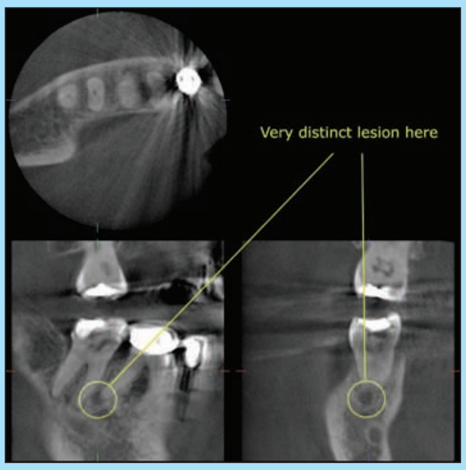


Figure 2b: XYZ slices, produced by Morita Veraviewepocs 3D

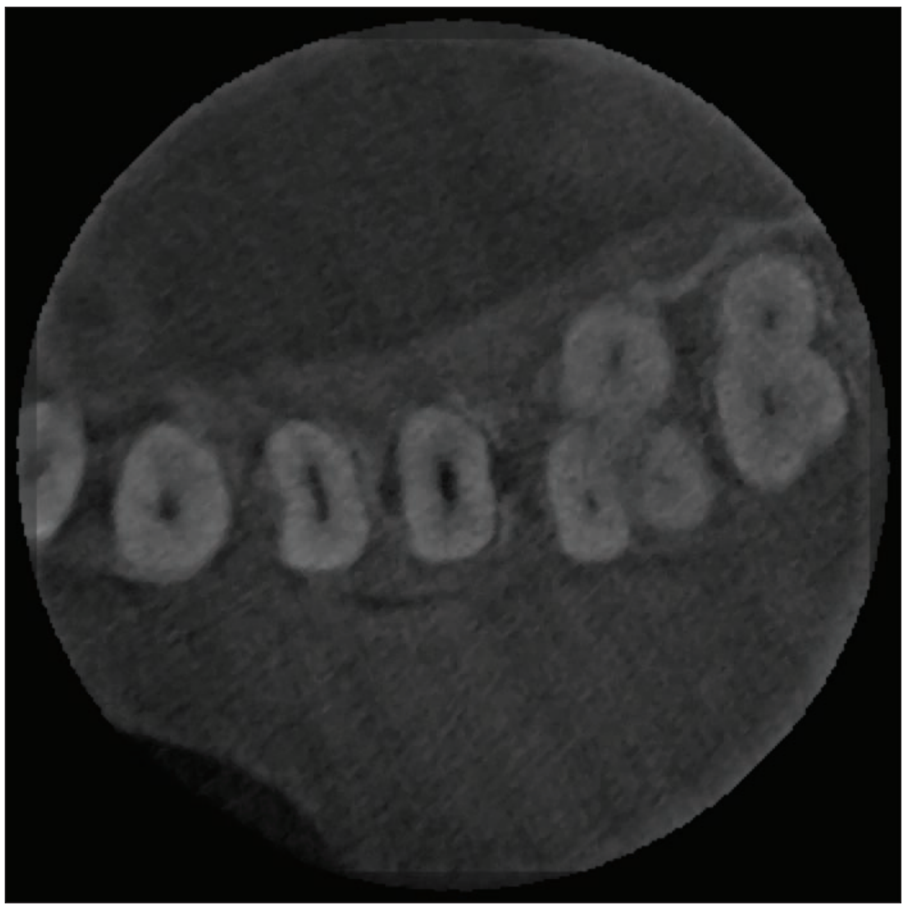


Figure 3: Vertical crown fracture. Mesial and distal narrow pockets of bone loss associated with a vertical crown fracture of a vital UR5.


Figures 4a (X-plane) and 4b (Y-plane): Apical perforation. Standard X-plane view shows a post and root filling aligned along the central axis of the UL5. The root filling actually perforates palatally into the maxillary sinus.

existing restorations and root fillings. These factors will impact significantly on diagnosis and treatment planning. The presence of any radiopaque material causes artefact that affects the appearance of the tooth and surrounding structures. The denser the material the more significant is the artefact, causing characteristic streaks (aliasing artefact) that appear as dark lines which radiate away from sharp corners. One has to effectively ignore the information in the coronal tooth structures where restorations are present in the vicinity of the scan. Even heavily radiopaque structures from further afield can superimpose artefact over the scanned area and can be mistaken for pathology (Figure 2). Non-metallic root fillings do not cause major artefacts but are seen to have associated shadows within the canal. Metal posts and implants can cause enough artefact to render diagnostic information from adjacent bone obsolete.

Understanding and interpreting CT artefacts as well as using techniques to minimise these, will be important skills in this emerging field of technology and is an area in which I have started to carry out some research. It is important to state that standard periapical and bitewing views are therefore still necessary to fully diagnose and plan endodontic treatment.

In planning the integration of such an expensive piece of equipment into a practice, the financial and practical implications need to be carefully considered. Apart from simple space requirements, health and safety aspects must be paramount, with full compliance of the radiation protection officer. Although the scanner is equipped with two powerful PCs, total scan volumes can be over 500 Mb in size, so network infrastructure will need to be fast enough to sustain these transfers together with a large capacity backup facility.

I decided early on that I would not charge patients a separate fee for a scan, counter to the most common practice nowadays. I am therefore able to take objective decisions on whether to scan a patient based on clinical need rather than financial goals. I am not financially target driven, and consider the equipment to be part of my diagnostic arsenal. I do not charge my patients for each radiograph, for the use of endo-ice, the electric pulp tester or even the tap of my mirror handle!

In summary, the arrival of the Morita CBCT scanner has heralded a new era in my own endodontic practice and teaching. In just a few months I have gathered enough cases to lecture for years on the power of this technology to radically enhance diagnostic and treatment planning in endodontics. We are currently carrying out research into the ideal settings for periradicular lesion identification, and the recognition and reduction of dental artefact, but with the relentless march of technological innovation these images will continue to improve together with further reductions in radiation. Welcome to the future!

References

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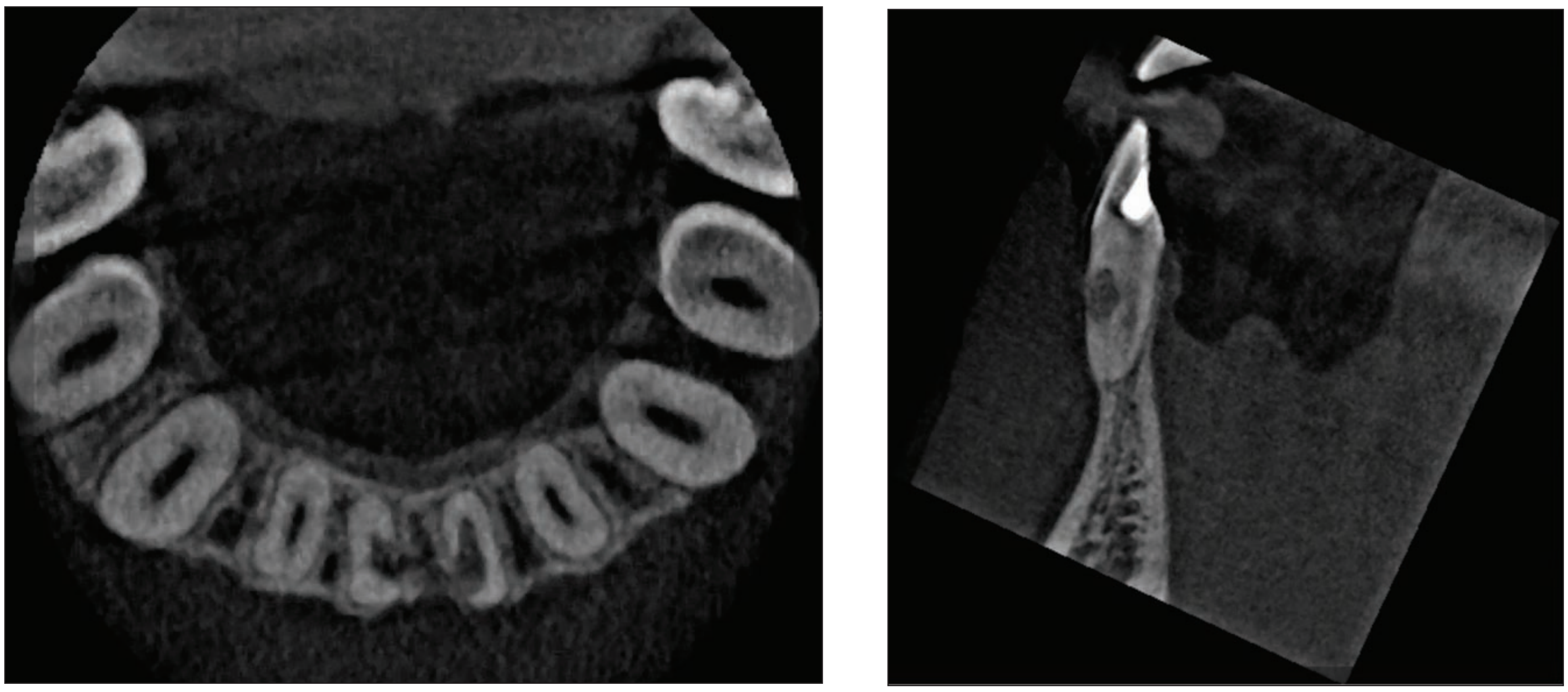
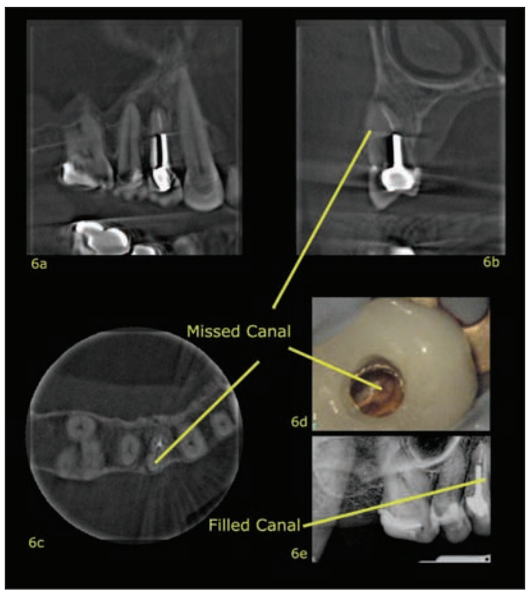
Table 1: Dental X-ray radiation and CT machines

The radiation exposure doses below are taken from a recent article in the International Endodontic Journal (Patel et al, 2007). The Morita Accuitomo 3D is the original large scale version of the Morita Veraviewepocs 3D. (The doses for the Veraviewepocs 3D have yet to be verified. Sources at Morita quote the dose listed below.)

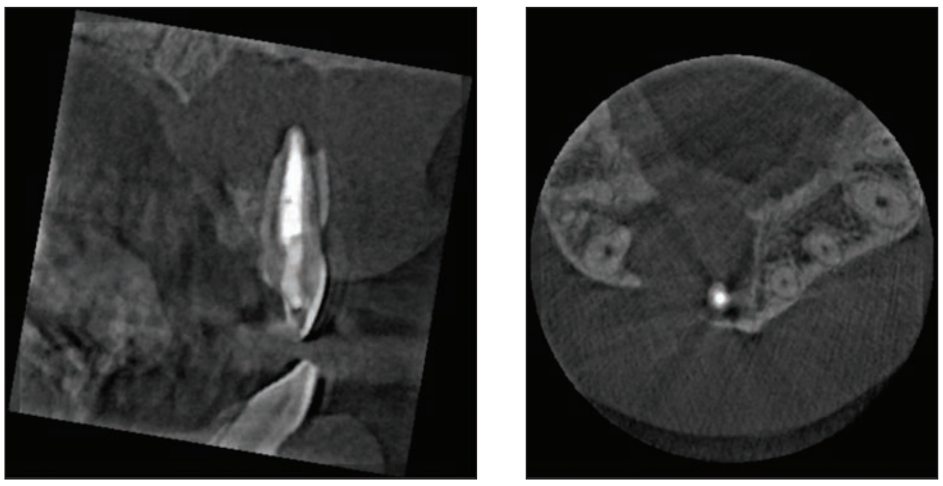
Conventional CT	
Upper jaw	**1400 µSv**
Lower Jaw	**1320 µSv**
Dental CT	
Mercuray 9” FOV	**435.5 µSv**
Mercuray 6” FOV	**283.3 µSv**
i-CAT 12” FOV	**193.4 µSv**
i-CAT 9” FOV	**104.5 µSv**
NewTom 3G 12” FOV	**58.9 µSv**
Morita Accuitomo 3D 4”x4”	**7.3 µSv**
Morita Veraviewepocs 3D 4”x4”	**~30 µSv (unverified, includes scout OPG)**
Dental X-Ray	
Periapical/Bitewing	**5 µSv**
Cosmic Radiation	
During a Paris-Tokyo return flight	**150 µSv**



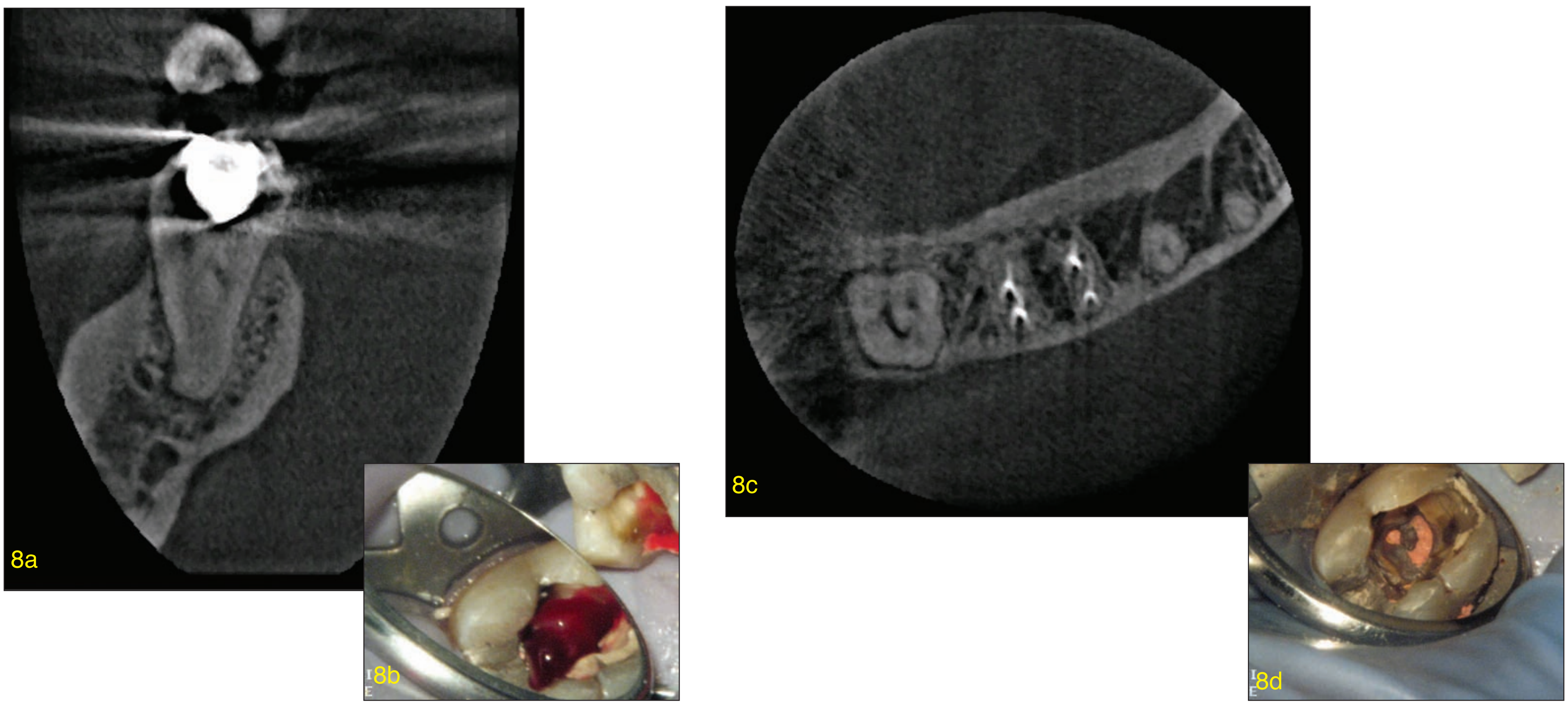
Figures 5a (Z-plane) and 5b (Y-plane): External inflammatory resorptive lesions at LL1 and LR1 due to trauma. Extent and positions of the lesions are clearly visible an invaluable aid in treatment planning and prognosis.



Figures 6a (X-plane), 6b (Y-plane), 6c (Z-plane), 6d, and 6e: Missed canal. The lesion associated with the post crowned UR4 would ordinarily require planning for post crown removal and retreatment, or an apicectomy. The scan identifies that the buccal canal has not been treated and the lesion could be associated with the contaminated material in the buccal canal, allowing a more conservative means of treatment (Figure 6e). Note the artefact caused by the post.



Figures 7a (Y-plane) and 7b (Z-plane): Planning apical surgery. A large lesion associated with a root filled UR1 has extended buccally and palatally, perforating both outer cortical plates. Apical surgery from the buccal side alone will lead to epithelial ingrowth from the palatal side and poor healing. Furthermore, vessels supplying the vital UR2 would be damaged by surgery. In this case the lesion was decompressed to attempt to stimulate bone healing before apicectomy to remove the main focus of infection.



Figures 8a, 8b, 8c and 8d: Pulpitis and canal anatomy. Apical bone damage seen in Figure 8a due to toxins produced in pulpitis, evidenced by severe pulp haemorrhage. Without cortical plate involvement this cannot be seen on a routine radiograph. These signs can be particularly helpful in diagnosing the source of pulpal pain. C-shaped canal complexity in the z-slice (Figure 8c) can be predicted before treatment, and the passage of the canals tracked through the roots, with obturation shown in Figure 8d.