location and extent of root fractures. Bernardes et al concluded that CBCT provides enhanced and accurate information for the diagnosis of root fractures, thereby constituting an excellent alternative for diagnosis in the dental practice. Hassan et al found CBCT better than periapical radiographs in detecting vertical root fractures. Although one can't predictably demonstrate incomplete root fractures on CBCT, I have seen some rather dramatic cases.

Fig 5 shows a periapical image of an upper cusp with a lateral bony lesion mid root. Lateral periodontal cyst, lateral canal, non-healing endo, and fractured root were included in my differential diagnosis. CBCT (Fig 4) clearly shows a fractured root was the cause of the lesion.

Even if you can't see the fracture on CBCT, you can often see the amount and location of bone loss caused by them. Fig 5 shows a PA that is inconclusive. Fig 6 shows bone loss on the second molar consistent with vertical root fracture. (arrow)

**Internal or external resorption**

Fortunately, resorption is much rarer that fractures; it can be no less frustrating to demonstrate the location and extent of the defect on conventional two
dimensional periapical X-rays. CBCT makes this a breeze. Carlos Estrela, et al. concluded that: “CBCT seems to be useful in the evaluation of IRR (intra-irradiation root resorption) and its diagnostic performance was better than that of periapical radiography.”

Fig 9 shows a PA with suspected external inflammatory root resorption on the mesial of the second molar. Figs 10 and 11 show the location and extent of the defect much more precisely on CBCT. One can even measure how close to the pulp it gets!

Difficult anatomy (upper molars especially), dense-in-dentate, severe curves, etc
Here is another case where the anatomy hid the lesion. The PA was inconclusive (Fig 12). The patient was swollen and all the teeth quite tender. Instead of guessing, I could tell for certain which tooth was the cause of his pain and swelling with CBCT (see Fig 13).

Maxillary sinus involvement
The patient in Figs 12 and 13 is an MD radiologist who was diagnosed by a fellow radiologist with a sinusitis. Unfortunately they missed that an infected upper first molar was the source of the sinus infection. Fig 14 shows that the lesion on the palatal root had perforated the sinus floor. Fig 14a shows a medical CT that the patient was swollen and all the teeth quite tender. Instead of guessing, I could tell for certain which tooth was the cause of his pain and swelling with CBCT (see Fig 15).

Gaggers, physically challenged, patients unable to tolerate intraoral X-rays
We all have a few of these. Some patients tolerate treatment just fine, but cannot stand to have film, the sensor, or a phosphor plate in their mouth. Pre and post treatment X-rays taken with a CBCT is a breeze for them.

Trauma cases
Are the roots fractured, is the bone fractured? You often can’t tell if the buccal plate is broken and the tooth subluxated in a trauma case. CBCT will usually show the extent of such injuries. Fig 15 illustrates a badly fractured tooth from trauma. It is easy to see the extent of the fracture.

Retreatment etiology (perforation, missed canals, inadequately root canal filling etc)
I routinely take CBCT on any retreatment case. Knowing that there is a missed canal, a perforation, inadequate filled canals, or some other etiology invisible on 2D images gives me an advantage in recommending retreatment versus surgery, versus extraction.

Surgery planning (apico, reimplant, endo/perio, perforations, mental nerve, inferior alveolar nerve, maxillary sinus)
Knowing the size and extent of the periapical lesion as well as its proximity to the nerve or sinus, takes the guess work out of endodontic surgery.

Expected pathologic lesions size and location
Again, it is good to know what you are up against.

Calibrated canals
Location and existence of calibrated canals are easier visualised on 5D CBCT than on 2D periapical radiographs.

Locate extra canals, calibrated canals, MB2 MB5
Do you need to chase the MB2 canal until you perforate or does it join the MB1 just a couple of mm beyond where you are searching? Preoperative CBCT tells you that for sure. Here is a case (see Fig 16,18,19,30) with three canals in the mesial root of a lower second molar. Not common, but you know they are probably there. I found it with a scope and didn’t have a pre treatment CBCT but it looks cool on the report to the referring doctor.

Facial pain cases to rule out odontogenic etiology
It makes you more confident in making the referral to the oral pain specialist or neurologist when you can be sure there is a tooth the patient thinks is the cause of their neuralgia and you get a normal response to pulp tests.

Endo-perio cases
CBCT is very useful in determining the extent and location of periodontal bone loss. Fuhrmann et al. showed that only one out of 14 furcation defects were visible on periapical X-rays where all 14 were visible on CBCT. How much bone is lost, does the endo lesion communicate with the perio defect? Here is a case of an upper incisor (Fig 21) with extensive periodontal bone loss to the apex. The pulp remained vital to cold tests.

Implant planning and placement
This is a whole presentation in itself. Hans-Joachim Nickenig et al. concluded that CBCT guided implant placement is “significantly more accurate than free-hand insertion”. If you are placing implants, it is much easier to treat planning and place them with a guide generated by CBCT than to just “eye ball” it. Even basic software allows measurement of bone, tracing the nerve and virtual placement of implants (Fig 22).

Here is a case (Fig 23) from a well respected oral surgeon who does a lot of implants and probably wishes he had taken a CBCT to guide him in this case.

Measure canal length
In most cases, our CBCT is more accurate in determining tooth and canal length than an intra-treatment 2D image or an apex locator. Figure 24 shows case I measured accurately on CBCT without using trial length PA or apex locator.

Intra-operative to find canals
It is easy to demonstrate with two-dimensional if you are off to the mesial or distal on a calibrated canal but what if you don’t know if the canal is to the lingual of buccal of where you are searching. Three-dimensional CBCT shows that precisely and saves time and anxiety.

Implant placement guidance using a CBCT generated surgical guide certainly helps avoid misplacing implants and makes the whole process much more predictable.

Post-treatment evaluation for healing
Several articles describe how useful CBCT is for recall to determine if lesions are healing or not.

Conclusions
Can we practice endodontics without CBCT? Yes, we did it for years, but then some of us used to work without microscopes, digital x-rays, and apex locators. Why not have the best information available to make your diagnosis and treatment plan? The more you know about the patient’s anatomy and the shape and number of roots and canals in those roots, the better you will be to diagnose and treat their dental disease. We live and treat patients in a 3D world. Why not use 3D CBCT to better visualise anatomy and pathology?

About the author
Dr Jones has been in private practice limited to endodontics in the greater Kansas City area for 51 years. He received his Doctor of Dental Surgery from the University of Missouri, Kansas City in 1968. He practiced general dentistry in Lawrence, Kansas for over 2 years after graduating in 1975 with distinction with a DDS from the University of Missouri, Kansas City. Prior to dental school, he attended the University of Kansas School Of Pharmacy. He was one of the first Endodontists in his area to utilise computers in the office (late 1980′s), digital radiography (early 1990′s) and Cone Beam CT (2009). He has lectured extensively in Endodontic Diagnosis, Maximizing the Use of Technology in your Personal and Professional Life, Dental Implants from an Endodontic Perspective, and Three Dimensional Cone Beam Computed Tomography in Endodontics. He is a member of Omnnov Kappa Ipsilon and Phi Kappa Phi honorary societies. He is a member of the American Association of Endodontists, the American Dental Association, the Kansas Dental Association, the Fifth District Dental Society, the Chicago Dental Society, the Kansas City Dental Implant Study Club, the Dental Abstract Study Club, and the American Academy of Oral and Maxillofacial Radiology. He is an associate professor in Endodontics at the University Of Missouri, Kansas City School Of Dentistry.
The fight against bacteria
Dr Michael Sultan discusses the importance of cleanliness in the field of Endodontics

Dentistry often involves a battle against bacteria – the invisible invaders that wreak havoc with our oral health, infiltrating into gums and teeth causing tenderness, pain and sensitivity. The basic premise of endodontic procedures is to remove inflamed and infected tissue from the tooth, to clean the root canal system and to seal the tooth back up again. In short, endodontics is all about infection control; one of the fundamental elements of good dentistry.

The rubber dam
It goes without saying that maintaining cleanliness throughout the endodontic procedure should be key to a successful outcome. Nevertheless, teeth are incredibly complex structures and it is impossible to get the tooth sufficiently clean for it to be considered completely sterile.

The endodontist needs to carry out everything within their powers to facilitate infection control to reduce the risk of failure. For this reason, placing a rubber dam during treatment is mandatory.

This thin square of latex rubber serves to isolate the tooth from its environment, in particular from bacteria in the oral cavity, permitting a clean, dry operative field and enabling the treatment of the appropriate tooth without contamination from blood or saliva. I actually find that most patients prefer to have a rubber dam in place as a protective barrier. Medico-legal ly, one of the first questions to be asked following a mishap is whether a rubber dam was used during the procedure, so this device not only protects the tooth and the patient but also the practitioner.

Single-use instruments
The roots of teeth contain very fine, narrow and tortuous channels, some of which can be easily missed or undetected. Despite continuing advances in dental technology, the equipment at the dentist’s disposal is hopelessly inadequate for the job it has been designed to do. Relying on a small, stainless steel file or even super flexible nickel titanium files to successfully clean, shape and decontaminate the nooks and crannies within the tooth is really quite unrealistic.

Nevertheless, they are vital for opening up the canals so that they are accessible to our chemicals for disinfection.

Surprisingly, despite the recommendations that files should be for single-use only, the sales of such instruments for endodontics have actually fallen over the years, suggesting that some practitioners are reusing the same instrument on more than one patient. Aside from the obvious risks this poses to patients’ health and cross infection control, this also contravenes Department of Health legislation which states: “Dentists should ensure that Endodontic reamers and files are treated as single use in order to reduce the risk of prion transmission in dentistry".

If we are to protect the health of our patients and their teeth, reusing single use items is simply not an option.

Chemical options
Most endodontists use chemicals to combat bacteria. A variety of options are available and gaining popularity, enabling endodontists to undertake tasks with minimal energy needs such as flushing through the canals, irrigating the root canals, preventing the entry of bacteria and disinfecting the root canal system.
However, some forms of bacteria such as enterococcus faecalis are resistant to bleach. This microorganism is commonly detected in teeth with asymptomatic, persistent endodontic infections and its prevalence in such infections ranges from 24 per cent to 77 per cent. Enterococci faecalis are hardy bacteria able to compete with other microorganisms, invade dentinal tubules, and resist nutritional deprivation. Currently the most effective methods used to combat these bacteria within the root canal systems of teeth include the use of good aseptic technique, and soaking the tooth in iodine for ten minutes during treatment.

After the root has been successfully treated and bacteria eliminated, the next challenge that must be overcome is how to keep bacteria out. Although the endodontist often will place a temporary seal after treatment, the duty of fitting a permanent restoration with a good coronal seal usually falls to the GDP. This will prevent coronal leakage, which will inevitably compromise the long-term prognosis of a root canal treated tooth.

This should be done as soon as possible to protect the tooth and reduce the chance of fracture. Similarly, if the tooth lacks sufficient structure to hold the restoration and a post has to be placed, the post hole should be left empty for the minimum time possible and ideally dressed with calcium hydroxide.

Indeed, no matter how well the root is treated, if the coronal seal is poor, the root treated canal may well fail and the patient will have to return for further treatment.

Can it be cleaned?
In short, the clinician needs to ask themselves two fundamental questions when considering Endodontic treatment: Can the root be cleaned and can we keep it that way? If the answer to both questions is yes, then endodontic treatment is a very effective option to reduce infection and relieve oral discomfort. With the help of a well-trained and efficient nurse who also appreciates the fundamental importance of cleanliness in Endodontics, the patient can enjoy a very high success rate and make use of their natural teeth for many more years to come.

About the author
Dr Michael Sultan BDS MSc DFO is a specialist in Endodontics and the clinical director of EndoCare. Michael qualified at Bristol University in 1986. He worked as a general dental practitioner for five years before commencing specialist studies at Guy’s hospital, London. He completed his MSc and in Endodontics in 1993 and worked as an in-house endodontist in various practices before setting up in Harley St, London in 2000. He was admitted onto the specialist register in endodontics in 1999 and has lectured extensively to postgraduate dental groups as well as lecturing on Endodontic courses at Eastman CFD, University of London. He has been involved with numerous dental groups and has been chairman of the Alpha Omega dental fraternity. In 2008, he became clinical director of Endocare a group of specialist practices. To talk to a member of the Endocare team call 020 7224 8899 or email reception@endocare.co.uk or for more information please visit www.endocare.co.uk.