CBCT – the justification process, audit and review of the recent literature

Abstract
As part of the quality assurance programme in a dental radiology referral centre, the reasons for taking cone beam CT (CBCT) images were analysed and the volume sizes of the field of view (FOV) were noted. Eighty CBCT scans were carried out in the period examined. Implant planning accounted for 40% of the scans, 26% were for assessment of lesions of endodontic origin, 19% for assessing impactions and 10% for pathology. A review of the recent literature showed that a CBCT scan gives the potential for an improved diagnosis for the patient and has a great range of clinical applications. The effective dose for some of the more common scans was estimated to enable an assessment of the net benefit of the scan to the patient, and to help in developing a scanning protocol.

Introduction
Cone beam computed tomography (CBCT) was developed for dental use in 1998. Kau et al., in a recent review of the market, found 23 different CBCT machines, each with its own software. A typical scan takes approximately 20 seconds, in which the machine orbits the patient and images a cylindrical volume or field of view (FOV). Typical sizes in smaller FOV machines are: 8cm diameter x 8cm height for imaging the dentate area of the maxilla and mandible; 8cm x 5cm for either jaw alone; and, 4cm x 5cm for small areas. Larger FOV machines have volumes up to 20cm in diameter.

The reconstruction server and computer work station collate the approximately 300 individual x-rays into small cubes or voxels, which vary in size from 0.12mm (high resolution) to 0.4mm (low dose). A typical scan can contain 100 million voxels. Secondary reconstruction allows the computer software to organise the voxels into the various planes and the 3D rendering that we see on the screen (Figure 1).

The reconstruction allows for the creation of a pseudo-panoramic image, cross-sectional images and plotting the course of a nerve, as in Figure 2. Simulated implant placement is another very useful function (Figure 3).

When the Dental Council published its criteria for a clinical audit in radiology (see www.dentalcouncil.ie/ionisingradiation), ’justification’ was one of the criteria. An x-ray examination is justified if there is a net gain to the patient. This gain may be diagnostic, an alteration of the treatment plan, or increased confidence for the surgeon contemplating a surgical procedure. This gain has to be balanced against the increased radiation dose; therefore, the dose has to be assessed. The European Commission’s Euratom framework has financed a collaborative project to develop a scientific base for the use of CBCT. This SEDENTEXCT (Safety and Efficacy of a New and Emerging Dental X-Ray Modality) project has produced provisional principles for CBCT use.

There are 20 principles in all. The first and second principles deal with justification, stating that: “CBCT examinations should potentially add new information to aid the patient’s
management”. Principles 9 and 10 deal with ‘optimisation’ and state that, when machines offer a choice, the smallest FOV and lowest resolution should always be used. Principles 19 and 20 deal with the radiological report in FOVs outside the dentate area, and state that these reports should be made by a specially trained dento-maxillofacial (DMF) radiologist or by a medical radiologist.

This audit is carried out in a dental radiology referral centre where the CBCT practitioner is a dentist with an advanced degree in dental radiology. The referring dentist must supply sufficient clinical information to aid the justification process. In all cases, the referring dentist did not get the required information from conventional dental x-ray imaging and felt that additional information would be available from a CBCT scan. Using the ALARP (as low as reasonably practicable) principle, CBCT should only be used when the information that is required is not available from conventional imaging because of the increased radiation dose to the patient undergoing a CBCT examination.

In conventional radiography, selection criteria aid the practitioner in assessing the net benefit to the patient and thereby help in the justification process. However, there are currently no selection criteria for the use of CBCT. The SEDENTEXCT project hope to have CBCT selection criteria guidelines published in the near future; however, in their absence, a review of the recent literature helps to outline the main uses of CBCT.

Some images are used to illustrate observations. This review has an emphasis on justification and on the net value of the scan to the patient. The dose received from a CBCT scan will then be reviewed in order to assess the net benefit to the patient.

Implant placement
Worthington et al. outlined the benefits of CBCT in implant planning. They conclude that CBCT provides the anatomical data that can generate a collaborative treatment plan to achieve optimal results for the dentist and patient. This conclusion is derived from the following advantages. The dentist has an improved visualisation and comprehension of the patient’s anatomy. Reconstructed images can be measured directly on the screen. The prosthodontic plan can be transferred to the scan using a fabricated radiographic guide (or stent) where a radio-opaque marker indicates the desired placement position of the implant, allowing the dentist to evaluate the anatomy directly under the marker. The information can be used to form a surgical guide or template.

To get full value from the CBCT scan, the dentist contemplating placing implants should work out what information they actually require beforehand, e.g., bone height, bone width, bone quality, condition of previously placed graft material, and whether any pathology is present. Specific queries in a mandibular scan would be the position of the inferior dental nerve canal, the anterior portion of the mental nerve, and the presence of mandibular concavities, while maxillary considerations would include the maxillary antrum.

When looking at or deciding to request a CBCT scan for implant assessment, Scarfe and Farman outlined some limitations. Bone quality assessment is unreliable, as greyscale values (improperly called Hounsfield units in CBCT) vary greatly for specific tissues and thereby invalidate their use. Artefacts including ‘stars’, photon starvation and ‘pseudo’ fracture of alveolar bone occur adjacent to...
deep metallic restorations like implants or root canal fillings, as in Figure 4. Patient motion during the scan may produce double contours. Another inherent problem is partial volume averaging, where the structure being imaged is smaller than the voxel size or falls between voxels and is washed out of the image. This is important in that gains made in dose reduction by choosing a larger voxel (low-dose) scan may be lost by losing some narrow structures like a thin cortical plate of bone.

Endodontic assessment
Patel and Horner posed the question: “What potential additional relevant information can a CBCT scan yield over and above conventional radiography, which may ultimately improve the management of the potential endodontic problem?” Patel outlined the following uses for CBCT in endodontics:

1. CBCT is better at the detection of apical periodontitis than conventional radiography, especially in maxillary and mandibular second molars. This may be due to the elimination of ‘anatomical noise’ – the superimposing roots or the zygomatic arch, as in Figure 5.

2. An earlier diagnosis results in a better treatment result. This also means that CBCT is very useful in determining the outcome of treatment. The resolution of a peri-apical radiograph is greater than that of a CBCT image. Newer CBCT machines with a higher resolution and designed specifically for endodontics are now on the market.

3. Pre-surgical planning is greatly facilitated, as CBCT allows the anatomical relationship of apices to anatomic structures to be assessed. The true size and extent of pathology is appreciated, as well as the root to which the pathology is associated.

4. The sagittal plane examination is very useful in assessing dental trauma. CBCT obviates the need for taking images at different angles when checking for a fracture.

5. CBCT is very useful at assessing root canal anatomy, as in Figure 6, and in the management of resorption cases.

Patel noted limitations with CBCT, namely that image resolution fell well short of conventional radiology and that artefacts result in areas with minimal diagnostic value adjacent to highly radio-opaque restorations. Scarfe et al., in their analysis, concluded that: “The usefulness of CBCT can no longer be disputed – CBCT is a useful task-specific imaging modality … in a comprehensive endodontic evaluation.” While outlining similar uses and limitations to those mentioned by Patel, they also showed one intra-operative case where CBCT was used to correct the access preparation.

Orthodontic uses
The British Orthodontic Society introduced guidelines for CBCT use, where Isaacson et al. only recommend the use of CBCT in “highly selected cases where conventional radiography cannot supply satisfactory diagnostic information”. These may include CP cases, assessment of unerupted tooth (and supernumerary) position, root resorption and planning orthognathic surgery. Kapila et al., in their review of CBCT use in orthodontics, illustrate the same protocols as Isaacson et al. and include the evaluation of “boundary conditions”. They also state that the American Association of Orthodontics passed a resolution that CBCT technology “is not routinely required for orthodontic radiography”. Merrett et al. have illustrated some of the situations (ectopic eruption with resultant resorption, odontome presence), where the use of CBCT in the treatment plan helped to plan the surgery and altered the treatment outcome.

Relationship of lower wisdom tooth roots to the inferior dental nerve
While CBCT did not help to predict whether the patient would suffer nerve damage or not, Ghaiminia et al. found that, compared to a pantomogram, CBCT gave a better bucco-lingual appreciation of the nerve canal and aided in planning the surgical approach, when the nerve was lingually placed.

CBCT dose
The Radiation Protection Institute of Ireland (RPII) has estimated the average per capita overall radiation dose as 3,950µSv (microSieverts),
or approximately 4mSv (milliSieverts). This is made up from various sources of radiation, the largest in Ireland being exposure to radon gas. Other contributions come from background, cosmic and medical radiation. Diagnostic x-rays form the greater part of medical radiation and are carefully monitored by the RPII and governed by the HSE. The main tenets of radiation protection are justification and optimisation. The justification principle is satisfied if the radiological examination produces a positive net benefit. The optimisation component is based on the ALARP principle of keeping the dose as low as reasonably practicable. Therefore, CBCT should not be considered if the necessary information can be obtained from conventional radiography.

There is a risk of increased cancer in a population from the combined population radiation dose. This risk is considered stochastic, where there is no threshold dose and risk increases as dose increases. This risk has been estimated by the International Commission on Radiological Protection (ICRP) as 0.055 events per Sievert (Sv). The ‘effective dose’ is still accepted as the most suitable to measure the radiation risk for patients.

Pauwels et al. estimated the effective dose from a wide range of CBCT scanners. The results ranged from 19 to 265µSv. They concluded that a single average effective dose is not a concept that should be used with CBCT. Based on this, scans should have an exposure protocol that leads to an acceptable image for their specific indication. Qu et al. also noted significant reported differences in dose for different CBCT machines, and also differences in dose for different examinations or techniques with the same unit. They investigated the effect of different dental application protocols on the dose from the same CBCT machine – the Promax 3D (Planmeca, Helsinki). The results and extrapolation of the results of their study are used in this audit (as a similar machine is used) to estimate the dose from the different scan settings of combinations of patient size, volume size and image resolution. These doses are detailed in the results section.

Justification and optimisation are inextricably linked, as the dose is reduced by choosing a small FOV and a lower resolution; by reducing the dose, the net benefit to the patient increases.

Patel used the cosmic radiation dose from a return flight from Paris to Tokyo to compare with the effective dose of 150µSv from a 12in FOV iCat exposure. It is a crude comparison and is used in this study to help to quantify the dose of ionising radiation for the purpose of risk assessment.

Materials and methods
As part of the quality assurance programme, the database was searched for all the scans taken in the period of June 1, 2009, to December 21, 2010. All the scans were carried out using the Promax 3D. A total of 80 scans were identified. The scans were collated with the request letters and viewed. Each scan was sorted under the category of the request, of which there were eight in total. The volume size of each scan was noted, and in the case of the smallest volume (4cm x 5cm) the location was recorded.

The doses of the most common scans were estimated using the results and extrapolations of the study by Qu et al. There are approximately 45 combinations of settings of patient size, resolution and volume size in the Promax machine, not to mention the dose variations in the various parts of the dentate area that can be scanned in the smallest volume. Qu et al. covered 12 settings, and their findings, listed below, were used to extrapolate volume settings commonly used in the audit but not calculated by Qu et al.:

- There are five preset patient sizes in the Promax settings. As the tube current increases with patient size, the effective dose rises proportionally.
- The effective dose for a maxillary scan is 44% of the dose for both jaws.
- The effective dose for a mandibular scan is 57% of the dose for a full 8cm x 8cm scan.
- The anterior 4cm diameter FOV scan of the maxilla is 42% of the effective dose of the whole maxilla; an upper molar scan is 66% of the dose of the 8cm maxillary scan.
- The effective dose for all patient sizes is similar for low dose scans, as exposure factors do not greatly increase.

Doses were calculated to help devise a scanning protocol in the radiology centre. For the purpose of comparison to the more common scans, doses of cosmic radiation received on airline flights were calculated using examples from the RPII study.

Results
Implant planning accounted for 40% of the scans taken. The second most common request (26%) was for the assessment of lesions of endodontic origin. Impactions made up 19% in total, approximately half of which were for the relationship of wisdom teeth to the ID canal; the other scans were for supernumerary position, palatally impacted canines and lower premolars. There were eight scans (10%) to image pathological lesions and two for TMJ assessment. The results are represented graphically in Figure 7.

The most common scan size, of which there were 39, was the 8cm x 5cm volume, which images the dentate portion of one jaw. The next most used volume size was the smallest FOV (4cm x 5cm), of which...
there were 31 images, and there were 10 of the largest scan size (8cm x 8cm). These choices are illustrated in Figure 8. The most common region of interest for the smallest volume scan was the upper molar area followed by the upper incisor area.

The effective dose in microSieverts was estimated for the most common exposures in the audit and any relevant figures from Qu et al.’s study are included in Table 1 in red. Extrapolated figures are in italics. Selected exposures are compared to the cosmic radiation doses on return flights from Dublin to the named destination for the relevant scan in Table 2. These comparisons may help in assessing the net benefit to the patient.

Discussion
It is not surprising that the majority of scan requests were for implant planning, where the potential for new and additional information is very high. Apart from the accurate measurements and the simulation of implant placement, the shape of the ridge and the bone quality are important considerations best assessed by CBCT. Figure 9 shows a cross-section of a mandibular ridge. The thin width of the ridge would not be visible using conventional radiography.

Figures 1 and 6 demonstrate the advantages to the surgeon in having a three-dimensional view of the site prior to surgery. Dental Protection, in their recent publication, leave one to conclude that a pre-operative scan will become the standard of care in implant planning.20 It is important to highlight that there must be a clinical indication rather than a medico-legal reason for scanning.

From reading the literature, it is obvious that there are a myriad of uses for CBCT. There is an equal variation in the doses for the various machines, FOV size and image resolution. When the region of interest is close to the glandular tissues of the thyroid, parotids and the submandibular glands, then the dose rises. This explains why the mandibular dose is greater than the maxillary dose.17,18,19 Pauwels et al. conclude that dose optimisation should ensure that patient scans are made using an exposure protocol that leads to an acceptable image for the specific indication.20 An example of marrying the technical dose information to the clinical evaluation would be the selection of the smallest FOV at the lowest dose for the assessment of a supernumerary or impacted canine position in a child, as in this case the resolution of the image is not of the utmost importance and a child is potentially more sensitive to the risk of ionising radiation than an adult. It is also important to stress that if there is any possibility that the region of interest is potentially larger than initially estimated, then the smallest FOV should not be chosen. Audit and evaluation of image quality help in the development of a protocol in the absence of selection criteria.

Conclusion
CBCT has a great range of clinical applications. The 3D information from a CBCT scan gives the potential for an improved diagnosis for the patient and must do so to justify the higher dose than that used in conventional radiology. The dose can be optimised by using a lower resolution and as small a volume as possible. The quality assurance programme will be used to develop a protocol for the optimisation of dose.

References
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Objective: To assess, based on the existing literature, the benefit of socket preservation therapies in patients with a tooth extraction in the non-molar regions in humans:

**a systematic review**


**Material and methods:** MEDLINE-PubMed and the Cochrane Central Register of controlled trials (CENTRAL) were searched till June 2010 for appropriate studies, which reported data concerning the dimensional changes in alveolar height and width after tooth extraction with or without additional treatment like bonefillers, collagen, growth factors or membranes.

**Results:** Independent screening of the titles and abstracts of 1,918 MEDLINE-PubMed and 163 Cochrane papers resulted in nine publications that met the eligibility criteria. In natural healing after extraction, a reduction in width ranging between 2.6 and 4.6mm, and in height between 0.4 and 3.9mm was observed. With respect to socket preservation, the freeze-dried bone allograft group performed best with a gain in height; however, this was concurrent with a loss in width of 1.2mm.

**Conclusion:** Data concerning socket preservation therapies in humans are scarce, which does not allow any firm conclusions. Socket preservation may aid in reducing the bone dimensional changes following tooth extraction. However, they do not prevent bone resorption because, depending on the technique, on the basis of the included papers one may still expect a loss in width and in height.


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**Subgingival debridement of periodontal pockets by air polishing in comparison with ultrasonic instrumentation during maintenance therapy**

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**Aim:** The objective was to determine clinical and microbiological effects and perceived treatment discomfort of root debridement by subgingival air polishing compared with ultrasonic instrumentation during supportive periodontal therapy (SPT).

**Material and methods:** The trial was conducted as a split-mouth designed study of two-month duration including 20 recall patients previously treated for chronic periodontitis. Sites with probing pocket depth (PPD) of 5-8mm and bleeding on probing (BoP+) in two quadrants were randomly assigned to subgingival debridement by: (i) glycine powder/air polishing applied with a specially designed nozzle; or, (ii) ultrasonic instrumentation. Clinical variables were recorded at baseline, 14 and 60 days post treatment. Primary clinical efficacy variable was PPD reduction. Microbiological analysis of subgingival samples was performed immediately before and after debridement, two and 14 days post treatment.

**Results:** Both treatment procedures resulted in significant reductions of periodontitis-associated bacterial species immediately and two days after treatment, and in significant reduction in BoP, PPD and relative attachment level at two months. There were no statistically significant differences between the treatment procedures at any of the examination intervals. Perceived treatment discomfort was lower for air polishing than ultrasonic debridement.

**Conclusion:** This short-term study revealed no pertinent differences in clinical or microbiological outcomes between subgingival air polishing and ultrasonic debridement of moderate deep pockets in SPT patients.


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**A review of the relationship between alcohol and oral cancer**

Reidy, J., McHugh, E., Stassen, L.F.

This paper aims to review the current literature regarding the association between alcohol consumption and oral cancer. The authors have discussed the constituents of alcohol-containing beverages, the metabolism of ethanol and its effect on the oral...
microflora. The local and systemic carcinogenic effects of alcohol have been detailed. The beneficial effects of alcohol consumption on general health have also been considered. A possible relationship between alcohol-containing mouthrinses and oral cancer has been suggested in the literature. The authors conclude that this relationship has not yet been firmly established. However, the use of alcohol-containing mouthrinses in high-risk populations should be restricted, pending the outcome of further research.


**A clinical study evaluating success of two commercially available preveneered primary molar stainless steel crowns**

Leith, R., O’Connell, A.C.

**Purpose:** To evaluate the success of posterior NuSmile® and Kinder™Krown and to determine the level of parental satisfaction with this treatment option.

**Methods:** Forty-eight crowns were placed in 18 children with a mean age of five years. A split mouth design was used. Each participant randomly received each crown type on two or four pair matched molars. Two trained operators completed all treatments. Two additional trained and calibrated clinicians blindly re-evaluated crowns according to specified variables. A visual analogue scale was used to determine parental satisfaction. Examiner reliability was determined by Cohen’s kappa scores and results were analysed statistically using Fisher’s exact test.

**Results:** All crowns were retained after 12 months with no statistical difference in the clinical and radiographic success of posterior NuSmile® and Kinder™Krown. Overall success was high, with 81% of facings intact and 83% free of gingival inflammation after 12 months. Radiographically, 81% were successful. Veneer facing wear was significantly more likely to occur with opposing crowns (p=0.02). Parental satisfaction was excellent with a mean score of 9.3 out of 10.

**Conclusions:** These crowns combine the durability of conventional stainless steel crowns with improved aesthetics and are proposed as a suitable alternative where aesthetic demand is increased.