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CASE REPORT

Journal of Clinical Case Reports and Reviews

The Efficacy of Cone-beam computed tomography in diagnostic imaging

David MacDonald*

Division of Oral and Maxillofacial Radiology, University of British Columbia, Canada

Case report

ACBCT was introduced to dentistry just over 20 years ago with the NewTom. It has since been viewed as an indispensable tool in the assessment of patients and diagnosis of a wide range of lesions and other clinical phenomena. Although a voluminous literature has developed over that time (under 4000 hits on PubMed), much of simply outlines its use rather than evaluating its clinical value.

Some decades ago, Fryback and Thornbury created a six-step hierarchy [1] addressing this in medical radiology. While many papers address the lower steps of 'technical efficiency' and 'diagnostic efficiency' only a few reach the 3rd step of 'diagnostic impact' and even fewer the 4th step of 'therapeutic impact.' Almost none proceed further to the highest of 'patient outcome' and 'socio economic benefit.' This concentration on the lower steps is even more pronounced for CBCT. Horner earlier wrote about this deficiency [2]. It was to clarify these higher steps of Fryback and Thornbury, that work in the fields of endodontics [3] and orthodontics [4] was performed.

The application of CBCT to pre-implant planning occurred when any form of cross-sectional imaging was deemed essential [5]. The lower radiation dose of CBCT has completely displaced medical CT. In addition it superior spatial resolution (image detail) was superior to that of medical CT and all tomographic systems (Scanora, ComCat etc.). The plethora of software to be used in conjunction with CBCT for pre-implant planning continues to expand, each development meeting the evolving needs of both the implantologist and the prosthodontist.

CBCT has done more than displace medical (Fan-beam) CT form implant dentistry, invite itself into Operating rooms (ORs) and Emergency rooms (ERs) for intra-operatory use, it is now applied to the field of Oto-rhino-laryngology to high-resolution imaging of the petrous temporal bone which houses the exquisitely detailed middle and inner ears and their surgically-vulnerable and intimate anatomical neighbours, such as the carotid artery, jugular bulb, facial nerve among others.

The technology moved from the original medical-CT-like NewTom in which the patient lay supine on the 'bed' or 'table' to the panoramic radiographic-like gantries which could more readily fit in a dental office [2]. The patients were seated in the earlier versions to a more common standing position. Some, such as Planmeca, actually use the same gantry for both CBCT and panoramic radiographic work [6].

Another specialty which benefited from the advent of CBCT was endodontics. The first unit which addressed the high spatial resolution needs was the Carestream 9000. Its resolution was 0.078 mm voxel size. This has been joined by the Morita Accuitomo, which first emerged nearly 20 years ago as a small field unit and was frequently used to complement the Imaging Sciences International's iCAT or the Hitachi CB MercuRay.

Although high-spatial-resolution CBCT joined the microscope as essential parts of the armamentarium of most endodontists, it has not displaced conventional radiography (Most usually periapical radiography). A recent study performed in an endodontic graduate program at a major North American dental school revealed that conventional radiography alone was the only imaging necessary to complement the clinical examination. This was particularly true for those teeth which had not been previously root-treated. CBCT was used only in one-out-of twelve cases, overwhelmingly for those endodontically-treated teeth that require retreatment, 76%. CBCT was significantly better at revealing periapical radiolucencies, missed canals and vertical root fractures [4]. As the last almost invariably results in extraction, it is particularly invaluable as the endodontist and patient's time is not wasted on an attempt to treat that with such a poor prognosis. This report is perhaps the first to reveal the application to two of Fryback and Thornbury's higher levels with regards to dentistry. CBCT performed significantly better than conventional radiography with regards to 'Diagnostic impact' (P=0.001) and 'Therapeutic Impact' (P=0.005)

The presence of a number reconstructions of the dataset allows the clinician to glean the best information from it. There are generally three types of reconstructions available, multiplanar, curved and oblique. The multiplanar (known as multiplanar reformation or MPR) is the standard default reconstruction for most cross-sectional imaging modalities (Figures 1-3). It follows the traditional anatomical planes of axial, coronal and sagittal. In medicine it is invariably the standard, is it nevertheless of limited use when applied to the jaws. The jaws horseshoe shape requires a different reconstruction. Long prior to the Advent of dental CBCT, the 'dentoscan' was developed medical CT, which allowed the reconstruction to follow this horseshoe (Figure 4). A panoramic reconstruction is first created from which 'transections at right angles to the panoramic are created. This reconstruction is used as standard by implantologists and surgeons. This allows optimal placement of the implants within minimal damage to important anatomical structures such as the mandibular canal and submandibular fossa (and the submandibular gland it principal content).

Following on directly from these CBCT has also been used for pre-surgical planning of deeply placed or other wise difficult

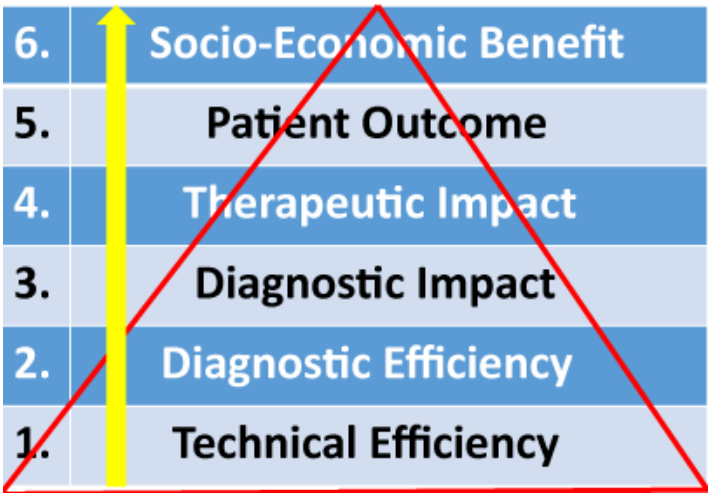

Figure 1. Fryback and Thornbury's hierarchy for the efficacy of diagnostic Imaging. Created from their text in Fryback et al. [1].

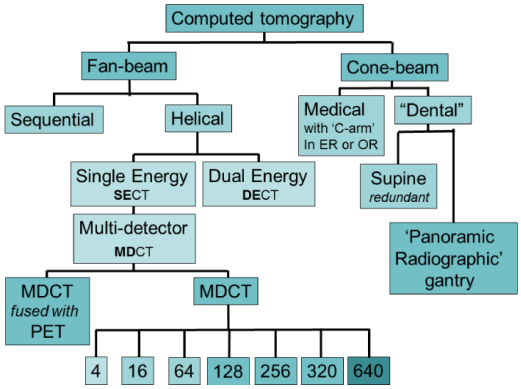

Figure 2. The relationship and development of the nomenclature of computed tomographic technologies. Reproduced with approval from David MacDonald [2].

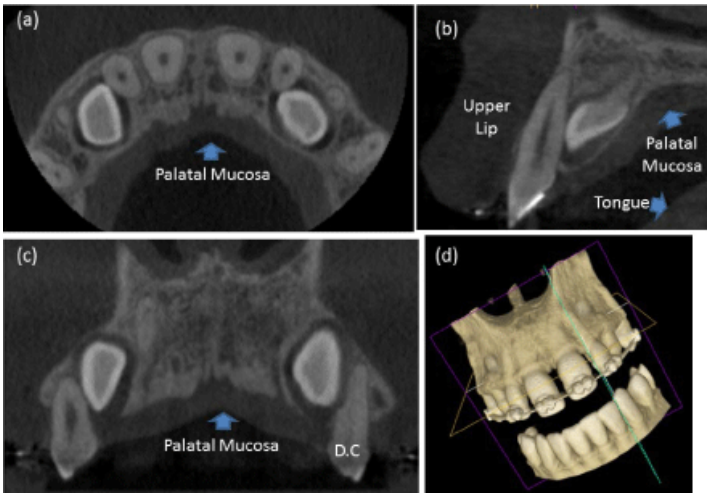

Figure 3. Small (5 x 5) FOV multiplanar reformatted (MPR) CBCT of impacted maxillary canines prescribed after parallax using conventional intra-oral radiographs was equivocal. Axial (a), sagittal (b) and coronal (c) reconstructions were made of the dataset represented by the 3-D reconstruction (d). The position of each plane is clearly displayed in (d). Note. The lower (mandibular) teeth were cropped out in order to compile the above figure. (a) and (b) reveal that the crown of the maxillary canine is in intimate contact with the roots of the erupted permanent lateral incisors, but are not resorbing them at this moment. (c) displays the left maxillary canine resorbing the root of the deciduous canine. This kind of resorption is expected and desirable. Reproduced with approval from David MacDonald [2].

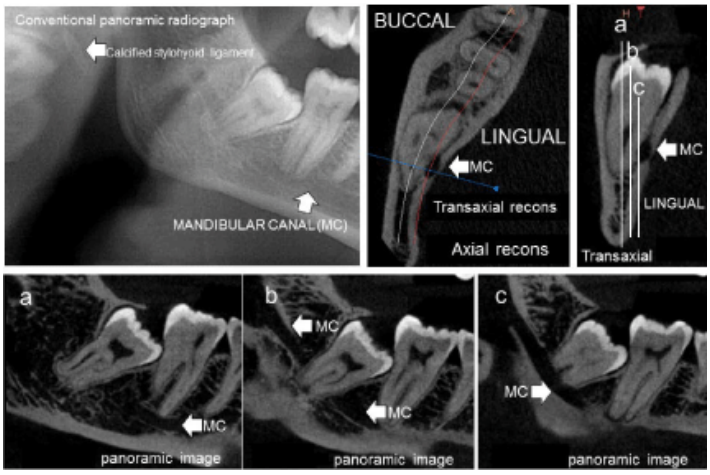

Figure 4. Part of the conventional panoramic radiograph and a Small (5 x 5) FOV CBCT of the impacted right third molar (wisdom tooth). It is in an intimate relationship with the mandibular canal (MC). It is grooved by the MC, which in turn has compressed it against the lingual cortex which the MC in turn has markedly eroded. Note also that the apex of the distal root of the impacted right third molar is very slightly hooked; this may complicate the ease of removal of that root. This can be moved buccally or lingually. The reconstructed panoramic images b and c represent reconstructions more lingual to reconstructed panoramic image a. Note how the mandible shape changes between the three reconstructed panoramic images! The blue line on the axial reconstruction perpendicular to the white line represents a transaxial reconstruction. Reproduced with approval from David MacDonald [2].

impacted third molar teeth (Wisdom teeth) [7]. Usually the curved reconstruction is used for these. In orthodontics impacted maxillary canines are problematic, since they occur at the 'corner' of the upper jaw, hence their name in German, 'Die Eckezahnen,' meaning the 'corner teeth'. A study in the graduate orthodontic program again in a large North American dental school, revealed that both MPR and curved reconstructions played a role in the optimal determinant of the tooth position, root resorption, root dilaceration, cortical dehiscence and proximity to the floors of the maxillary sinus and of the nasal cavity. The determination of which reconstruction was best varied from case to case. This was encountered even as the cases used varied only slightly from each other at the outset of the study. The conclusion was that both reconstructions should be applied for the evaluation of impacted maxillary canines.

A developing field in imaging of the face and jaws is artificial intelligence (AI). Orhan et al. [7] recently applied AI, based on deep learning concepts, to periapical radiolucencies [7] in an endodontic context. Although this is an important step forward, periapical radiolucencies of inflammatory origin (PRIOs), which are the most expected cause of such radiolucencies, they are by no means the only ones. MacDonald has addressed this matter with the use of CBCT [8], and more recently [6,9].

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Correspondence: David MacDonald, Division of Oral and Maxillofacial Radiology, University of British Columbia, Canada, Tel: (604) 822-9762; E-mail: dmacdon@dentistry.ubc.ca

Rec: Jan 06, 2020; Acc: Jan 20, 2020; Pub: Jan 24, 2020

J Clin Case Rep Rev. 2020;3(1):147
DOI: gsl.jccrr.2020.0000147