Suggested Application of CBCT as Indicated by Current Literature

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Since the introduction of the clinical use of Conebeam Computerized Tomography (CBCT) by the Mayo Clinic Biodynamics Laboratory, and more specifically for the use in the cranio-facial region with the introduction of the first commercially available CBCT unit in 2001, the possibilities for the utilization of CBCT in the maxillo-facial region has expanded exponentially. [1] This creates a current vacuum for evidence-based use of the technology that has applications within dentistry including the specialties maxillo-facial and oral surgery, endodontics, orthodontics and periodontics.[2]

The introduction of CBCT technology has certainly brought about a major improvement in the imaging of the cranio-facial region and has many advantages over conventional radiography and multislice computerized tomography (MCT) that has been well documented in several studies. CBCT have been shown to be superior to conventional peri-apical radiographs in the evaluation of peri-apical disease and diagnosis. In endodontics, CBCT has also been shown to be superior to conventional radiographs in indicating periodontal bone loss and more accurate and more reliable in the morphological evaluation of bone during implant planning.[2] CBCT may also, under certain circumstances, allow for more detailed visualization of small field of view at radiation doses equal to or even less than conventional 2D radiographs.[2,3] If the cumulative radiation dose of a range of radiographs are further compared to a single larger field of view CBCT, providing increased detail of the same anatomical region, this may also result in less radiation exposure to the patient.[2,4-6] Cost of a full mouth series including a panoramic radiograph, as compared to a single imaging session with CBCT, providing more detailed imaging of the same region must also be considered.[5] Advantages of CBCT over the use of MCT have also been well described and includes decreased radiation of approximately 90% less than MCT, high resolution CBCT provides superior imaging when compared to MCT with higher spatial resolution than MCT, as well as a significant decrease in cost of the examination.[5-9] The artifacts produced due to the presence of metallic restorations or objects are less with the performance of a CBCT and this investigation are therefore preferred in the evaluation of metallic foreign objects in the facial region, and could furthermore produce superior imaging in patients with extensive dental restorative work.[10]

CBCT certainly has its disadvantages and is most certainly not a replacement for current imaging modalities, this new technological advance should be used with due regard for patient safety and cost and well documented radiological principles should be adhered to in order to ensure the safe and cost-effective use of the modality. Disadvantages over 2D radiographs are the increase in radiation dose to the patient, it should however be noted that this is all dependent on the specific CBCT unit being used, the field of view selected, the image quality selected and the specific settings selected on the CBCT unit.[2] CBCT has poorer soft tissue contrast resolution, when compared to MCT, and is therefore not useful for the evaluation of soft tissue.[11] Scanning of a similar volume is much faster with a MCT and therefore movement of the patient during scanning has a bigger impact on image quality with a CBCT scan. [2-4] Scatter and beam hardening in regions neighboring high-density areas impact negatively on image quality of the CBCT obtained, this is however also applicable with the use of MCT. [3,12]

In establishing guidelines for the use of CBCT it is important that the practitioner requesting the imaging adhere to well established principles. The goal during the utilization of an imaging modality would be to balance the uses and limitations of imaging choices in order to achieve the desired diagnostic information of sufficient quality while keeping the risks along with the costs to

the patient as low as reasonably possible.[4] In achieving this goal the practitioner would improve diagnostic accuracy, risk assessment, treatment efficiency and outcome, reduce treatment complications and in doing so, reduce the cost of treatment.[4] CBCT meets the legal definition of standard of care for imaging in the USA and has been recognized as the standard of care in the management of certain conditions in dental practice. The use of new technology in patient care not only provides advantages and opportunities but also carry with it responsibilities and obligations for the practitioner involved.[4,7] The development and availability of CBCT scanners have contributed significantly to treatment planning and this relates to improved treatment planning with the possibility of many risks related to procedures that can now be avoided. In the state of California the reduction or elimination of risk with the use of CBCT is such that the failure by the practitioner to offer CBCT imaging may be seen by the courts as substandard care.[4] It is interesting to note that according to Curley & David complications related to implants where another expert's opinion or legal counsel was sought by the patient, the first investigation performed was a CBCT, and furthermore that the CBCT was the basis for a legal claim in the majority of cases.[4]

In deciding on the diagnostic use of CBCT in a particular patient the following well established general principles apply:

1. As low as reasonably achievable (ALARA) principle of radiation. The imaging modality must be selected that would result in the lowest possible radiation exposure that would result in images of acceptable and adequate diagnostic qualities.[11,13]
2. The smallest volume that will image the area of interest should be selected. This leads to lower patient radiation exposure but will furthermore provide a higher image resolution than a larger field of view. It has the further advantage of limiting the imaging of neighboring anatomy that would need interpretation by the practitioner and therefore limiting legal liability and would also lower the cost of the imaging for the patient.[7,12]
3. Imaging should have appropriate diagnostic quality; poor quality imaging only leads to radiation exposure to the patient with no diagnostic benefit.[11]
4. The practitioner should be appropriately trained in the use of the equipment.[2,11]
5. The practitioner should be appropriately trained and competent in the interpretation and recognition of pathology or suspicious areas in the entire CBCT scan taken, or should refer the images to a specialist for interpretation.[2,7,11]
6. On deciding to utilize 3D imaging for the evaluation of bony morphology or pathology the patient is entitled to be informed of the advantages of CBCT over MCT (lower cost, lower radiation, and increased accuracy) according to the informed consent doctrine.[7]
7. The total volume scanned needs to be evaluated and not only the region of interest.[2]
8. Where a MCT is likely to provide diagnostic information, a CBCT is a sensible alternative, reducing radiation and cost to the patient, provided that soft tissue imaging and contrast is not needed for evaluation of the pathology. [10]

Current literature acknowledges the role CBCT plays in the fields of general dentistry, maxillo-facial and oral surgery, orthodontics, endodontics and periodontics. [1-3,6,8,10,12,14-18] The general principles already discussed are applicable for each of these disciplines and the following section will be dedicated to each of the specific applications of CBCT technology.

Maxillo-facial and Oral Surgery

Trauma

The use of CBCT in the evaluation of the complex high contrast structural pathology of maxillo-facial fractures are mentioned as a logical application of CBCT and the use of MCT in the evaluation of facial fractures have been accepted in the literature for many years. [1,19] CBCT have been described for the effective use in fractures of the midface, frontal region, naso-ethmoiedal complex, orbits, mandible and combinations of these.[19]

CBCT is also clearly superior to conventional 2D imaging in the evaluation of dental trauma and suspected root fractures of teeth. CBCT shows increased sensitivity over conventional imaging in the detection of horizontal root fractures of human lateral incisors under experimental conditions.[12,16] Before the advent of CBCT imaging a large number of conventional views were recommended in the evaluation of suspected root fractures, mitigating the radiation dose increase where CBCT is applied. It was further found that a large number of root fractures were not detected at the time of injury despite the use of conventional radiographs and this has been shown to lead to improper treatment and unfavorable outcomes. Of all the imaging modalities the diagnostic accuracy was found to be the highest with the use of CBCT in suspected root fractures and it is therefore suggested that CBCT is the most reliable imaging modality in these cases.[16,20]

Pathology

CBCT are being used for the evaluation of benign cysts and tumors for the evaluation of margins, especially in poorly circumscribed lesions, as well as the evaluation of cortical perforations to determine margins of resections during surgical planning. CBCT is of particular value in the follow up of these benign tumors or cysts to exclude recurrence.[6,10]

The use of CBCT in malignant conditions of the head and neck is more restricted and confined to lesions where no soft tissue imaging is needed.[10] Where a MCT of the neck and chest is needed for the evaluation of regional and distant metastasis with contrast the sensibility of a CBCT as a separate procedure needs to be evaluated and is often advisable in such instances to request a MCT of the primary as well as neck and chest regions.[15]

In the evaluation of inflammatory conditions of bone it could be argued that CBCT would be able to identify periosteal reactions and pathology earlier and more accurate than conventional imaging and may be of benefit.[10] CBCT has been found to be superior in the identification of small bone sequestra in osteomyelitis in need of surgical debridement and is therefore a better imaging modality than conventional radiographs for osteomyelitis.[10]

CBCT are helpful in the identification of sinus pathology that include mucus retention phenomena, antral polyps, sinonasal polyposis, and malignant tumors of the sinuses. The use of CBCT in the evaluation of sinus disease is of particular importance in the exclusion of sinus disease in orofacial pain. Imaging with CBCT should be considered if there suspicion of an oro-antral fistula.[10]

In patients involved in motor vehicle accidents, industrial accidents or gunshots where foreign metallic objects need to be localized in the face or where a dental needle has broken and has been

retained imaging derived from CBCT is superior to MCT imaging and is therefore the investigation of choice due to the decrease in degraded artifacts.[10]

Tempero-mandibular joint (TMJ)

The literature is currently unclear as to the exact role of CBCT imaging in the evaluation of TMJ pathology with some authors advocating and some authors rejecting the role of CBCT in the evaluation of TMJ pathology, what is however very clear from current literature is that CBCT is superior to both MCT and MRI in evaluating the bony pathology within the TMJ complex and inferior to MRI in evaluating the soft tissue component of the TMJ complex.[9,14] It is suggested that TMJ pathology that is painful or do not reduce will need imaging studies and adequate information regarding soft tissue may be derived from CBCT imaging. [9] Initial evaluation of the TMJ complex in patients with symptoms has previously been a panoramic radiograph or a tomogram; both of these investigations have been shown to be inferior to CBCT imaging.[9] It is furthermore clear from the literature that in those patients presenting with TMJ pathology where osseous pathology or deformation of the TMJ is suspected CBCT is superior to both MCT and MRI.[9,14] It is the author's opinion that CBCT imaging provides the opportunity for the evaluation of sinus and dental pathology that could indirectly impact on bruxism and TMJ function, taking the radiation exposure and cost of a panoramic radiograph, TMJ tomograms, a full mouth series and sinus views into considerations a single large field of view CBCT that gives information related to all these structures are an overall safer procedure with less radiation and most probably lower cost to the patient.

The role of CBCT in the evaluation of evaluation of fractures involving the TMJ complex, remodeling, osteoarthritis, inflammatory arthritis, developmental structural abnormalities and tumors of the TMJ are well documented. [9]

Impacted teeth

The use of CBCT has been well documented in the evaluation of impacted teeth. The principle of assessing the relationship of the inferior alveolar nerve in the removal of impacted mandibular third molars are well established and this has been achieved with a panoramic radiograph in the past. The routine use of CBCT in evaluating impacted third molars is not advocated and the panoramic radiograph remains the imaging modality of choice.[21] The use of CBCT imaging in cases where a close relationship exists between a mandibular third molar and the inferior alveolar canal is however justified.[6,21] The localization of impacted canines and supernumeraries with CBCT imaging is stated as to be so obvious that no research are being done on the usefulness of CBCT in these cases, CBCT furthermore provides a wealth of additional information to the orthodontist in these cases that influences treatment decisions and outcomes and the use of CBCT in these cases are therefore advised.[4,13,18,21]

In a scenario where an impacted tooth in an unusual position or close to other vulnerable anatomical structures e.g. Coronoid process, near the orbital floor or the lower border of the mandible it would most probably be good judgment and practice to obtain 3D imaging and as discussed already a CBCT would be the image modality of choice in these instances.

Cranio-facial Surgery

It is mentioned in various publications that the use of CBCT in craniofacial surgery holds particular advantages as the congenital craniofacial population are usually at an age where radiation doses is of particular concern, although these patients may benefit from 3D imaging and treatment planning. The use of CBCT could therefore reduce radiation dose significantly while the benefits of better imaging and surgical planning may be achieved.[6,15,18]

Patients presenting with acquired craniofacial defects due to oncological or trauma induced defects have very complex 3 dimensional defects that demands very complex prosthesis, careful treatment planning and difficult surgical reconstructions for which the benefits of 3 dimensional imaging, 3 dimensional models and prosthesis have been well accepted and published in the literature, as a consequence these patients will benefit form all the advantages mentioned above related to the use of CBCT imaging where soft tissue evaluation is not needed.

Orthognathic Surgery

Lateral cephalometric imaging has been the standard for surgical planning and evaluation in orthognathic patients.[6] These images may be derived from the CBCT volume and studies have been conducted comparing the use of conventional cephalometric imaging and imaging derived form 3D volumes. These studies found no statistically significant differences in linear or angular measurements between CBCT derived and conventional cephalograms, measurement errors have however been found to be less in CBCT derived cephalograms.[18] The use of a CBCT volume is comparable to the radiation from a full set of conventional 2D imaging panoramic radiograph (14,2µSv-24,3µSv) , lateral cephalogram (10,4µSv) and full mouth series (13-100µSv) usually employed in the evaluation of the orthognathic patient, these imaging may be derived form the CBCT volume and it is therefore advisable to utilize CBCT in these specific circumstances if available, especially where other indications for CBCT exists.[18] The use of conventional cephalometric imaging is known to be inadequate for the evaluation of deformities like hemi-facial microsomia, facial asymmetries and occlusal cants and CBCT is indicated in these circumstances. [6,18]

Implant Surgery

The American Academy of Oral and Maxillofacial Radiology (AAOMR), in 2012, released a position statement on the use of radiology in dental implantology with specific emphasis on the Use of CBCT and of all the literature surrounding the use of CBCT in implantology this is probably the most practical and useful.[11] An earlier position statement in 2000 by the AAOMR stated that in view of the evidence in the literature reviewed some form of cross sectional imaging is needed for implant placement, at this time conventional tomography was advised. The development of CBCT technology has prompted a review of the position statement and the statement consists of various recommendations, which provides clear, concise and practical evidence based guidelines for the use of radiology during implant placement.[11]

Recommendation 1: Panoramic radiography should be used in the initial assessment of the dental implant patient.[11]

Recommendation 2: Use intra-oral peri-apical radiography to supplement this preliminary information from the panoramic radiography.[11]

Recommendation 3: Do not use cross sectional imaging, including CBCT, for the initial assessment of the implant patient.[11]

Most studies indicate that data from these imaging modalities are insufficient to accomplish the goals of pre-operative radiological implant site assessment: establishing the morphological characteristics of the alveolar ridge, determine the orientation of the alveolar ridge, identify local or pathological conditions restricting implant placement and matching the image findings with the prosthetic plan. It was further found that these images provided inadequate information to determine treatment difficulty.[11] It is however the authors opinion that from a practical viewpoint the above imaging modalities only adds to radiation exposure and treatment cost if CBCT is used for implant assessment, as the use of CBCT would provide all the information derived form the above imaging modalities, and should be omitted if specific indications for their use are not present

Recommendation 4: The radiographic examination of any potential implant site should include a cross sectional image orthogonal to the site of interest.[11] This is supported by the fact that is virtually impossible to predict which cases would not benefit from having the additional CBCT imaging performed before obtaining it.[22]

Recommendation 5: CBCT should be considered as the imaging modality of choice for pre-operative cross sectional imaging.[11]

Recommendation 6: CBCT should be considered where clinical examination indicates the need for augmentation procedures.[11,17,22]

Recommendation 7: CBCT should be considered before implant placement where augmentation or reconstruction procedures have been performed.[11,17,22]

For the evaluation of post-operative implant placement the following recommendations are made:

Recommendation 8: In the absence of clinical signs or symptoms use intra-oral peri-apical radiography or panoramic radiography for the evaluation of implants as the resolution of CBCT is inferior to conventional radiographs when evaluating bone-implant interface and peri-implant bone height due to beam hardening and scatter occurring with CBCT.[11]

Recommendation 9: Use of cross sectional imaging (particularly CBCT) is advised immediately post-operative if implant mobility or altered sensation is present.[11,17,22]

Recommendation 10: Do not use CBCT for periodic review of asymptomatic implants.[11]

Recommendation 11: Where implant retrieval is considered the use of CBCT in particular is advised.[11]

Apart from principles already discussed the AAOMR also advise that the imaging should extend beyond the immediate area of interest to include areas that could be affected by implant placement. Renton and co-workers indicated that inferior alveolar nerve injury related to implant placement was associated with only 10% of patients that had a CBCT and 50% of patients that had a panoramic radiograph and that CBCT imaging was of value in reducing immediate post-operative complication and the assessment of risk of inferior alveolar nerve injury.[22] The use of CBCT in the placement of implants are also obvious in cases where implant guides are needed for the correct placement of implants in guided cases.[17]

Orthodontics

CBCT have been found to demonstrate better imaging for the localization of impacted and supernumerary teeth, in the evaluation of retained teeth, root resorption and cleft lip and palate patients than conventional 2D imaging. When the treatment planning of orthodontic patients have been evaluated with conventional 2D images these treatment plans were modified in more than a quarter of teeth when the CBCT images were viewed. Of particular use in orthodontic patients is the evaluation of impacted and transposed teeth in order to identify associated pathology, root resorption and to help plan surgical access to these teeth as well as the most optimal pathway for extrusion on the oral cavity.[13,18,23] CBCT may also be used to evaluate boundary conditions, which may limit or dictate the movement and final position of teeth. [18] The evaluation of the TMJ by CBCT may also be of particular value in the planning of the orthodontic patient's management and the use of CBCT in the orthognathic surgical patient have been discussed already.[18,23] CBCT may have value in the evaluation of the airway in patients with obstructive sleep apnea but this has not been confirmed with any scientific studies.[18,23]

Endodontics

CBCT has been found to be significantly more sensitive than conventional imaging in detecting apical periodontics and have been found to detect 62% more peri-apical lesions than conventional imaging. CBCT is therefore important in the earlier detection of apical periodontitis and in these cases a better outcome is anticipated for the non-surgical treatment root canal treatment performed. The assessment of the outcome of endodontic treatment review CBCT images are to be compared with pre-operative imaging for follow up. Improved outcomes and decrease iatrogenic injuries to neighboring teeth are also encountered in the evaluation for peri-apical lesions managed with apicectomies.[12,16,24,25] As mentioned before CBCT is far more sensitive in the evaluation of horizontal root fractures and is therefore invaluable in the assessment and determining the outcome of treatment in patients with dento-alveolar trauma, CBCT is also reported to be very sensitive in the detection of vertical root fractures. CBCT is also an extra-oral imaging modality and the investigation being more comfortable for the patient with dento-alveolar trauma than conventional intra-oral imaging is more accurate en more suitable for these patients.[16,25] CBCT has also been indicated to be superior to conventional peri-apical imaging in the assessment for external root resorption of teeth subjected to trauma and consequently improves the prognosis and outcome of the management of these teeth.[16,24,25]

The detection of supplemental canals has been proven to be superior with CBCT if compared to conventional endodontics and has been found to be an accurate and reliable tool to evaluate the curvature in teeth. CBCT is a useful tool in the planning of endodontic treatment for teeth with anatomical and morphological anomalies such as fused teeth or dens invaginatus.[12,16,24,25]

The sensitivity of conventional radiography is significantly poorer than CBCT in the early detection of root resorption and is an effective and appropriate method of evaluating root resorption while conventional radiographs are not.[16,25] The use of CBCT is also advised when complications of endodontic therapy are encountered.[24,25]

Periodontics

CBCT performs superiorly in the evaluation of buccal or lingual periodontal defects when compared to alveolar radiographs due to the superimposition of teeth and alveolar bone on conventional radiographs and is therefore advantageous in the evaluation of buccal, lingual and furcation defects and may replace surgical re-entry as a technique for assessing regenerative therapy outcomes.[12]

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