Cone Beam CT for Diagnosis and Treatment Planning in Trauma Cases

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- Cone beam computed tomography
- Three dimensional imaging
- Trauma
- Technology

Three-dimensional imaging offers many advantages in making diagnoses and planning treatment. This article focuses on cone beam CT (CBCT) for making diagnoses and planning treatment in trauma-related cases. CBCT equipment is smaller and less expensive than traditional medical CT equipment and is tailored to address challenges specific to the dentoalveolar environment. Like medical CT, CBCT offers a three-dimensional view that conventional two-dimensional dental radiography fails to provide. CBCT combines the strengths of medical CT with those of conventional dental radiography to accommodate unique diagnostic and treatment-planning applications that have particular utility in dentoalveolar trauma cases. CBCT is useful, for example, in identifying tooth fractures relative to surrounding alveolar bone, in determining alveolar fracture location and morphology, in analyzing ridge-defect height and width, and in imaging temporomandibular joints. Treatment-planning applications include those involving extraction of fractured teeth, placement of implants, exposure of impacted teeth, and analyses of airways.

In hospital settings, it is common to use CT in patients with trauma and pathologic conditions. However, in dental practice, practitioners depend almost entirely on two-dimensional plain films. The applications and advantages of the third dimension in dental medicine still remain largely unrealized.

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In 1998, Mozzo and colleagues\(^1\) reported on the NewTom 9000 (Quantitative Radiology, Verona, Italy), the first CBCT unit developed specifically for dental use. Other similar devices introduced at around that time included the Ortho-CT, which was renamed the 3DX (J. Morita Mfg. Corp., Kyoto, Japan) multi-image micro-CT in 2000.\(^2\) In 2003, Hashimoto and colleagues\(^3\) reported that the 3DX CBCT produced better image quality with a much lower radiation dose than the then newest multidetector row helical CT unit (1.19 mSv versus 458 mSv per examination).

Two major differences distinguish CBCT machines from conventional hospital CT scanners (helical, spiral, fan). First, CBCT uses a low-energy fixed anode tube, similar to that used in dental panoramic radiograph machines. Second, CBCT machines rotate around the patient only once, capturing the data using a cone-shaped x-ray beam. These differences make possible a less-expensive, smaller machine that exposes the patient to approximately 20% of the radiation of a helical CT, which is equivalent to a typical exposure from a full-mouth periapical series.\(^4\) The volumetric capturing difference provides CBCT with a more focused beam, resulting in images with higher geometric accuracy, higher spatial resolution, and considerably less scattering in comparison with images from conventional CT scanners. One disadvantage of the volumetric capturing method is that the Hounsfield units, which provide density information, cannot currently be captured in a reliable fashion when using CBCT. Ongoing projects are working on such calibration, but no method is currently commercially available.

Due to CBCT’s volumetric data capturing method, related articles have referred to this technology with a variety of terms including cone beam volumetric tomography, cone beam computed volumetric tomography, cone beam volumetric radiography, dental CT, dental volume tomography, digital volumetric tomography, and cone beam 3D. This multiplicity of terms stems largely from disagreement over whether CBCT capturing methods can truly be called tomography. The result is a lack of terminology consensus in the literature, making it more difficult for researchers and clinicians to stay up to date with the latest projects and publications because different key words need to be searched.

All of the CBCT scanners on the market use the same volumetric capturing technology, but have significant hardware differences. Scanners can be categorized according to type of detector, patient position (sitting, standing, or supine), field of view, the use of fixed radiation settings or user-controlled settings, and whether or not the scanner is dedicated or hybrid. The detector can be either an amorphous silicon flat-panel detector or a combination of an image intensifier and a charge-coupled device camera. Both these technologies have been proven to be accurate and reliable and provide sufficient resolution for dental medicine needs. The field of view stands for the final image size produced by the scanner. Different scanners offer different field-of-view capabilities resulting in images ranging in size from 1 in to 12 in. To best accommodate collimation capabilities and reduced radiation exposure as much as possible, the field of view used should match the region of interest. In other words, if all the clinician wants is to evaluate an area of suspected fracture, the relationship of the alveolar ridge to an impacted tooth, or area of suspected pathology, there is no need to capture an image that would show the patient’s entire head. Some scanners offer both large and small field-of-view capabilities, while others, tailored for more specific applications, offer only small field-of-view capabilities.

A significant lack of standardization found in the commercially available CBCT scanners has to do with the radiological settings. Depending on the scanner, the milliamperage used may range from 1 mA to 15 mA, with most scanners using around 6 mA. Often the radiological settings are fixed and cannot be changed without the
intervention of the manufacturer’s engineers. So radiation exposure depends largely on the scanner used, since it plays an important role on the settings used.

Effective CBCT radiation dose depends on the settings used (kilovolt [peak] and milliampere), collimation, and exposure time. The use of lower settings reduces the radiation dose received by the patient, but could also diminish image quality. The choice should always be the lowest possible settings that also accommodate a diagnostic-quality image. However, specific settings for different clinical applications have yet to be determined. This can only be done by considering the image quality because radiation exposure information without image quality control is just half the story. The settings, including milliampere, kilovolt (peak), and field of view, are going to be different for different clinical applications. For example, as the settings for diagnostic screening will differ from those for implant planning. Settings should be consistent among imaging centers, and the scanners should have such settings as options. This is the only way to efficiently apply the ALARA (as low as reasonably achievable) principle.

Within every field, the introduction of new technology raises several fundamental questions, such as: For what practical applications can the new technology be used? and: Is the new technology truly superior to existing modalities? These questions are not easily answered, but require research and comparison. CBCT diagnostics in posttraumatic clinical applications appear to offer advantages over medical CT and conventional dental radiography.

Because all images can be taken in around 10 seconds with a single rotation of the x-ray source, CBCT is useful in trauma, intraoperative, and sedation cases.

CLINICAL APPLICATIONS IN TRAUMA DIAGNOSIS: OVERCOMING CONVENTIONAL CT DIAGNOSTIC CHALLENGES AND ADDING A NEW DIMENSION TO CONVENTIONAL RADIOGRAPHY

CBCT equipment is smaller and less expensive than medical CT equipment and is particularly well suited to evaluating the jaws because of a lower level of metal artifacts in reconstructions versus its helical predecessor. In a conventional CT, for instance, an area of the jaws close to a metallic restoration, a crown, or an implant is difficult to analyze because of the artifacts and distortions that the metal in the region of interest creates. On a CBCT image, the area around metal is usually of diagnostic quality, and with little scattering and no distortion (Fig. 1). When compared with dental panoramic radiograph, CBCT is useful in identifying the location of cortical plate fracture that is not through and through (Fig. 2). Additionally, CBCT is more sensitive and accurate in imaging the maxilla and mandible. It is reported that mandibular fractures not evident in conventional CT can be identified using CBCT. Also, when using CBCT, as compared to CT and conventional radiograph, information about dentoalveolar fractures is more detailed. This makes CBCT uniquely useful in alveolar fracture diagnosis.

Another common diagnostic challenge is presurgical evaluation of mandibular lingual cortical bone. During open reduction of mandibular fractures, not all fracture sites can be readily exposed for direct visualization. CBCT allows for fracture diagnosis. Similarly, the lingual cortical plate, although not fractured through and through, may present with a concavity or alveolar bone defect. This concavity or defect complicates dental-implant placement either by appearing to have wider alveolar ridge than what is actually there, or by limiting the amount of space available between bone and the inferior alveolar canal. Visualization of alveolar bone morphology and the relationship to other structures, such as the inferior alveolar canal, can be clearly identified using CBCT (Fig. 3).
Location of alveolar ridge relative to anatomic structures, such as the inferior alveolar nerve, maxillary sinus, mental foramen, and adjacent teeth, are readily identified using CBCT. The CBCT image allows for precise measurement of the ridge area and volume in relation to local anatomy (Fig. 4) and thus increases diagnostic confidence.

Furthermore, three-dimensional imaging captures skeletal and soft tissue details. Both can be displayed together to examine the relationship of fracture to soft tissue (Fig. 5) or individually to examine the details of either. The resulting images are
user-friendly, provide far more information than conventional two-dimensional radiographs, and lack the inherent distortion found in conventional radiography. All possible two-dimensional views taken with conventional radiography can be created from a single CBCT scan, which can take less than 10 seconds. One possible reconstruction is the conventional dental panoramic image (Fig. 6). A single CBCT following a traumatic event quickly captures a significant amount of useful patient information for diagnosis.

**IMPLANT PLANNING**

Implantologists have long appreciated the usefulness of three-dimensional imaging, especially for handling posttrauma restoration cases. In the case of trauma, multiple

*Fig. 2. CBCT image of a 13-year-old male patient. (A) Facial view shows buccal cortical plate fracture (arrow). (B) Lingual view shows no fracture to lingual plate. (C) Fracture is visible on panoramic radiograph, with no distinction possible if the fracture is buccal, lingual, or both.*

*Fig. 3. Twelve-year-old male patient with anterior facial trauma. CBCT reconstruction shows #9 tooth fracture, thinner than 2 mm, but intact buccal plate, and the bucco-lingual relationship of the fractured root to the alveolar ridge.*
implants are often necessary. CBCT images, unlike conventional dental radiography, clearly identify buccolingual alveolar ridge deficiency. Conventional CT scans have been used to assess the osseous dimensions, relative bone density, cortical plate thickness, and alveolar ridge height. CBCT technology makes this information available with less radiation and less cost. CBCT reconstruction software includes measurement tools that can be used to measure height, cortical thickness, and distance between landmarks (Fig. 7).

CONE BEAM CT–GUIDED IMPLANT PLACEMENT SURGERY

Once the trauma patient is stabilized, the fractured alveolar bone and debris are removed, the soft tissue and mucogingival surgery is completed, and preimplant bone grafting is completed and healed, the case is ready for implant restoration phase. Mounted diagnostic cases and photographs are prepared for diagnostic work-up. A CBCT scan appliance is made with radiopaque pins for barium teeth. A CBCT is taken using settings appropriate to specific products being used. Setting protocols vary depending on the CBCT scanner used. Also, settings of surgical guide software may vary. These specific settings should be verified before scanning. Once scanned, the image is analyzed. Virtual planning involves identifying adequate diameter, length,
and number of implants. Many planning software products accommodate selection of brand-name implants and allow for selection of placement location and angulation such that available bone is used and local anatomy, such as adjacent teeth, nerves, and sinuses, are avoided. Even the bone quality can be somewhat assessed when virtually placing the implants (Fig. 8). In the case of trauma, it is important to avoid other traumatized areas where bone grafting was not completed. Bone to house the selected implants at those particular positions is verified directly on top of the CBCT image. Laboratory-fabricated stereolithographic guides are useful for transferring the planned surgery to the patient. This way, virtually planned locations and angulations can be accurately and predictably re-created in patients during surgery. In cases lacking adequate anchorage for surgical guide stability during surgery, such as in cases with multiple missing teeth along with alveolar, trabecular fractures, such products as anchorage pins are useful.

Fig. 5. Twenty-two-year-old female patient with anterior facial trauma, #9 avulsion, and #10 luxation. (A) CBCT shows facial soft tissue. (B) CBCT shows buccolingual width of postavulsion defect, #9 edentulous area, and #10 luxation area.
AIRWAY ANALYSIS: AN ANCILLARY BENEFIT

CBCT can be used as an improved method for evaluating airways (Fig. 9). Conventionally, airway analysis has been done using lateral cephalograms. A comparison of lateral cephalograms to CBCT shows a moderate variation in the measurement of the upper airway area and volume.\(^\text{10}\) CBCT has also demonstrated significant differences in measurements of airway volume and the anterioposterior dimension of the oropharyngeal airway between obstructive sleep apnea patients and gender-matched control.\(^\text{11}\) Three-dimensional airway analysis is useful when sedation is planned for dental reconstruction. Preliminary studies show that three-dimensional image

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**Fig. 6.** Twenty-two-year-old female patient with anterior facial trauma, #9 avulsion, #10 luxation. Panoramic reconstruction available based on CBCT data. Note panoramic reconstruction does not give information about bucco-lingual ridge width. CBCT axial slice data in **Fig. 5** reveals bucco-lingual ridge width defect.

**Fig. 7.** Forty-seven-year-old female patient with blunt facial trauma, avulsion #30. Buccal cortical fracture, avulsed tooth, and close proximity of defect to inferior alveolar canal are apparent. Additionally, measurement tools are available for precise measurement.
reconstructions are useful as “virtual laryngoscopy” in airway management during general anesthesia.12

Because trauma cases, once stabilized, are transferred to the operating room for surgical correction, an ancillary benefit of the CBCT originally taken for diagnostics, is the usefulness in anesthesia planning. Additional research and protocol development are needed for this application.

BONE GRAFT ANALYSIS

Volumetric analysis offers better prediction of defect morphology. Understanding the morphology of a traumatic defect is critical in developing the implant site before
planned implant placement. Defect size and shape affect the factors that guide treatment-planning decisions. For example, defect size and shape form the basis for calculating how much graft material is needed, for predicting the likely stability of the postgraft arch, for estimating quality of bone graft over time, and, in growing patients, for predicting how treatment will affect overall facial growth.\textsuperscript{13}

**SUMMARY**

Trauma cases present with a wide range of diagnostic challenges. Not all of these are addressed by either medical CT or conventional dental radiography alone. By comparison, CBCT by itself can often deliver enough information for a diagnosis in one quick scan. It is useful in identification of fracture and defect morphology. It is also useful for determining defect dimensions and the relative locations of pertinent anatomic structures. Such information is needed for planning restorations that involve alveolar bone augmentation and implant placement. Additionally, CBCT shows promise in airway identification, an application that can be developed to reduce operating room occupation times. CBCT in posttraumatic applications enables dentists to address many patient needs.

**REFERENCES**


