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Cone-beam CT (CB Throne®) Applied to Dentomaxillofacial Region

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Abstract

Cone-beam CT (CBCT) systems specifically designed for hard-tissue imaging of the maxillofacial region have recently become commercially available. The newly-developed CBCT system, CB Throne® (Hitachi Medical Corp., Tokyo), is characterized by a number of features such as low dose, sub-millimeter spatial resolution, and a small footprint. This system has been clinically applied at Chiba Hospital, Tokyo Dental College, since April 2005. This article reports the characteristics of this system, and its diagnostic power for maxillofacial lesions and the pre-operative planning dental implants.

Key words: Cone-beam CT—Anatomical depiction—Clinical cases—Dental implant planning—Maxillofacial region

Introduction

Conventional CT imaging is used as a diagnostic tool not only in maxillofacial region examinations¹⁷), but also in the preoperative evaluation of dental implants¹⁸). Recently, this has led to the development of various image-guided applications. A conventional CT scanner acquires sliced-image data with a fan-shaped X-ray beam and rows of detectors. Contiguous cross-sectional images are reconstructed based on numerous projection data collected by high-speed rotation, after which they are displayed three-dimensionally. This means that longitudinal spatial resolution is sometimes sacrificed⁹), as a result of which the details of anatomical structures in the maxillofacial region are insufficient to allow adequate visualization in some clinical cases.

Recently, cone-beam CT (CBCT) systems specifically designed for hard-tissue visualization of the maxillofacial region have become
clinically available\cite{2,3,6,8}. The CBCT scanner can collect volume data by means of a single rotation taking between 9–40 sec due to the use of a cone-shaped X-ray beam and two-dimensional detectors. Thus, CBCT systems offer three-dimensional images with high spatial resolution both longitudinally and axially through employment of an isotropic voxel matrix. This means that CBCT scanners have the potential to offer additional benefits in hard-tissue visualization of the maxillofacial region and evaluation of skeletal morphology. Earlier studies\cite{2,3,6,8} have shown that CBCT offers great advantages in comparison with conventional CT in depiction of the maxillofacial region, in terms of accuracy, scan time reduction, dose reduction, and convertible field of view (FOV), and so on. However, at the moment such systems also suffer from the disadvantages of being relatively expensive and unreliable in demonstrating soft tissue abnormalities.

In this article, we provide an overview of a newly-developed CBCT system, the CB Throne\textsuperscript{®} (Hitachi Medical Corp., Tokyo, Japan) (Fig. 1), and its capabilities in terms of anatomical depictions and representation of maxillofacial lesions. Moreover, we also discuss its clinical validity as a tool for the preoperative evaluation of dental implants.

**Characteristic of CB Throne\textsuperscript{®}**

There are two types of X-ray detection system\cite{4}. One type, which includes the CB Throne\textsuperscript{®}, uses an X-ray image intensifier (I.I.) and a charge-coupled device (CCD) as a detector\cite{2,3,6,8}. An X-ray beam is converted to an optical signal by CsI crystals, and then converted to photoelectrons. Those electrons are then accelerated and converted to an optical signal, which is detected by the CCD. The other type uses a flat-panel detector (FPD) consisting of a scintillator screen and a Si-photo-sensor array\cite{6}.

Several systems have been developed and made commercially available\cite{2,3,6,8} since the CBCT principle\cite{4} was applied in a clinical setting. The CB Throne\textsuperscript{®} is the second CBCT unit, and follows the CB MercuRay\textsuperscript{®}, which was developed by Hitachi Medical Corporation\cite{3,4}. The rotational arm of the CB Throne\textsuperscript{®}, which consists of an X-ray tube and a reciprocating detector, is located under the patient’s chair so that the patient does not have the sensation of pressure that is generated by the around-the-head-type assembly. The footprint, 6 ft × 6 ft, is smaller than that of its predecessor.

**CB Throne\textsuperscript{®} Specifications**

The tube voltage ranges from 60 to 120 kV at 20 kV intervals. The tube current is 10 or 15 mA. There are two alternatives voxel sizes and FOV combinations. One is 0.1 mm with a 2 in diameter (D-mode) (Fig. 2a), and the other is 0.2 mm with a 4 in diameter (I-mode) (Fig. 2b). The sensitive I.I. area can be set to either 4 or 7 in diameter depending on the mode selected. The scan time is 9.6 sec for a 360-degree rotation, and 288 projections are carried out. The reconstruction is processed according to the Feldkamp algorithm\cite{4}, and the resultant image matrix is isotropic 512 × 512 × 512.
The software, CB Works, is capable of displaying variously processed images, such as Multiplanar reconstruction (MPR), Volume rendering (VR), Surface rendering (SR), Maximum intensity projection (MIP), Cross-sectional View, and partial Panoramic View.
with dental software (Fig. 3). The projection data are reconstructed so as to allow simultaneous provision of as many as 512 MPR frames. The standard displays are axial, coronal, and sagittal MPR frames in three orthogonal planes.

**Anatomical Depiction of Maxillofacial Region** (Fig. 4)

As CB Throne® voxels are intrinsically isotropic images can be re-orientated so that anatomical features may be seen accurately in any plane. This is important for images of the maxillofacial region, which are structurally complex. Skeletal details of the maxilla and the mandible (a), including the temporomandibular joint (b), are clearly demonstrated using I-mode. Teeth structures are also better depicted using D-mode (c) than conventional CT. In addition to cross-sectional images, the dental software generates corresponding partial panoramic images after the curve
Fig. 4 Anatomical structures on MPR image and dental reformatted images

a: Maxillary and mandibular bone on MPR image using I-mode.
Each number indicates as follows; 1–8: dental root (1. first incisor; 2. second incisor; 3. cuspid; 4. first bicuspid; 5. second bicuspid; 6. first molar; 7. second molar; 8. third molar), ans: anterior nasal spine, npc: nasopalatine canal, mp: maxillary process, ms: maxillary sinus, nc: nasal cavity, mb: mandibular body, mc: mandibular canal, mr: mandibular ramus, mf: mental foramen

b: Temporomandibular joint on MPR image using I-mode.
at: articular tubercle, js: joint space, mf: mandibular fossa, mc: mandibular condyle, eam: external auditory meatus, mac: mastoid air cell

c: Teeth on MPR image using D-mode.

d: Mandibular canals on dental reformatted images obtained from axial image using I-mode.
Not only teeth, but also surrounding structures such as mandibular canals (arrow) are demonstrated in cross-sectional and panoramic views.
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Fig. 5
marking the dental arch is defined on an axial image obtained by I-mode (d). These images can show bone status, as well as the relationship between the teeth and the surrounding anatomical structures such as the mandibular canal.

Clinical Examples of Maxillofacial Region Images (Fig. 5)

Several reports have shown that the CB Throne® was of value in evaluating conditions and pathoses of the dentition, jaw, and
temporomandibular joint in the oral and maxillofacial field\textsuperscript{2,3}). The CB Throne\textsuperscript{®} has been used to evaluate a variety of conditions and tasks. In Fig. 5a, MPR and VR images, cross-section images, and panoramic images reveal that the left canine (arrow) is slightly impacted horizontally. The crown is located adjacent to the second incisor root, and the root is close to the root of the first bicuspid. The apex of the root is curved. In Fig. 5b, the fracture line (arrow) is visible in any plane on an MPR and VR image. The space between the fractured segments appears minimal. The widening of the periodontal ligament space is observed. There is no significant bone loss in the alveolar process. In Fig. 5c, MPR and VR images reveal a lesion (arrows) with a well-defined cortical boundary in maxilla. The epicenter of the lesion is located at the root apex of a nonvital second incisor in the right maxilla. Dental caries can be detected efficiently by means of intraoral films, and the CB Throne\textsuperscript{®} also allows detection of caries. In Fig. 5d, reformatted dental images show that caries has reached the dental pulp (arrow) at the distal surface of the right first molar. In this situation caries would not appear on images provided by conventional CT due to artifacts from metal restorations. Moreover, the CB Throne\textsuperscript{®} allows arthrography of the temporomandibular joint, making it a useful tool in the diagnosis of perforation of the joint articular disk. In Fig. 5e, an MPR image shows the flow of a contrast agent into the lower joint space from the upper joint space (black arrow), where the disk was perforated. There is erosive change at the top of the condyle. A VR image shows the contrast media in the upper and lower joint spaces.
Preoperative Distance Measurement for Dental Implants (Fig. 6)

The development of dental implant surgery necessitates easily comprehensible volumetric maxillo-mandibular imaging. Due to its high spatial resolution in any plane and dimensional accuracy, the CB Throne® system could play a major role in three-dimensional visualization and prediction in preoperative examination of the jaw for dental implants. Moreover, the CB Throne® system provides dose savings by restricting the exposure field to fit adjusted FOVs. The CB Throne® can generate detailed cross-sectional pictures of the jaw area in which prospective dental implant treatment is being planned.

Conclusion

We believe our findings clearly indicate the clinical validity of the newly-developed CBCT system, CB Throne®, in hard-tissue visualization of maxillofacial lesions and preoperative evaluation of dental implants.

References


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