 Prague Medical Report / Vol. 118 (2017) No. 1, p. 14–25

3D Multislice and Cone-beam Computed Tomography Systems for Dental Identification

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Received September 14, 2016; Accepted March 9, 2017.

Key words: Forensic dental radiography – 3D Multislice tomography – Cone-beam CT

Abstract: 3D Multislice and Cone-beam computed tomography (CBCT) in forensic odontology has been shown to be useful not only in terms of one or a few of dead bodies but also in multiple fatality incidents. 3D Multislice and Cone-beam computed tomography and digital radiography were demonstrated in a forensic examination form. 3D images of the skull and teeth were analysed and validated for long ante mortem/post mortem intervals. The image acquisition was instantaneous; the images were able to be optically enlarged, measured, superimposed and compared prima vista or using special software and exported as a file. Digital radiology and computer tomography has been shown to be important both in common criminalistics practices and in multiple fatality incidents. Our study demonstrated that CBCT imaging offers less image artifacts, low image reconstruction times, mobility of the unit and considerably lower equipment cost.

This study was supported by project 00064203 (FN Motol), and VF 20152015041.

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https://doi.org/10.14712/23362936.2017.2

Introduction

Identification of human remains depends on dead body decomposition state. If soft tissues are preserved, the accepted scientific means of identification are anthropological facial comparison, fingerprint analysis, DNA analysis and dental comparisons. In the case of skeletal findings, the identification includes a complete anthropological examination, e.g. information relating to post mortem interval and biological profile including sex, age, ethnicity, pathological characteristics, accident changes, dental status etc. Acquired post mortem data are compared with ante mortem data of the missing person (*DVI Guide* – INTERPOL, 2008; *Forensic Odontology Guidelines* – Australian Society of Forensic Odontology Inc., 2008).

Forensic odontology has two main areas of use – diagnostic examination for the typing in the database of missing persons and the identification of individuals, especially casualties in criminal investigations and mass disasters. The odontological identification examination of decedent is based on a systematic comparison of the ante mortem and post mortem acquired data. This process is simple in concept, but it is complex in execution and requires the skills and expertise.

The teeth are very resistant to environmental factors, fire and alkali. Characteristics associated with the teeth may provide an important and effective method to identify a person (Sweet and DiZinno, 1996). The presence of metallic and non-metallic restorations and prosthetic placements are often the main and critical determinants of identity.

A variety of techniques are used to assist in the identification issue, e.g. radiology, chemical analysis of dental materials, virtual simulation. However, radiology has been shown to be useful not only in terms of one or a few of dead bodies but also in multiple fatality incidents (Mulligan et al., 1988). Identification of the deceased by clinical or radiographic examination of the teeth has been used for many years. The first recorded use of radiographic techniques in skull identification was by Schüller in 1921.

Material and Methods

Imaging techniques are an important tool for the forensic science. Forensic radiology significantly supports the results mainly due to higher anatomical details and multi-parametric analysis of pathological changes. The following methods examine methodically the visualization in forensic odontology.

X-ray generators

Digital radiography is now a typical form of X-ray imaging, where digital X-ray sensors are used instead of traditional photographic film. There are two major variants of digital image capture devices: flat panel detectors and high-density line-scan solid state detectors. The portable NOMAD Handheld X-ray with sensors, film, phosphor plates with 0.4 mm focal spot producing sharp, high-resolution images is frequently used in forensic practice and for DVI evaluation (Figure 1).

Figure 1 – NOMAD portable and handheld X-ray with digital imaging systems.

Figure 2 – Mandible – teeth No. 45, 46 without metaloceramic crowns.

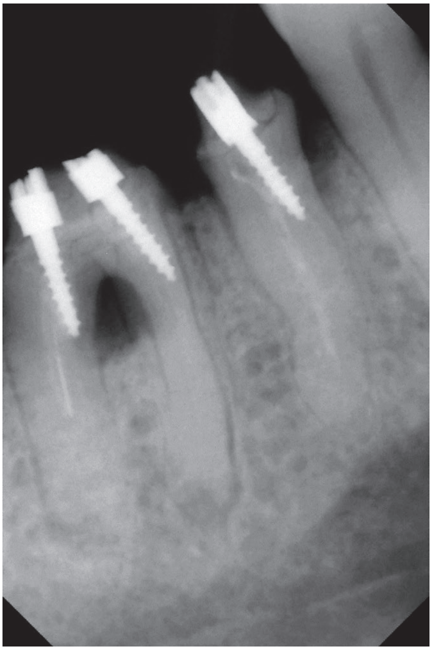

Figure 3 – RVG of mandible – titanium posts in teeth No. 45, 46 (see Figure 2).

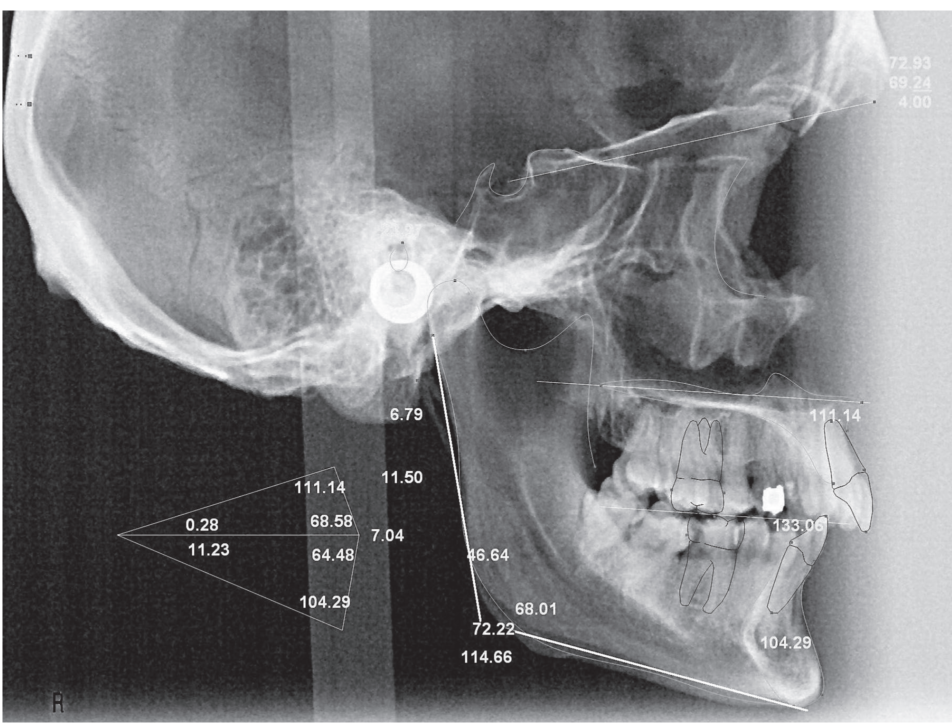

Figure 4 – Cephalometric analysis of the forensic skull.

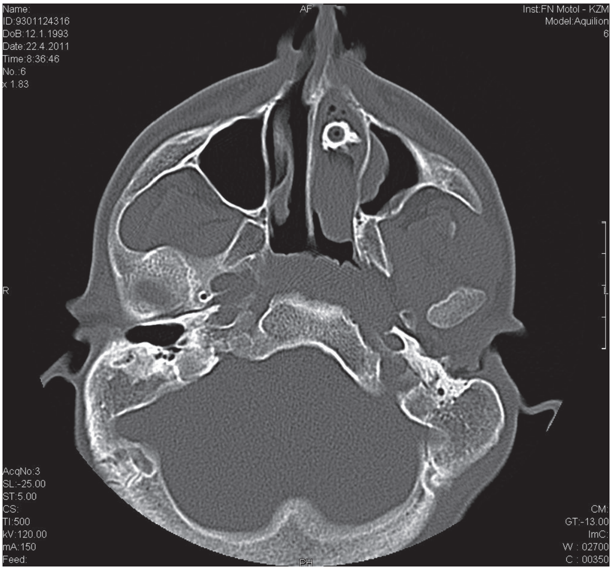

Figure 5 – CT sequence of the skull with the foreign body in the nasal area.

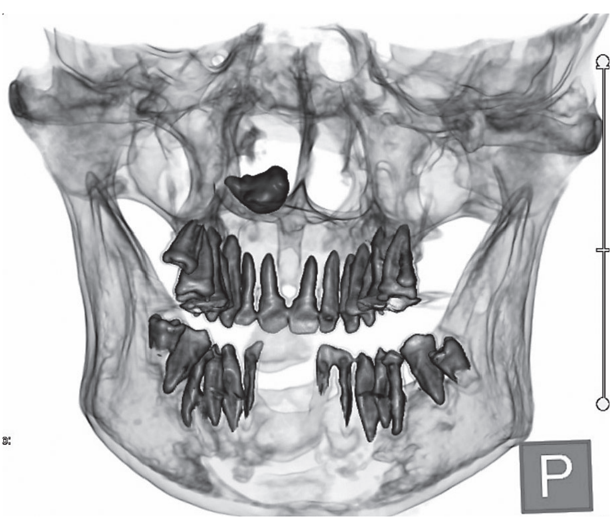

Figure 6 – CT – reconstruction of teeth and foreign body in nasal area from Figure 5.

The radiological examinations in dentistry may be classified into intraoral – where the film or sensor is placed in the mouth, the purpose being to focus on a small region (Figures 2 and 3) of the mandible or maxillofacial region and extraoral – where the film or sensor is placed outside the mouth aiming to visualize the entire mandible and maxillofacial region. Extraoral imaging is further divided into orthopantomogram and telerentgenogram (Figure 4) for cephalometric analysis. Computed tomography (CT) (Figure 5) displays parallel projection sequences of the whole skull or chosen regions and enables their 3D reconstruction (Figure 6).

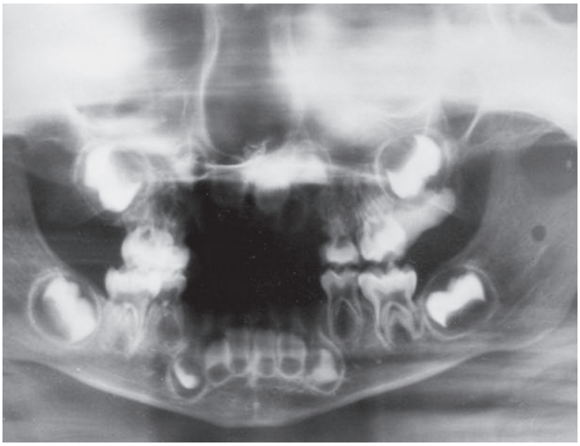

Figure 7 – Tooth development data from radiographs are used in the estimation of the biological age of infants – three years old boy.

Figure 8 – Superimposition of the skull on the portrait photography of the missing boy. The correspondence between the skull and the face confirms identity.

Dental identification

Radiographically assisted dental examination enables to identify unknown dead bodies and also to estimate the age of infants. In the case of identification process experts compare post mortem and ante mortem dental characteristics. The ante mortem radiographs are evaluated in term of quality, type and time of examination and compared with the radiographs exposed after death. Consequently, the examination is focused on special image analysis of fillings, stub morphology and teeth geometry (Figure 7). If radiological examination demonstrates deciduous dentition or incomplete permanent dentition, then the forensic odonatologist can determine age group to which the deceased belongs. The identity is confirmed via superimposition the skull onto portrait photograph (Figure 8). The plain radiographs are based on the detection of normal radiological appearance or pre-existing abnormalities (congenital or acquired) (Pfaeffli et al., 2007; Sidler et al., 2007).

Virtual autopsies are currently becoming increasingly common worldwide in forensic medicine. Use of multislice CT or multidetector CT before classic medicolegal autopsy gives the forensic pathologist considerable information on injuries and cause of death (Dedouit et al., 2014). The introduction of imaging in anthropology is of course not new, and many radiographic applications have been already described and published (Ciaffi et al., 2011) but multislice CT examination is directly connected with image quality, spatial resolution and contrast. Also field of view and slice thickness and after acquisition the following 3D reconstruction could prepare optimal reconstruction (Thali et al., 2003).

Computerized tomography (CT) has been used for many years in clinical fields such as maxillofacial surgery, oncology, traumatology, etc. It can be also used as a supplement to the forensic autopsy (Figures 9 and 10) or skeletal findings examination (Figure 11). 3D virtual model of dentition or skull with dentition can be generated from CT data. Virtual models enable us to view and interact with them using special software. Models are used for comparison with ante mortem photos, X-rays, dental casts and for simulation of bite marks.

Figure 9 – The skull with trepanation (after subdural haematoma).

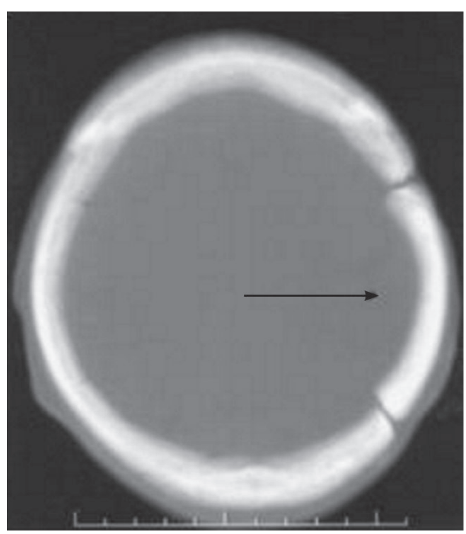

Figure 10 – CT sequence (ante mortem) of the skull shows localization of trepanation.

Figure 11 – Post mortem skull with trepanation.

Cone-beam computed tomography (CBCT) for forensic purposes

CBCT scans of the same cadaver half heads and mandibles were acquired with an I-CAT Platinum CBCT unit with a scanning field adjusted to the vertical dimension of the specimen and a resolution of 0.25 mm. Panoramic images of the jaws were reconstructed from each CBCT volume using I-CAT Vision software. Advantage of CBCT is connection of single tooth evaluation (Figure 12), detail panoramic image (Figure 13) and precise skull volumes (Figure 14).

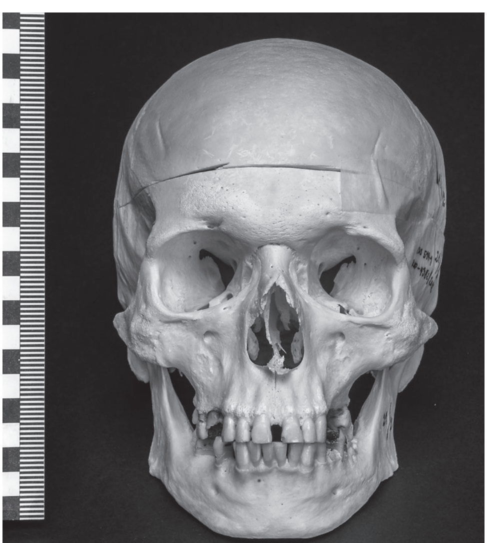

Figure 12 – Unknown body – skull – frontal view.

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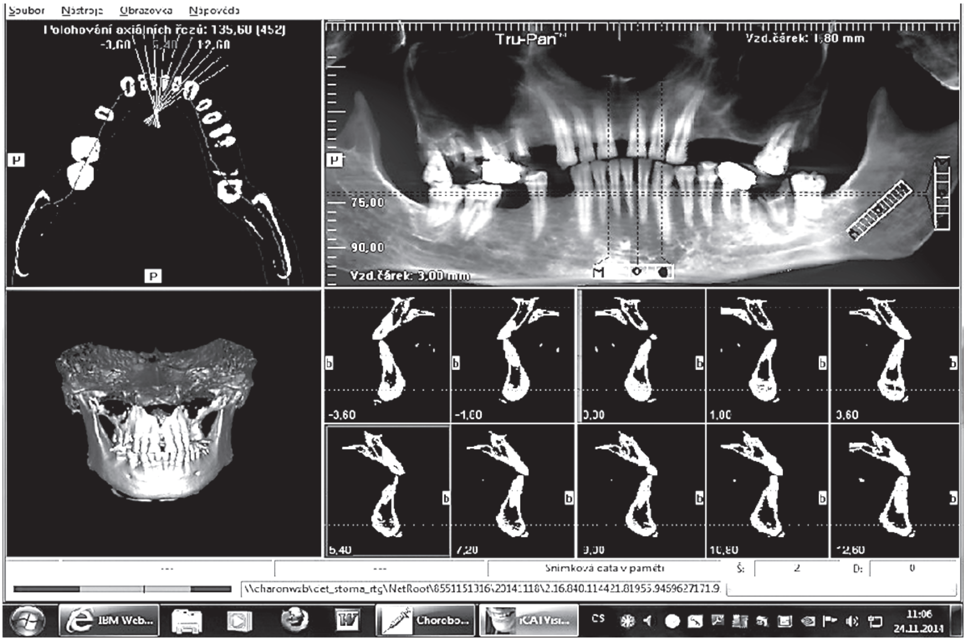

Figure 13 – Cone-beam reconstruction including generated ortopantomogram.

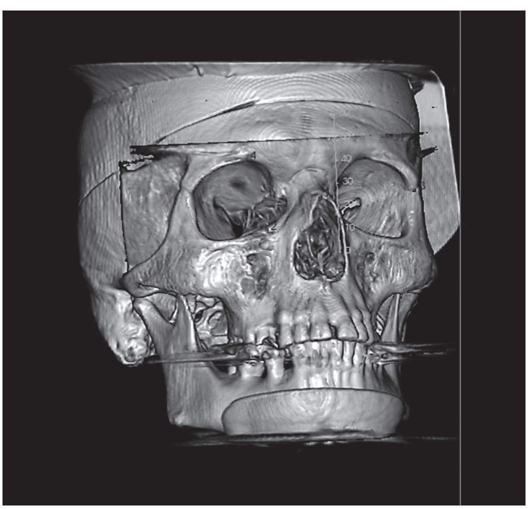
Figure 14 – Ante and post mortem skull reconstruction.

Results

Precise 2D dental radiographic images are frequently used in forensic identification, e.g. intraoral periapical radiographs, lateral oblique radiographs, cephalometric radiographs, panoramic radiographs, digital imaging and advanced imaging technologies.

Table 1 – Advantages and disadvantages of imaging systems including radiation dose in forensic odontology

Radiological method	Forensic odontology and anthropology	Advantages	Disadvantages	Radiation dose
X-ray image	ante and post mortem identification	usual dental examination small movable digital detector	small size of image incorrect vertical and horizontal angulation reverse image	0.6–5 μSv
Ortopantomo-gram-digital panoramic	ante and post mortem identification	usual dental examination	2D plain image distorted image of teeth	2.9–11 μSv
Cone-beam computed tomography	generated panoramic image	precise: single tooth evaluation detail panoramic image scull volumes	metal alloy artifacts	19–368 μSv 20 second scan 68 μSv
Multislice computed tomography – medical CT	skeletal findings examination	digital autopsy	3D virtual models	lower jaw 1320 μSv upper jaw 1400 μSv bimaxillar 2100 μSv

Cone-beam computed tomography (CBCT) and multislice computed tomography (MSCT) are two new 3D radiological techniques for forensic purposes. In contrast to spiral multislice computed tomography (MSCT) with a collimated fan beam, CBCT uses a pulsed cone-shaped X-ray beam with a two-dimensional detector, generating a three-dimensional image. Advantages and disadvantages of all systems including are radiation dose are in Table 1.

Radiation doses for dental radiographic examinations are the most important factors for dental assessment but not for forensic radiology (daily background: 8 μSv (micro Sieverts); Digital Panoramic 2.9–11 μSv; CBCT 19–368 μSv (20 second scan: 68 μSv); Medical CT – MSCT – lower jaw (1320 μSv); upper jaw (1400 μSv); bimaxillar (2100 μSv). The effective dose for MSCT was 42% higher compared to CBCT (De Cock et al., 2015).

Discussion and Conclusion

Recently, conventional multislice computed tomography has been used for forensic identification (Thali et al., 2003). It has been used successfully to acquire about 60% of the information required for the physical description in section D of the

INTERPOL disaster identification form (Sidler et al., 2007; INTERPOL, 1977 – http://www.interpol.int/Public/DisasterVictim/Guide.asp).

Identification of the deceased or skeletal remains by clinical or radiographic examination of the teeth has been used for many years (Wood and Kogon, 2010), has been empirically proven to be reliable (Adams, 2003), and has been validated for long ante mortem (AM)/post mortem (PM) intervals (Dostalova et al., 2012). Although the presence of both metallic and non-metallic restorations and prosthetic replacements are often critical determinants of identity, the comparison process does not entirely depend on the presence of restorations (Wood et al., 1999).

The various types of digital units and the capturing images methods can be used in forensic exercises. From a practical standpoint they offer many advantages. Image acquisition is instantaneous; the images can be optically enlarged, measured, superimposed and compared prima vista or using special software and exported as a file. These systems can be useful internationally.

Digital radiology and computer tomography has been shown to be useful both in common criminalistics practices and in multiple fatality incidents (Thomsen et al., 2009). Post mortem multislice computed tomography has demonstrated important practical benefits in the identification of bodies in advanced stages of tissue damage or decomposition, certain limitations, particularly related to image resolution, artifacts from metallic dental work, scanning time and cost of CT equipment, have emerged (Trochesset et al., 2014). Further studies confirming the accuracy of CBCT in dental aging of adolescent and young adult victims should be investigated using the atlas and scoring methods in common use (Schour and Massler, 1940; Demirjian and Goldstein, 1976; Roberts et al., 2007). Our study demonstrated that CBCT imaging addresses some of these limitations in forensic dental identification by offering routine scanning times below 30 s, less image artifact, low image reconstruction times, mobility of the unit and considerably lower equipment cost.

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