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*Original Research Article*

# Comparing digital panoramic radiography with cone-beam computed tomography for the detection of the mandibular canal as part of the preoperative evaluation of dental implants

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## Abstract

**Introduction:** The effectiveness of various imaging modalities in locating the mandibular canal was evaluated, including computed tomography (CT), panoramic radiography, and tomography. Cone-beam computed tomography (CBCT), a recently established imaging technique, appears to be a promising one that, when compared to conventional CT, also significantly lowers patient exposure. There are no studies in the literature comparing its performance with other conventional imaging modalities in such delicate tasks as mandibular-canal identification. This study compared digital panoramic photos and CBCT-reformatted panoramic images to identify the mandibular canal as part of preimplant evaluation.

**Materials and Methods:** Three different imaging modalities' panoramic images were compared for general maxillofacial diagnosis and preimplant evaluation. Direct panoramic radiographs using a charge-coupled device (DIMAX; Planmeca, Helsinki, Finland), CBCT-reformatted panoramic pictures (I-CAT; Imaging Sciences, Hatfield, PA), and digital panoramic radiographs using a storage phosphor system (DENOPTIX; Gendex, Chicago, IL). We used three separate groups of photos (40 in each group) taken from patients who had one of the aforementioned imaging modalities employed on them over the course of six months. A total of 68 mandibular canals (out of a potential 80) were assessed using each imaging technique. Using a 4-point scale, four skilled raters evaluated the quality of the visualization of the mandibular canal in each modality's images over the course of three sessions under standardized conditions.

**Results:** In terms of identifying the mandibular canal, the CBCT reformatted panoramic photos performed better than the digital panoramic images.

**Conclusions:** The CBCT pictures were devoid of magnification, superimposition of surrounding structures, and other difficulties common to panoramic radiology since they were reformatted slices of the maxilla and mandible. The mandibular canal may appear more clearly in the images as a result of this.

**Keywords:** CBCT, panoramic, digital, implant, mandibular canal

## Introduction

The evaluation of normal anatomical structures, the detection of pathologies close to possible implant placements and the determination of the quantity and quality of the accessible bone are among the aims of diagnostic imaging when it is employed for preimplant assessment. The position of the mandibular canal should be taken into account while choosing a site for implant treatment in the posterior mandibular region. In actuality, the mandibular canal's estimated distance from the crest of the alveolar ridge is the height of the edentulous site that is now accessible. Before making any height estimates, it is crucial to accurately identify both of these anatomical landmarks in order to choose the right implant fixtures and avoid difficulties.

Preimplant evaluation has included a range of imaging modalities, including panoramic radiography (conventional and digital), tomography, and computed tomography (CT). In the past 30 years, panoramic radiography has made a substantial contribution to maxillofacial diagnosis. Digital panoramic radiography has been around for a decade now, and it seems to have some advantages over film-based panoramic radiography, including quicker image acquisition, the elimination of darkroom procedures and darkroom upkeep, less radiation exposure for the patient, and the availability of different image-processing tools. The same principles as conventional radiography are used to create panoramic images via digital panorama radiography, however instead of utilizing traditional film, the images are now taken by either a charge-coupled device (CCD) or a storage phosphor imaging plate (SPIP).

The film and film container (cassette) are replaced in CCD-based digital panoramic systems by an electronic detector that incrementally captures the radiographic image and transmits it to a computer for digital conversion, display, and storage. The x-ray or light-sensitive cells or pixels that make up this detector, known as the CCD, can produce an electrical charge in response to the quantity of light or x-rays reaching them [1-3]. The detector and a scintillator, a substance that emits light energy when exposed to x-rays, are fiberoptically connected. As a result, just before the detector, the x-ray energy is transformed into light energy, and it is light that stimulate the detector's sensitive pixels. Because the scintillator makes the x-ray radiation more intense when it is converted to light, this procedure actually lowers patient exposure (for each x-ray photon striking the scintillator, several light photons are produced) [3].

The computer of the system receives the electrical charges produced in each of the CCD's pixels, identifies them, and stores them. All of these charges will be converted to digital format by an analog-to-digital converter (ADC), which will give each one a number in proportion to the electrical energy. In the end, this number will correspond to the pixel intensity value (in grayscale tones) of the particular area of the digital image. Similar to film-based panoramic systems, storage phosphor-based digital panoramic systems (also known as SPIPs, or simply storage phosphor imaging plates) record images. However, in this instance, a reusable plate in a standard film holder (cassette) without intensifying screens replaces the radio-graphic film. An phosphor layer in SPIPs absorbs the x-ray energy. These phosphors are coated on a plastic basis, quite similar to traditional film and most frequently contain europium-doped barium fluorohalide. In fact, when x-rays hit the plates, they trigger a series of electron shifts in the phosphors' crystal lattice, creating a latent image that resembles that of traditional film. 4 With storage phosphor plates, however, specialized laser scanners will read out the latent image as opposed to conventional film processors [5]. The SPIPs in these scanners will release the stored x-ray energy after receiving the necessary light stimulation, which will then be converted to an electrical charge. The electrical signal is finally given a

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number by an ADC that is proportional to its strength. Based on the initial x-ray energy that was initially stored on that region of the plate, this number will eventually represent the pixel intensity value (in shades of gray) of the particular spot of the digital image. The SPIP is bathed with light after the scanning procedure is over. Any remaining latent image will be removed in this process, making the plate suitable for additional exposures. The main drawback of these panoramic systems compared to CCD-based systems is the extra time required for the scanning and erasing of SPIPs.

Cone-beam computed tomography (CBCT), a recent innovation, produces 3-dimensional (3D) image data by performing a single scan around the imaging volume of interest. In order to do this, a cone-shaped x-ray beam and an oppositely moving digital detector are used to acquire several single x-ray projections. Following this series of projections, a 3D volumetric data set will be created, which may be utilized to produce primary reconstruction pictures in three orthogonal planes (axial, sagittal and coronal) [6]. Additionally, these data can be presented in any manner that is clinically relevant, such as sagittal and coronal pictures of the temporomandibular joint or panoramic and cross-sectional images of the maxilla and mandible. CBCT is a good imaging tool for the craniofacial region. It is incredibly helpful for determining bone quality since it produces excellent images of highly contrasted structures. [7, 8] Accurate measurements may be drawn from the reformatted data because the images displayed have already been corrected for magnification.

Taking into account all of these factors and the fact that medical CT exposes patients to less radiation, CBCT is a very promising imaging technique for maxillofacial diagnosis. No studies comparing CBCT for such a delicate diagnostic task as the mandibular-canal identification with other imaging modalities traditionally utilized by dentists were found in our literature search.

In order to identify the mandibular canal as part of the preimplant evaluation, this study compared CBCT with digital panoramic radiography. According to our "null hypothesis," there are no statistically significant changes between storage phosphor-based digital panoramic photos, direct digital panoramic images, or CBCT re-formatted panoramic images.

## Material and Methods

In this study, CBCT (I-CAT; Xoran Technologies, Ann Arbor, MI and Imaging Sciences International, Hatfield, PA), digital panoramic radiography (DIMAX; Planmeca, Helsinki, Finland), and digital panoramic radiography based on a storage phosphor system-three imaging modalities used for general maxillofacial diagnosis and preimplant assessment-were compared (DENOPTIX, Gendex, Chicago, IL). 40 photographs from each of three separate groups of patients who had examination using one of these imaging modalities during a six-month period were used. From the electronic patient records of the three dental practices participated in the study (CBCT [ICAT], oral surgery practice; DIMAX, digital panoramic-orthodontic practice; and DENOPTIX, storage phosphor panoramic/dental school), patients and their corresponding images were randomly chosen. Panoramic photos with positioning flaws or artifacts that would have affected the diagnostic quality of the images were disregarded. Out of a total of 80 mandibular canals, 68 were chosen at random for each imaging technique.

Each patient's CBCT data was converted to one panoramic image (slice) (5.2 mm in thickness). The axial plane's midline of the mandibular body served as the direction of the line denoting the panoramic reformation.

All study images were taken as uncompressed images (tagged image file format files) from the originating software (capturing software) and imported into a separate image-processing and evaluation program (Photoshop 7.0; Adobe Systems, San Jose, CA), where they were resized to be of comparable dimensions. Additionally, using the same software, vertical lines

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were added to the photos to clearly show the posterior, middle, and anterior thirds of the mandibular canal. For clarity of visualization of the mandibular canal in three locations clearly marked on the image (the posterior, middle, and anterior thirds of the mandibular canal), four experienced raters evaluated the images of each modality in three sessions under standardized conditions (e.g., room, dimmed light, monitor, and image size) using a 4-point (from 0 to 3) scale (Table 1). Each session's image order and each rater's session order were both random. Using Adobe Photoshop software and the "fit on screen" feature, the photographs were viewed on a 17-inch LCD (liquid crystal display) monitor. No image editing was permitted. Before each viewing session, the raters got both verbal and written instructions. For calibration purposes, a sample of photos with their corresponding scores regarding visualization of the mandibular canal were also presented to the raters prior to a rating session. Examples of the three types of panoramic photographs that were compared in this study are shown in Figures 1, 2 and 3, as seen using Adobe Photoshop. Any differences between the various imaging modalities were found using the Kruskal-Wallis (P <.001) test. Additionally, Friedman's test revealed changes in the depiction of the mandibular canal depending on the anatomical location (posterior, middle, or anterior) (P <.001).

**Table 1:** Mandibular Canal Visualization Rating Scale

| | |
|---|---|
| 0 | Less than 25% of the mandibular canal (in the premarked area) is seen. |
| 1 | More than 25% but <50% of the mandibular canal (in the premarked area) is seen. |
| 2 | More than 50% but <75% of the mandibular canal (in the premarked area) is seen. |
| 3 | More than 75% of the mandibular canal (in the premarked area) is seen. |

## Results

No matter the location (posterior, middle, or anterior mandibular canal), all raters considerably (P<.001) higher the CBCT reformatted panoramic images (Figs 4, 5). The DENOPTIX photographs received the lowest rating and the DIMAX panoramic pictures came in second. DIMAX and DENOPTIX photos differed statistically significantly when compared side by side.

The mandibular canal's posterior third had the best depiction, with statistically significant differences between it and the middle third (ranked second) and anterior third (rated lowest in terms of depiction) (Figs 4, 5). This was true across all raters and testing modes.

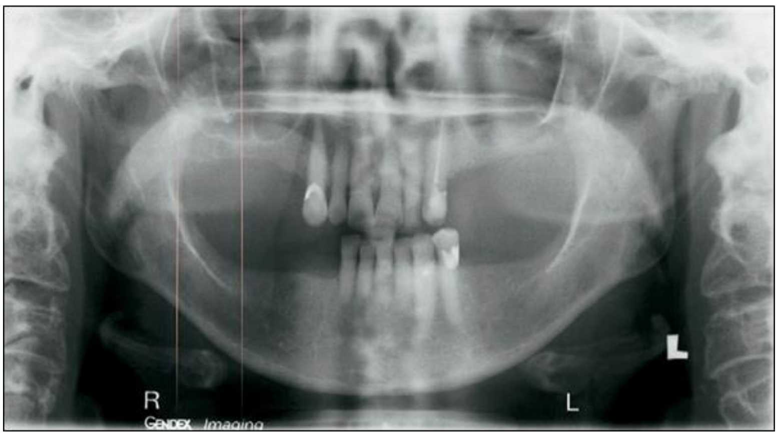


**Fig 1:** Storage phosphor-based (DENOPTIX, Gendex, Chicago, IL) digital panoramic radiograph

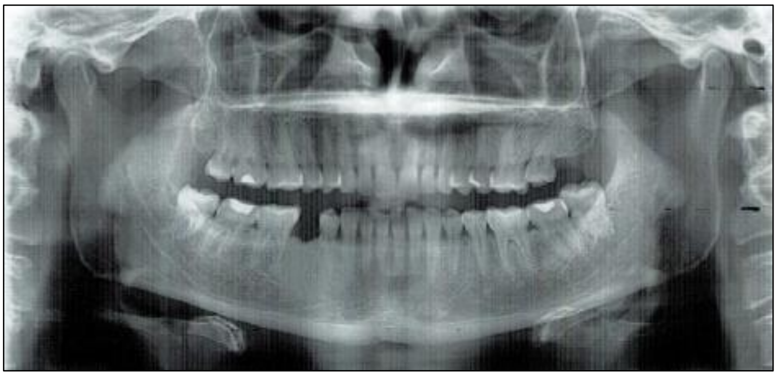

**Fig 2:** Direct digital (CCD) panoramic radiograph (DIMAX, Planmeca, Helsinki Finland). Vertical lines separate the mandibular canal into posterior, middle and anterior thirds

**Fig 3:** CBCT

| | Posterior MC | Middle MC | Anterior MC |
|---|---|---|---|
| SPP panos | 2.13, (SD 0.847) | 1.02, (SD 0.964) | 0.88, (SD 1.109) |
| DIMAX panos | 2.53, (SD 0.636) | 1.49, (SD 1.038) | 0.92, (SD 1.011) |
| CBCT reformatted panos | 2.94, (SD 0.243) | 2.60, (SD 0.557) | 2.01, (SD 1.014) |
| | | | |

**Fig 4:** Average scores and standard deviations for visualization of the mandibular canal (MC) for the 3 types of panoramic images

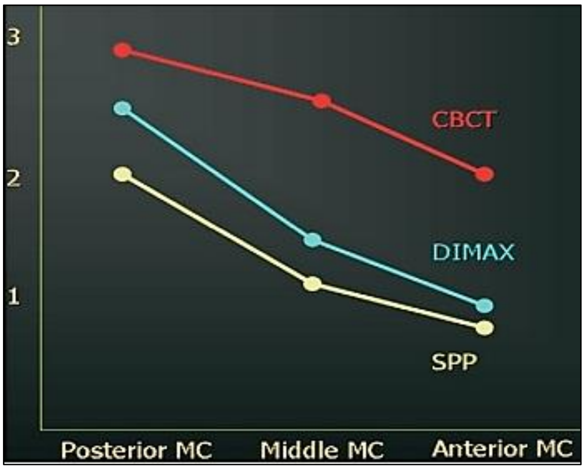


**Fig 5:** Graphic representation of performance of the 3 imaging modalities tested for the visualization of the mandibular canal (MC). The CBCT reformatted panoramic images depicted the mandibular canal better than digital panoramic radiographs did. It is also clear that the posterior third of the mandibular canal was better visualized, regardless of modality

## Discussion

This study assessed the effectiveness of three imaging modalities for a challenging job, namely the mandibular canal identification. The method used to achieve this was the subjective grading of the appearance of the mandibular canal in 3 locations (posterior, middle, and anterior third) by four experienced raters using a 4-point scale. Each rater evaluated a different collection of digital images using each of the imaging modalities. The findings showed that the three groups judged the ability to see the mandibular canal differently. As a result, we disproved the null hypothesis. This variation could have been caused by a variety of elements. The type of imaging modalities might have made a difference because the panoramic images under comparison in this investigation came from three different sources. No matter the location, all raters reliably identified the mandibular canal to a higher extent using CBCT reformatted pictures (poste- rior, middle, or anterior). In fact, CBCT and DIMAX panoramic images, which came in second place, differed in a statistically significant way. Additionally, a notable distinction was discovered between DIMAX and storage phosphor-based panoramic images, which received the lowest marks (Figs 3, 4). The capture and formation of a digital image varied significantly between the imaging modalities investigated in this work. Cone-beam CT uses an x-ray beam in the shape of a cone, an image intensifier, and either an amorphous silicon plate or a solid-state detector to capture the image. Data can be gathered either for the entire maxillofacial volume or for specific areas of interest after a full rotation around the patient's head. 9 In comparison to the total amount of data gathered, the CBCT reformatted panoramic image is a rather little piece of data. A digital panoramic (or direct digital) camera with some additional tomographic capabilities is called the Planmeca DIMAX. The DENOPTIX storage phosphor-based panoramic system uses a latent picture to capture an image on a reusable plate (storage phosphor plate). The differences in how different populations identified an important anatomical component, like the mandibular canal, may in part be attributable to differences in the anatomical structure itself. The mandibular canal typically has a well-defined radiolucent zone with radiopaque superior and inferior margins in its radiographic appearance. This lucent structure's radiographic density varies. Furthermore, cortication of the canal is necessary for the development of a radiopaque outline. As a result, it is occasionally difficult to see the mandibular canal. The inferior alveolar bundle is not usually encircled by an ossified canal, according to Carter and Keen [10], Werhmann and Manson-Hing [11] and Carter and Keen. As part of the preimplant examination of posterior mandibular sites, Stella and

Tharanon [12] connected the dependability and accuracy of conventional tomography to the visibility of the inferior alveolar canal. They said that precise calculations of the available bone height could not be made when the canal was not visible (17.5% of their cadaveric specimens).

Even within the same person, the mandibular canal can appear differently. This study discovered that all raters and modalities provided a better representation of the posterior part of the mandibular canal (the mandibular ramus area) (Fig 3). The anterior third came next, followed by the middle third (molar region) (premolar area). The mandibular canal may have changed its buccal path before opening into the mental foramen as a result.

The results of studies like this one may potentially be influenced by the raters' expertise in recognizing such sensitive structures as the mandibular canal. Even though the mandibular canal is shown by the imaging modalities, less experienced raters may not be able to perceive it. Utilizing four skilled specialists-2 oral surgeons and 2 oral radiologists-who regularly handle such responsibilities, we attempted to account for such an influence. Our data show that all of our raters assigned similar ratings to the three sets of photos, even though we did not examine inter-rater reliability.

Only a few studies comparing the diagnostic quality of different types of digital or film-based panoramic images with either CBCT images or panoramic photos were found in our search of the literature. Prior to third molar surgery, Pawelzik *et al*. [13] compared the diagnostic accuracy of CBCT pictures (reformatted panoramic and cross-sectional images) with that of conventional panoramic images. Although traditional panoramic photos performed better than CBCT-reformatted panoramic images, cross-sectional CBCT images significantly improved the assessment of the direction of the mandibular canal [13]. For a separate diagnostic objective, namely the identification of the mandibular canal, digital panoramic images were judged considerably worse in the current investigation than CBCT-reformatted panoramic images. The reported discrepancies may have been caused by the diverse diagnostic task, the various slice thicknesses for the reformatted panoramic images and the various CBCT machines.

Digital panoramic radiographs created with various digital systems (Denoptix SPP, DigiDent SPP (now Paxorama HS), Digora SPP, DIMAX CCD and Orthophos CCD) were compared for diagnostic quality by Benediktsdottir *et al*. On a 4-point scale, three raters evaluated the image quality of all radiographs in 6 different locations. The usage of brightness, contrast, and gamma improvements was permitted by the raters. The photos from Denoptix SPP and Digi-Dent SPP were much worse in quality than those from Digora SPP, DIMAX CCD, and OrthophosPlus CCD digital panoramic systems. Their poorer performance may have been caused by these systems' lower default scanning resolution when compared to Digora. This is consistent with our analysis, which concluded that Denoptix SPP panoramic photos were outperformed by DIMAX panoramic photographs.

CBCT photos should not necessarily replace digital panoramic images since CBCT studies result in higher radiation exposures, even if the current investigation showed that CBCT reformatted panoramic images were superior in diagnostic efficacy to digital panoramic images (4 to 20 times greater). The ALARA (As Low as Reasonably Achievable) approach should be followed when choosing an imaging modality for diagnostic use. The decision should be based on the projected diagnostic yield [15].

For identifying the mandibular canal, it was discovered that the CBCT-reformatted panoramic images were superior to digital panoramic images. No matter who is looking or what imaging technique is used, the posterior section of the mandibular canal is better represented. Further research is needed to corroborate the study's findings because there isn't much literature on the subject at hand.

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