

Comparison of different radiographic methods for the detection of the mandibular canal

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ABSTRACT

Purpose : To compare the visibility of the mandibular canal at the different radiographic methods such as conventional panoramic radiographs, Vimplant multiplanar reformatting (MPR)-CT panoramic images, Vimplant MPR-CT paraxial images and film-based DentaScan MPR-CT images.

Materials and Methods : Data of 11 mandibular dental implant patients, who had been planned treatment utilizing both panoramic and MPR-CT examination with DentaScan software (GE Medical systems, Milwaukee, USA), were used in this study. The archived axial CT data stored on CD-R discs were transferred to a personal computer with 17" LCD monitor. Paraxial and panoramic images were reconstructed using Vimplant software (CyberMed Inc., Seoul, Korea). Conventional panoramic radiographs, monitor-based Vimplant MPR-CT panoramic images, monitor-based Vimplant MPR-CT paraxial images, and film-based DentaScan MPR-CT images were evaluated for visibility of the mandibular canal at the mental foramen, 1 cm, 2 cm, and 3 cm posterior to mental foramen using the 4-point grading score.

Results : Vimplant MPR-CT panoramic, paraxial, and DentaScan MPR-CT images revealed significantly clearer images than conventional panoramic radiographs. Particularly at the region 1 cm posterior to mental foramen, conventional panoramic radiographs showed a markedly lower percentage of "excellent" mandibular canal images than images produced by other modalities. Vimplant MPR-CT and DentaScan MPR-CT images did not show significant difference in visibility of the mandibular canal.

Conclusion : The study results show that Vimplant and DentaScan MPR-CT imaging systems offer significantly better images of the mandibular canal than conventional panoramic radiograph. (*Korean J Oral Maxillofac Radiol* 2003; 33 : 199-205)

KEY WORDS : Image Processing, Computer-Assisted; Dental Implants; Mandible

Precise presurgical localization of mandibular canal is one among very important factors for successful outcome of intraosseous implantation and prevention of neurosensory complication at mandibular premolar and molar region. Different imaging modalities are used for dental implant treatment planning.¹⁻³ Panoramic radiography is widely used by many dentists for preoperative evaluation in dental implantation surgery. However, it has some disadvantages, such as variable magnification from 10% to 30%, image distortion and invisibility in the facio-lingual dimension. Conventional cross-sectional tomography produces images with known, fixed, uniform magnification and provides accurate bone measurements in a facio-to-lingual and vertical dimension.

Computed tomography (CT) with multiplanar reformatting (MPR) is considered to be the most reliable technique for the assessment of bone measurements and localization of anatomic structures, although it has disadvantages like greater radiation exposure and cost.⁴⁻¹² Multiplanar reformatted CT images produce three basic images: axial images with a superimposed curve, cross-sectional images, and panoramic images. Dedicated multiplanar reconstruction softwares are DentaScan (General Electrics Medical Systems, Milwaukee, USA), Toothpix (Picker International, Cleveland, USA), and so on. Most of MPR softwares are those which run at the workstation-level computer.

Concerning the visibility of mandibular canal, it was reported that conventional tomography gave a significantly clearer image of the canal at the mental foramen and 1 cm posterior to it.¹³ Despite of it, it was also reported that in 17% of cases, it may be impossible to produce clear images enough to allow identification of the canal.¹⁴ Location of mandibular canal by means of CT was reported to be estimated more clearly than

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by conventional tomographic or panoramic radiography.¹⁵ According to study comparing two 3D rendering techniques using CT data, MPR and shaded surface display (SSD), MPR was a highly sensitive method in the detection of mandibular canal.¹⁶ In addition, comparing conventional panoramic radiographs with reconstructed volumetric computed tomography (VCT) panoramic views and VCT paraxial views, all reconstructed VCT paraxial images showed a clearer delineation of the mandibular canal than conventional panoramic radiographs. However, conventional panoramic radiographs were shown to be better than VCT reconstructed panoramic images.¹⁷

Vimplant (CyberMed Inc., Seoul, Korea) with 3D implant simulation software which run at the personal computer, was introduced in 2002. It has some extra function such as 3-dimensional reconstruction, panoramic ray sum and nerve detection, in addition to three basic images of MPR software.¹⁸

The aim of this study was to compare the visibility of the mandibular canal at the different radiographic methods such as conventional panoramic radiographs, Vimplant MPR-CT panoramic images, Vimplant MPR-CT paraxial images and film-based DentaScan MPR-CT images.

Materials and Methods

Data of 11 patients, who were performed mandibular dental implant treatment planned with both panoramic radiographic and multiplanar reformatted CT examination by DentaScan, were used. CT examination was performed with General Electric Hilight Advantage CT scanner (GE Medical system, Milwaukee, USA) and panoramic radiographic examination with PM 2002 CC proline Proline (Planmeca Co., Helsinki, Finland). DentaScan software and Vimplant system were used for multiplanar reconstruction. DentaScan software was run at the Sun SparcStation workstation (Sun Microsystems, Mountain view, USA) and Vimplant at the SamSung MagicStation (pentium IV 1.7 GHz CPU, 1.00 GB RAM, 40 GB HDD) with 17" TFT-LCD monitor (Magellan 700FS, Hansol LCD Inc., Seoul, Korea).

11 patients involved in this study were aged 22 to 62 years (average age, 44 years; 7 men and 4 women). All patients had been routinely examined using conventional panoramic radiographic machine, PM 2002 CC Proline. Eleven panoramic radiographs had been processed using the standard processing conditions. High resolution, 1.5 mm thick axial slices with 1.0 mm slice interval, 120 kVp, 120 mA, 15 cm field of view with a 512 × 512 matrix had been used as the

protocol of CT examination. The axial CT data had been transferred to a workstation and reformatted by DentaScan to generate paraxial and panoramic images and printed on film with Fuji medical laser imager FL-IM D (Fuji Photo Film Co., Tokyo, Japan). The archived axial CT data were stored on CD-R and transferred to a personal computer with 17 inch LCD monitor. Paraxial and panoramic images were reconstructed using Vimplant software.

All images obtained, i.e., conventional panoramic radiographs, monitor-based Vimplant MPR-CT panoramic images, monitor-based Vimplant MPR-CT paraxial images and film-based DentaScan MPR-CT images, were evaluated independently by two oral and maxillofacial radiologists for the detectability of mandibular canal at the mental foramen, 1 cm, 2 cm and 3 cm posterior to mental foramen. The judgements were then compared and, in case of disagreement, the radiographs were reexamined and a joint decision made. The 4-point grading score was used for assessment (1 = continuing smooth, sharply defined contour; 2 = some artefacts: local mild bloating and/or too narrow and/or discontinued for a short distance (1-3 mm); observer may need additional information; 3 = localization of canal possible, but unrealistic contours and/or discontinuity >3 mm and/or no visualization in the region of clinical interests; additional information necessary; 4 = no display as a result of impossible demarcation from surrounding tissue).

Statistical differences between the scores given for conventional panoramic radiographs and Vimplant MPR-CT panoramic images were tested with Wilcoxon's signed-rank test and those among the scores given for conventional panoramic radiographs, monitor-based Vimplant MPR-CT paraxial images and film-based DentaScan MPR-CT images with Friedman RM ANOVA on Ranks and pairwise multiple comparison procedure (Dunn's method) using SigmaStat v.3.0 (SPSS Inc., Chicago, USA).

Results

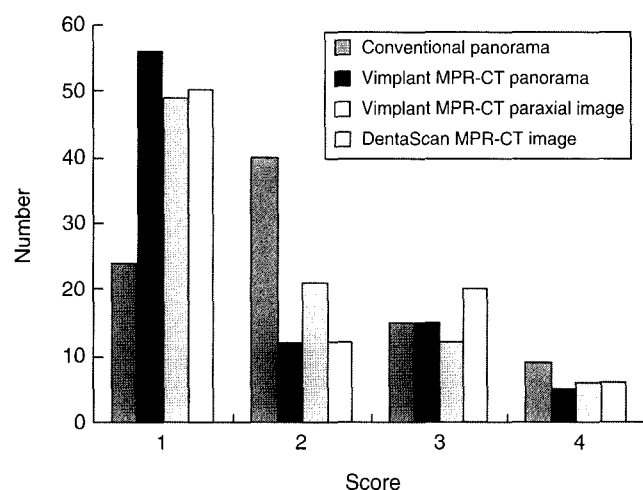
The overall distribution of grading scores for visibility of mandibular canal according to radiographic methods is shown in Table 1 and Fig. 1. The mandibular canal could not be identified in 10% of the regions on the conventional panoramic radiographs and in 7% on the Vimplant MPR-CT paraxial and DentaScan MPR-CT images. Excellent images of mandibular canal could be obtained in 27% only on the conventional panoramic radiographs and in 64%, 56%, 57% on the Vimplant MPR-CT panoramic, paraxial and DentaScan MPR-CT

Table 1. Overall distribution of grading score for visibility of mandibular canal, according to radiographic methods

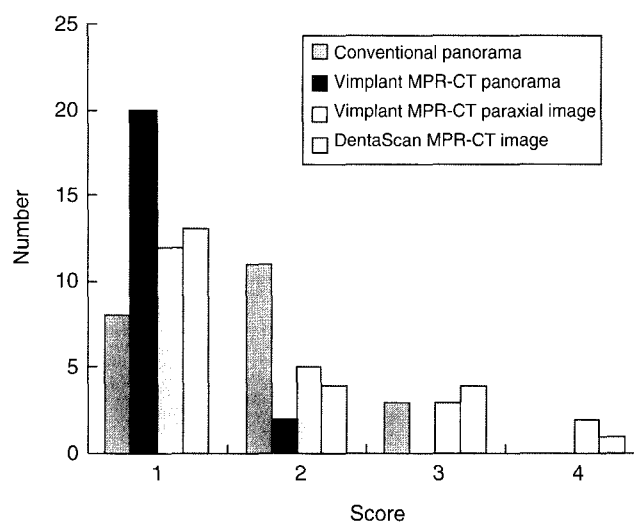
Grading score		Conventional panorama		Vimplant MPR-CT panorama		Vimplant MPR-CT paraxial image		DentaScan MPR-CT image	
		N	%	N	%	N	%	N	%
1	Excellent	24	27%	56	64%	49	56%	50	57%
2	Slightly limited	40	45%	12	14%	21	24%	12	14%
3	Severe limitation	15	17%	15	17%	12	14%	20	23%
4	Poor	9	10%	5	6%	6	7%	6	7%
Total		88	100%	88	100%	88	100%	88	100%

Table 2. Distribution of grading scores for visibility of mandibular canal at the mental foramen, according to radiographic methods

Grading score		Conventional panorama		Vimplant MPR-CT panorama		Vimplant MPR-CT paraxial image		DentaScan MPR-CT image	
		N	%	N	%	N	%	N	%
1	Excellent	8	36%	20	91%	12	55%	13	59%
2	Slightly limited	11	50%	2	9%	5	23%	4	18%
3	Severe limitation	3	14%	0	0%	3	14%	4	18%
4	Poor	0	0%	0	0%	2	9%	1	5%
Total		22	100%	22	100%	22	100%	22	100%

**Fig. 1.** Overall distribution of grading scores for visibility of mandibular canal, according to radiographic methods shows that the mandibular canal is better visualized with Vimplant MPR-CT panorama, paraxial images and DentaScan MPR-CT images than conventional panoramic image.

images respectively. Altogether, Vimplant MPR-CT panoramic images showed significantly clearer images than conventional panoramic radiographs ($p < 0.001$). Vimplant MPR-CT paraxial and DentaScan MPR-CT images revealed significantly clearer images than conventional panoramic radiographs ($p < 0.05$) and Vimplant MPR-CT paraxial and DentaScan MPR-CT images did not show significant difference in visibility of mandibular canal. The distributions of grading scores for visibility of mandibular canal according to radio-

**Fig. 2.** Distribution of grading scores for visibility of mandibular canal at the mental foramen, according to radiographic methods shows that the mandibular canal is better visualized with Vimplant MPR-CT panorama than the other radiographic images

graphic methods in the four regions (at the mental foramen, 1 cm, 2 cm and 3 cm posterior to the mental foramen) are shown in Table 2, 3, 4, 5 and Figs. 2, 3, 4, 5. At the mental foramen area, mandibular canal was better visualized with Vimplant MPR-CT panorama than the other images (Table 2, Fig. 2). Especially at the region 1 cm posterior to mental foramen, conventional panoramic radiographs showed markedly lower percentage of excellent mandibular canal image than the other images (Table 3, Fig. 3).

Table 3. Distribution of grading scores for visibility of mandibular canal 1 cm posterior to the mental foramen, according to radiographic methods

Grading score		Conventional panorama		Vimplant MPR-CT panorama		Vimplant MPR-CT paraxial image		DentaScan MPR-CT image	
		N	%	N	%	N	%	N	%
1	Excellent	2	9%	10	45%	11	50%	11	50%
2	Slightly limited	11	50%	3	14%	5	23%	1	5%
3	Severe limitation	6	27%	7	32%	4	18%	8	36%
4	Poor	3	14%	2	9%	2	9%	2	9%
Total		22	100%	22	100%	22	100%	22	100%

Table 4. Distribution of grading scores for visibility of mandibular canal 2 cm posterior to the mental foramen, according to radiographic methods

Grading score		Conventional panorama		Vimplant MPR-CT panorama		Vimplant MPR-CT paraxial image		DentaScan MPR-CT image	
		N	%	N	%	N	%	N	%
1	Excellent	5	23%	11	50%	11	50%	10	45%
2	Slightly limited	8	36%	2	9%	5	23%	6	27%
3	Severe limitation	5	23%	6	27%	4	18%	3	14%
4	Poor	4	18%	3	14%	2	9%	3	14%
Total		22	100%	22	100%	22	100%	22	100%

Table 5. Distribution of grading scores for visibility of mandibular canal 3 cm posterior to the mental foramen, according to radiographic methods

Grading score		Conventional panorama		Vimplant MPR-CT panorama		Vimplant MPR-CT paraxial image		DentaScan MPR-CT image	
		N	%	N	%	N	%	N	%
1	Excellent	9	41%	15	68%	15	68%	16	73%
2	Slightly limited	10	45%	5	23%	6	27%	1	5%
3	Severe limitation	1	5%	2	9%	1	5%	5	23%
4	Poor	2	9%	0	0%	0	0%	0	0%
Total		22	100%	22	100%	22	100%	22	100%

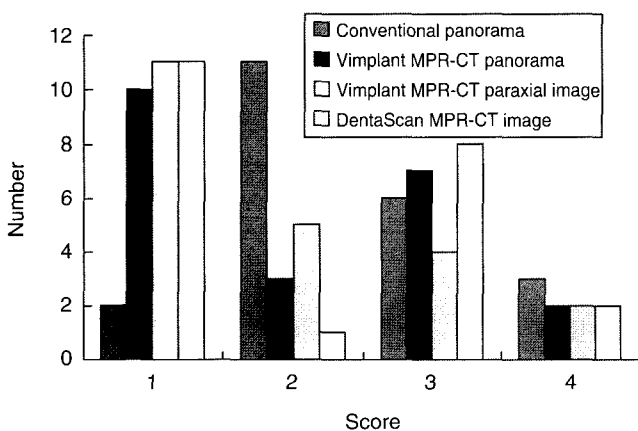


Fig. 3. Distribution of grading scores for visibility of mandibular canal 1 cm posterior to the mental foramen, according to radiographic methods shows that mandibular canal is better visualized with Vimplant MPR-CT panorama, paraxial images and DentaScan MPR-CT images than conventional panoramic image.

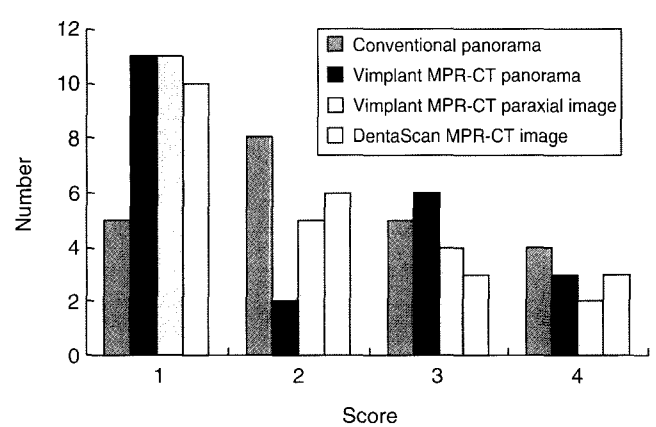


Fig. 4. Distribution of grading scores for visibility of mandibular canal 2 cm posterior to the mental foramen, according to radiographic methods shows that mandibular canal is better visualized with Vimplant MPR-CT panorama, paraxial images and DentaScan MPR-CT images than conventional panoramic image.

Different radiographic images of the same patient are shown in Fig. 6. Conventional panoramic image shows indistinct image of mandibular canal at mental foramen and 1 cm posterior to mental foramen, whereas Vimplant MPR-CT

panorama, paraxial images and DentaScan MPR-CT paraxial images show excellent clear image of mandibular canal.

Discussion

Conventional panoramic radiography is still the most commonly used imaging modality to localize the mental foramen and mandibular canal for the preimplant treatment planning in the posterior mandible, but the mandibular canal is often difficult to locate in these regions with this technique.¹³ Conventional tomography was reported to visualize mandibular canals more clearly at and 1 cm posterior to the mental foramen than panoramic radiography, while no differences between the methods 2 cm posterior to the mental foramen. However, in 17% of cases in the tomograms, the mandibular canal could not be identified.¹³ When panoramic radiographs, conventional tomographs, and CT were compared for their ability to locate the mandibular canal in the buccolingual direction, CT gave better visualization than panoramic radiographs or conventional tomographs (Scanora imaging). Mandibular canal could be seen in all CT scans, whereas

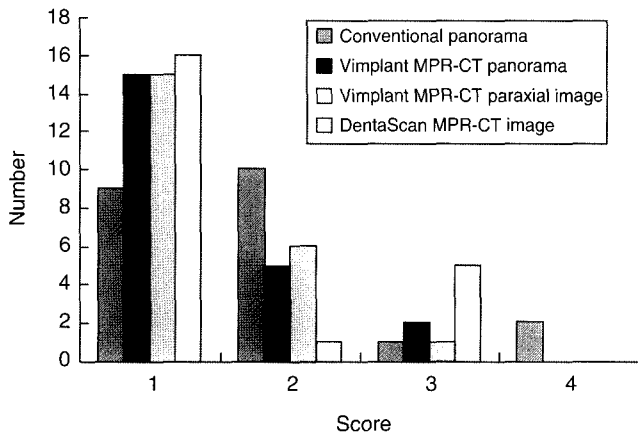


Fig. 5. Distribution of grading scores for visibility of mandibular canal 3 cm posterior to the mental foramen, according to radiographic methods shows that mandibular canal is better visualized with Vimplant MPR-CT panorama, paraxial images and DentaScan MPR-CT images than conventional panoramic image.

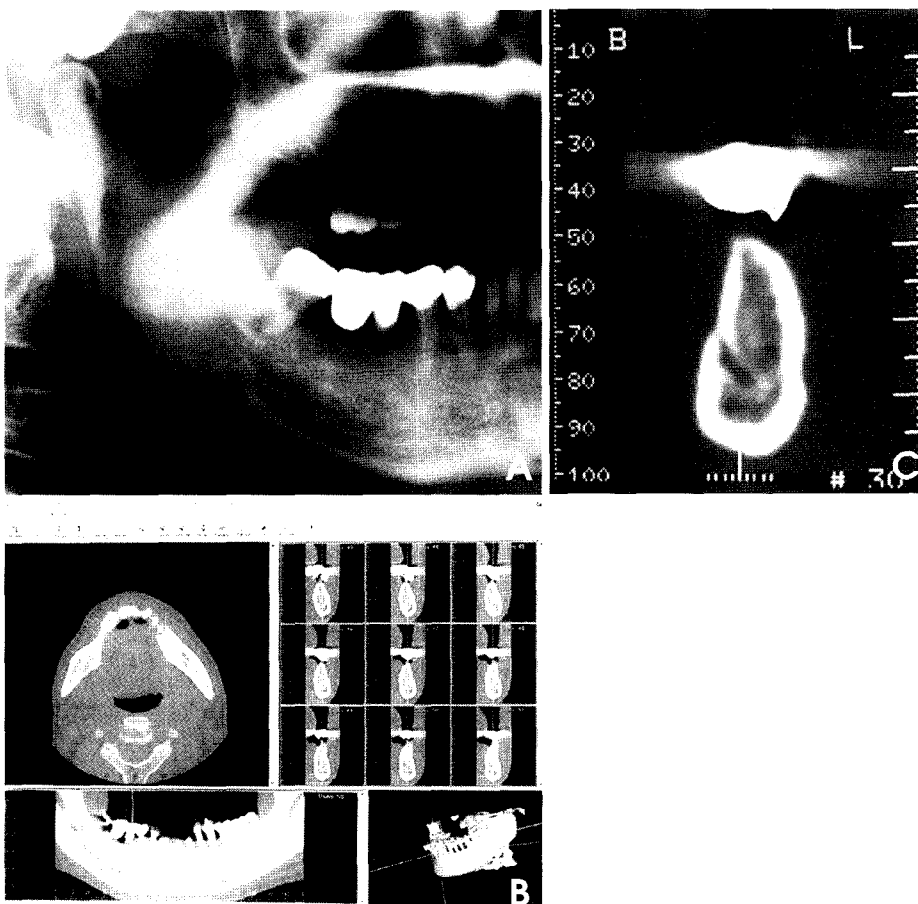


Fig. 6. Different radiographic images of the same patient. Conventional panoramic image (A) shows indistinct image of mandibular canal at mental foramen and 1 cm posterior to mental foramen, whereas Vimplant MPR-CT panorama, paraxial images (B) and DentaScan MPR-CT images (C) show excellent clear image of mandibular canal.

in Scanora imaging, in only 60% to 95% of cases.¹⁵ In the study comparing the periapical radiographs and CT scans with regard to the detection of the apical lesion and the mandibular canal, mandibular canal could be identified in 31 cases only among 80 cases in periapical radiographs, whereas in all patients in the CT scans.¹⁹ In another study comparing the detectability of the canal in panoramic radiographs, tomography and periapical radiographs, the incidence of “not visible” mandibular canals was higher for tomography and panoramic radiographs, leading to the conclusion that those imaging processes are not alternative to periapical radiographs with regard to the localization of the mandibular canal.²⁰ Solar et al.¹⁶ evaluated two different 3D rendering techniques, shaded surface display (SSD) and multiplanar reconstruction (MPR), for detecting the mandibular canal and found that both techniques were valuable, but the canal could be detected in 100% with MPR and 80.1% with SSD. In this study, excellent image of mandibular canal could be obtained in 27% only on the panoramic radiographs and in 64%, 56%, and 57% on the Vimplant MPR-CT panoramic, paraxial and DentaScan MPR-CT images respectively. And the canal could not be identified in 10% on the panoramic radiographs and in 7% on the Vimplant and DentaScan MPR-CT images. Vimplant and DentaScan MPR-CT images did not show significant difference in visibility of mandibular canal. In many cases conventional panoramic radiographs did not show excellent images, Vimplant MPR-CT and DentaScan MPR-CT image could be show better images of mandibular canal. However, in case the cortical bone of mandibular canal was of very poor quality, MPR-CT images could not visualize the mandibular canal.

On panoramic radiographs, the mandibular canal is usually well visualized in the ramus and in the molar regions. In these areas, the canal is in contact with and usually makes a slight depression in the lingual cortex of the mandible.¹⁵ In this study, conventional panoramic radiographs showed markedly lower percentage of “excellent” image at the region 1 cm posterior to mental foramen than the other images.

Pawelzik et al.¹⁷ compared conventional panoramic radiographs with volumetric computed tomography (VCT) images and showed that the VCT paraxial images gave a significantly clearer perception of the mandibular canal than conventional panoramic radiographs, but conventional panoramic radiographs were shown to be better than the VCT reconstructed panoramic images. In the contrary, Vimplant MPR-CT panoramic images showed significantly clearer images than conventional panoramic radiographs in this study. This might be because they used a new type CT scanner, cone beam CT

(NewTom-9000, Quantitative Radiology, Verona, Italy) for their research. Vimplant MPR-CT panoramic images comprised of multiple images of 1 mm interval facio-lingually. So the canal image could be traced relatively easily at the section involving the canal, in comparison with the conventional panoramic radiographs, kind of superimposed images.

Vimplant software used in this study, was introduced commercially in 2002. It has basically multiplanar and 3-dimensional reconstruction function using axial CT images at the personal computer with extra functions of panoramic ray sum, nerve detection, and implant simulation. Function of nerve detection is based the operator’s action to determine the path of canal and did not contribute to localize the mandibular canal of poor quality. Choi et al.¹⁸ evaluated the accuracy of the measurements of reformatted image using this software and concluded that this newly developed, PC-based Vimplant simulation program can be used as an alternative to the generally used workstation-based CT multiplanar reconstruction program. In this study, there was no significant difference in visibility of mandibular canal between Vimplant MPR-CT and DentaScan MPR-CT images.

In summary, the study results show that Vimplant and DentaScan MPR-CT imaging systems offer significantly better images of the mandibular canal than conventional panoramic radiograph. When conventional panoramic radiograph does not show mandibular canal clearly particularly at mental foramen and 1 cm posterior to mental foramen, the better images might be obtained with Vimplant or DentaScan MPR-CT. Also newly developed, PC-based Vimplant program can be used as an alternative to the generally used workstation-based CT multiplanar reconstruction program.

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