The Use of 3 Different Imaging Methods for the Localization of the Mandibular Canal in Dental Implant Planning

Ilkay Peker, DDS, PhD[1]/Meryem Toraman Alkurt, DDS, PhD[2]/Tansev Mihcioglu, DDS, PhD[3]

Purpose: *The purpose of this study was to investigate the efficiency of panoramic radiography, conventional (cross-sectional) tomography, and computerized tomography for location of the mandibular canal before implant placement in the posterior region of the mandible.* ***Materials and Methods:*** *Edentulous mandibles from 6 dry adult human skulls were used in this study. Four measurements (D_1, D_2, D_3, D_4) were made of 12 areas, one on each side of each mandible. Panoramic radiographs, conventional tomograms, and computerized tomograms were obtained. On each image, measurements were made for localization of the mandibular canal by one researcher. All measurements were repeated 3 times within a period of 3 weeks. Upon completion of imaging, the mandibles were surgically sectioned to provide direct measurements. The measurements obtained from the images were compared with direct measurements. Pearson correlation coefficients were calculated to detect statistical correlations between repeated measurements. The Dunnett* t *test was performed for statistical comparison of measurements from images and direct measurements.* ***Results:*** *Pearson correlation coefficients showed strong linear correlation for all measurements ($P < .01$). No statistically significant difference was observed between direct measurement and D_1, D_2, or D_4 ($P < .05$), but a statistically significant difference for D_3 (buccolingual width 5 mm under mandibular crest; Dunnett* t *test; $P > .05$) between measurements was obtained from the images and direct measurements.* ***Conclusion:*** *The measurements obtained from computerized tomographic images were more consistent with direct measurements than the measurements obtained from panoramic radiographic images or conventional tomographic images.* Int J Oral Maxillofac Implants 2008;23:463–470

Key words: *dental implant, imaging methods, mandibular canal, treatment planning*

Radiography plays an important role in implant dentistry.[1] The quality and amount of bone available should be determined during the planning stage.[2] Various radiographic imaging techniques such as panoramic, lateral cephalometric, periapical, and occlusal radiography and conventional and computed tomography have been used in planning dental implant treatment[3–5] and for posttreatment evaluation of the hard tissues surrounding implants.[6,7]

[1]Research Assistant, Gazi University, Faculty of Dentistry, Department of Oral Diagnosis and Radiology, Ankara, Turkey.
[2]Assistant Professor, Gazi University, Faculty of Dentistry, Department of Oral Diagnosis and Radiology, Ankara, Turkey.
[3]Professor, Gazi University, Faculty of Dentistry, Department of Restorative Dentistry and Endodontics, Ankara, Turkey.

Correspondence to: Dr Ilkay Peker, Gazi University, Faculty of Dentistry, Department of Oral Diagnosis and Radiology, 06510 Emek/Ankara, Turkey. Fax: +90 312 223 92 26. E-mail: drdtilkay@gmail.com

None of these imaging systems is perfect; false-negatives and false-positives are possible with each technique.[7,8] Panoramic and periapical radiographs usually provide sufficient diagnostic information for implant treatment planning in the anterior mandible. However, placing implants in the maxilla and the posterior mandible requires more accurate diagnostic information to avoid damaging vital anatomic structures. Two-dimensional radiographs do not provide information on bone thickness or the location of vital structures in a buccolingual direction. Hence, it is necessary to use imaging techniques that accurately display the size and buccolingual direction of the mandibular and incisive canals, the maxillary sinus, and the shape and density of the alveolar ridges and cortical plates.[9]

Several authors have emphasized the necessity of cross-sectional imaging for dental implant planning.[3,10–14] Many imaging techniques, such as conventional spiral, linear, hypocycloidal, and computed

Fig 1 A sample panoramic radiograph.

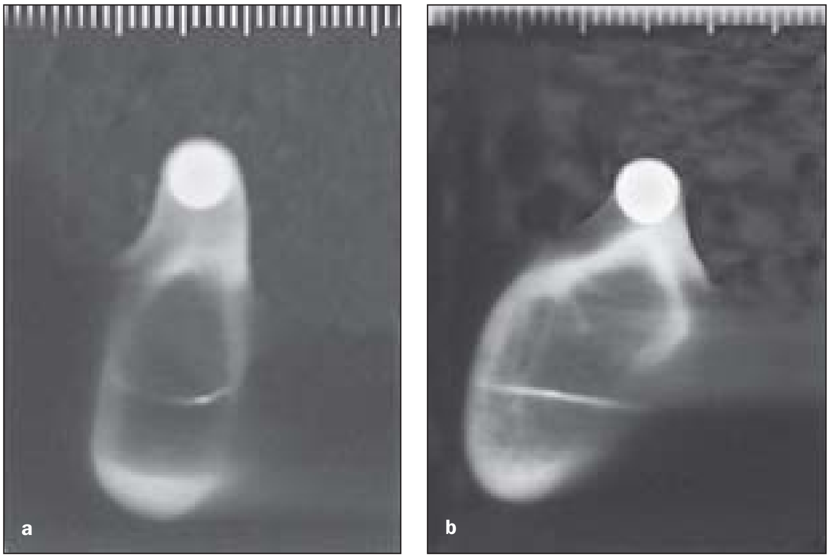

Fig 2 A sample conventional (cross-sectional) tomogram. *(a)* Premolar region. *(b)* Molar region.

tomography and magnetic resonance imaging are used for cross-sectional imaging.[12,15–17] Conventional and computed tomography are used especially in cases where implant placement could damage the mouth floor or the mandibular canal in the posterior mandible.[18]

The purpose of this study was to investigate the efficiencies of panoramic radiography, conventional (cross-sectional) tomography, and computerized tomography for detection of localization of the mandibular canal before placement of implants in the posterior mandibular region.

MATERIALS AND METHODS

Six dry edentulous adult human mandible samples were selected from Department of Anatomy of the Faculty of Medicine, Ankara University, Turkey. The sex and age of these samples were unknown. Areas with gaps of 5 mm extending from first premolar through the third molar were identified for each mandible bilaterally. Images of slices of 72 predetermined radiographic sliceswere made using panoramic radiography and conventional tomography by the Department of Radiology of the Faculty of Dentistry, Gazi University, Turkey.

Conventional panoramic images were taken with Trophy OP100 (Instrumentarium, Tuusula, Finland) panoramic unit equipment at 57 kV, 2 mA using a 15 × 30-cm Kodak screen cassette and Kodak T Mat G film (Eastman Kodak, Rochester, NY) with an exposure time of 17.6 seconds. An example of a panoramic image is shown in Fig 1.

Conventional tomography images were obtained with an OP100 panoramic unit using the linear tomography function. The OP100 panoramic unit produces linear tomographic images using Orto Trans program with Direct Laser Positioning system. A grid cassette (Kodak 15 × 30 cm) was used in this study according to the recommendation of the manufacturer. The Direct Laser Positioning system con-

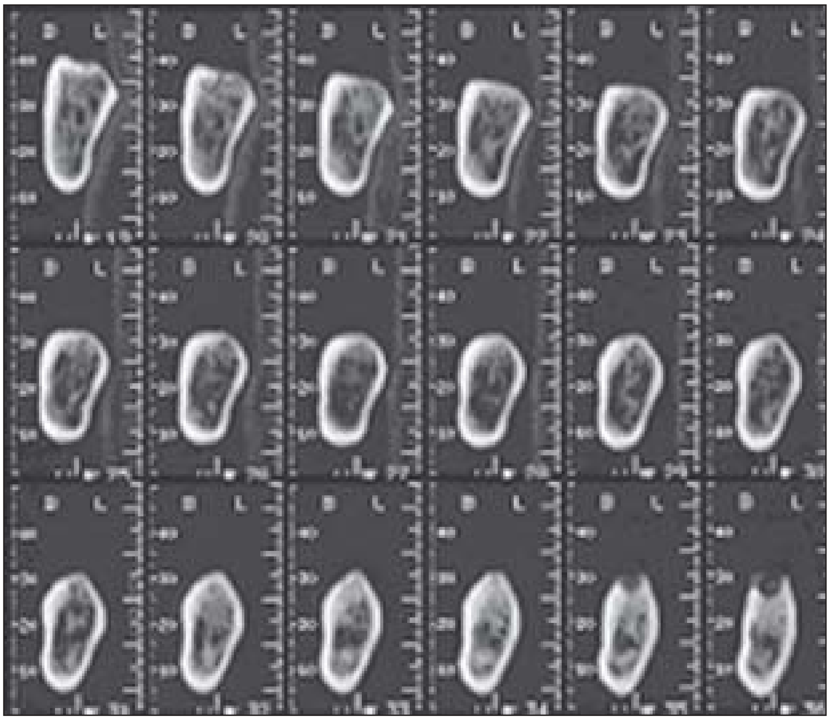

Fig 3 A sample computerized tomogram.

sists of 3 parts: computer software, laser beam units, and accessory tools. Using software, the movements of the machine can be controlled to obtain accurate locations and angles of the tomographic objective plane. The objective planes can be adjusted along the x- and y-axes and can be rotated around the center of the plane. The laser beams, which cross each other at right angles, indicate the location and angle of the tomographic objective planes.[19] In the present study, 3-mm-thick conventional cross sections of mandibles were used. These images were obtained with a 15 × 30 cm Kodak grid cassette and Kodak T mat G film (63 kVp, 6.4 mA) with an exposure time of 18.4 seconds. An example of a conventional cross-sectional tomographic image is shown in Fig 2.

All radiographs were developed in an automatic film processor (Velopex, Extra-X; Medivance Instruments, London, United Kingdom; NW107A) with freshly prepared solutions.

Acrylic resin stents were prepared from transparent acrylic resin, and metal balls 5 mm in diameter were placed on these stents in the first premolar/first molar region for determination of the magnification factor for each image. The following distances were measured on panoramic radiographs:

D_1: The distance from the alveolar crest to the inferior border of the mandible
D_2: The distance from the alveolar crest to the superior border of the mandibular canal

Computerized tomographic images were obtained at Gazi University, Faculty of Medicine, Department of Radiodiagnostics, Ankara, Turkey. A high-speed CTI (GE Medical Systems, Milwaukee, WI) scanner was used at 120 kV, 140 mA, 512 × 512 matrix data, with 15-cm field of view and bone detail algorithms. The axial plane was positioned parallel to the lower border of the mandible. Slice thickness and intervals were 1 mm, and the images were obtained in sequence. The data were transferred for postprocessing using DentaScan CT software (General Electric Medical System, Slough, Berks, United Kingdom). This software, which is used specifically for dental implant planning, produces reformatted images from axial scan data in the sagittal and coronal planes.[20] Axial computerized tomographic images were reformatted, and reformatted computerized tomographic slices were used perpendicular to the line passing through the middle of the dental arch to perform cross-sectional measurements. An example of a computerized tomographic image is shown in Fig 3.

The following distances were measured on conventional and computed tomograms:

D_3: Buccolingual width 5 mm under mandibular crest
D_4: Buccolingual width at the circumference of the mandibular canal

These distances are illustrated in Fig 4.

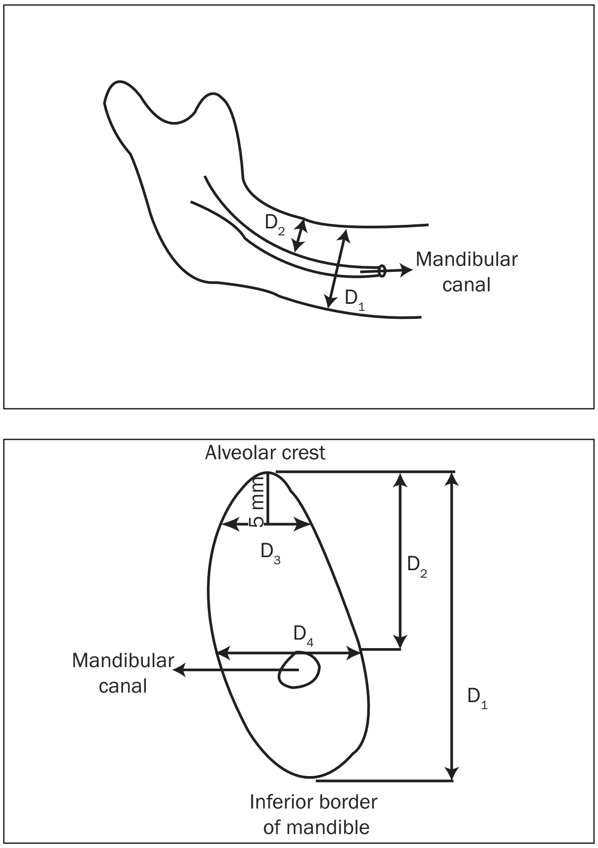

Fig 4 Measurements.

Fig 5 Slices of mandible.

Measurements were made using a digital caliper (Digimatic caliper; Mitutoyo, Andover, UK) with 0.01 mm sensitivity by a specialist in oral diagnosis and radiology with 10 years of experience on all images. Measurements were repeated by the same researcher 3 times in a period of 3 weeks.

The mandibles were then sectioned with a diamond disk under water cooling at each of the proposed sites, and identical measurements (D_1, D_2, D_3, D_4) were made. Measurements made on the actual

Table 1 Pearson Correlation Coefficients

	Measurement		
	1	2	3
Panoramic radiography			
D_1			
Measurement 1	1	1.000	1.000
Measurement 2		1	1.000
Measurement 3			1
D_2			
Measurement 1	1	1.000	1.000
Measurement 2		1	1.000
Measurement 3			1
Conventional tomography			
D_1			
Measurement 1	1	1.000	1.000
Measurement 2		1	1.000
Measurement 3			1
D_2			
Measurement 1	1	1.000	1.000
Measurement 2		1	1.000
Measurement 3			1
D_3			
Measurement 1	1	0.999	0.994
Measurement 2		1	0.996
Measurement 3			1
D_4			
Measurement 1	1	0.996	0.997
Measurement 2		1	0.998
Measurement 3			1
Computerized tomography			
D_1			
Measurement 1	1	1.000	1.000
Measurement 2		1	1.000
Measurement 3			1
D_2			
Measurement 1	1	1.000	1.000
Measurement 2		1	1.000
Measurement 3			1
D_3			
Measurement 1	1	0.999	0.994
Measurement 2		1	0.995
Measurement 3			1
D_4			
Measurement 1	1	0.999	0.997
Measurement 2		1	0.997
Measurement 3			1
Actual measurement			
D_1			
Measurement 1	1	0.998	0.997
Measurement 2		1	0.996
Measurement 3			1
D_2			
Measurement 1	1	0.999	0.995
Measurement 2		1	0.996
Measurement 3			1
D_3			
Measurement 1	1	1.000	1.000
Measurement 2		1	1.000
Measurement 3			1
D_4			
Measurement 1	1	0.996	0.994
Measurement 2		1	0.997
Measurement 3			1
Total			
Measurement 1	1	1.000	1.000
Measurement 2		1	1.000
Measurement 3			1

Table 2 Results of Dunnett *t* Test for All Methods and Distances

Distances/ methods	Mean difference	SD	*P*	95% Confidence interval Lower limit	Upper limit
D_1					
Panoramic radiography	0.79889	1.06437	.794	−1.7148	3.3125
Conventional tomography	−0.61181	1.06437	.892	−3.1255	1.9018
Computerized tomography	-0.22444	1.06437	.993	−2.7381	2.2892
D_2					
Panoramic radiography	0.85090	0.86077	.637	−1.1856	2.8874
Conventional tomography	−0.24162	0.84616	.985	−2.2436	1.7604
Computerized tomography	-0.51915	0.82124	.866	−2.4622	1.4238
D_3					
Conventional tomography	−0.72472	0.22031	.002*	−1.2153	−0.2341
Computerized tomography	-0.31333	0.22031	.266	−0.8039	0.1773
D_4					
Conventional tomography	−0.68792	0.28488	.061	−1.3223	−0.0535
Computerized tomography	−0.34583	0.28488	.372	−0.9802	0.2886

*Correlation is significant at the .05 level.

mandible served as a gold standard. The measurements obtained from images were compared with direct measurements. Slices of mandible are shown in Fig 5.

Data Analysis

Pearson correlation coefficients were calculated to detect statistical relationships between repeating measurements on panoramic radiographs, conventional tomograms, and computed tomograms. Dunnett *t* test was performed using SPSS (version 13.0) for statistical comparison between distance measurements (D_1, D_2, D_3, and D_4) obtained with each method and direct measurements.

RESULTS

Two distances were measured on each panoramic image and 4 on each conventional tomogram, and computed tomogram, for a total of 72 predetermined radiographic slices. Measurements were repeated 3 times in a period of 3 weeks. In all, 3,024 measurements were made.

A magnification rate of 28% to 34% was observed with panoramic radiography. The rate of magnification with conventional tomography was 40%; with computerized tomography, it was 4%. The location of mandibular canal could not be determined in 19.4% of panoramic radiographs or in 13.9% of conventional tomograms; it could be viewed in almost all computerized tomography images.

Pearson correlation coefficients varied between 0.994 and 1 (Table 1), and there was an excellent correlation for all measurements ($P < .01$).

Table 3 Error Rates for All Methods and Distances

Distances/ methods	Error ≤ −1 mm (%)	−1 mm < Error < 1 mm (%)	Error > 1 mm (%)
D_1			
Panoramic radiography	19.4	80.6	0
Conventional tomography	2.8	83.3	13.9
Computerized tomography	0	97.2	2.8
D_2			
Panoramic radiography	20.7	79.3	0
Conventional tomography	25.8	53.2	21
Computerized tomography	0	91.4	8.6
D_3			
Conventional tomography	0	81.9	18.1
Computerized tomography	0	100	0
D_4			
Conventional tomography	0	88.9	11.1
Computerized tomography	0	98.6	1.4
Total			
Panoramic radiography	20	80	0
Conventional tomography	6.5	77.7	15.8
Computerized tomography	0	96.9	3.1

No statistically significant differences were found between the measurements obtained from images and direct measurements for D_1, D_2, or D_4 ($P > .05$), but a statistically significant difference was found for D_3 ($P < .05$) according to the Dunnett *t* test (Table 2).

An error rate of measurement of less than 1 mm is preferred in preoperative implant treatment planning.[15] For this reason, the error rate was assessed at the level of ± 1 mm in measurements.[21] The error rates of panoramic radiography, conventional tomography, and computerized tomography measurements are presented in Table 3.

DISCUSSION

In this study, the relative efficiencies of panoramic radiography, conventional (cross-sectional) tomography, and computed tomography for detection of localization of the mandibular canal for preoperative dental implant treatment were investigated. Panoramic radiography is narrow-beam radiography, which gives information about the anatomic features of the jaws. The reliability of panoramic radiography is limited because of distortion and magnification.[22,23] In 1 study, the rate of horizontal magnification was reported as 20% to 35%, and the rate of vertical magnification was reported as 17.5% to 32%.[1] Horizontal and vertical magnification were found to be 30% in 2 studies,[12,24] and horizontal and vertical magnification reported as 30% to 33% in the anterior region and as 30.6% to 31.4% in the posterior region in other studies.[11,12] The rate of magnification for panoramic radiography was found as 28% to 34% in this study, which is comparable with previous studies.

The structure of bone and the distance between the superior border of mandibular canal and alveolar crest can generally be determined with panoramic radiographs.[15] However, several authors think that panoramic radiography is insufficient for the detection of vertical bone height.[25,26] It was reported in 2 studies that the superior border of the mandibular canal in the posterior region of mandible was not determined in 36% of panoramic radiographs.[12,26] The height of alveolar crest from the superior border of the mandibular canal could not be measured in 19.4% of panoramic radiographs in the present study. Differences between this study and previous reports in identification of the mandibular canal may be related to variation in the location of the inferior alveolar nerve, positioning errors, and evaluator error.

Conventional cross-sectional tomography is recommended by the American Academy of Oral and Maxillofacial Radiology for most patients receiving implants.[27] Nevertheless, it has been opined that currently there is no scientific evidence for their recommendation.[28] However, according to European Association for Osseointegration guidelines, conventional cross-sectional tomography is recommended for diagnostic imaging in single-tooth replacement, partially edentulous arches, and edentulous arches, and established low-risk surgical situation except in case where multiple regions are being treated.[29] The rate of magnification in conventional tomographic images was reported as 40% in 3 studies,[14,15,30] as 27.1% to 27.9% in another study,[9] as 52% in another study,[31] and as 30% in a sixth study.[11] The rate of magnification was found to be 40% in the present study. This result is in accordance with previous studies.

Naitoh et al[32] reported that the lower accuracy of linear tomography in other reports was mainly the result of difficulties in the adjustment of the objective planes but not the quality of the image. Also, it was reported that the position of mandibular canal was not determined in 14% to 50% of linear tomographic images.[9] Mandibular canal could not been localized at 13.9% of linear tomographic images in the present study; this is similar to the results of Todd et al.[9]

Computerized tomographic imaging has become a well-established aid in preoperative assessment prior to implant placement.[7] Computerized tomographic scans are more accurate than conventional radiographs.[33] Other advantages offered by computerized tomographic technology are direct volumetric reconstruction and faster and easier data transformation for use in 3-dimensional analyses.[34] Rates of magnification of 3.73% to 9.52%[9] and 0% to 4%[35] have been reported for computerized tomography. The rate of magnification for computerized tomographic images was found to be 3.86% in the present study, which is comparable to previously reported results.

It has been suggested that computerized tomographic imaging be used if there is difficulty locating the inferior alveolar nerve or the mental foramen.[36] Several authors[9,20,24] have emphasized that the location of the mandibular canal can be determined in almost all computerized tomographic images.

Repeatability of the measurements obtained from panoramic radiographs, conventional and computed tomograms was found as reliable in previous studies.[30,37,38] In this study, there was strong linear correlation between repeated measurements for all methods.

Some investigators have found no statistically significant differences between measurements obtained from panoramic radiography, conventional tomography, computerized tomography, and direct measurements vertically, horizontally, and buccolingually.[20,38,39] However, Peltola et al[30] made measurements in vertical and buccolingual directions and found a statistically significant difference between direct measurements and measurements on conventional cross-sectional tomograms made in a buccolingual direction. In the present study, no statistically significant differences were found between D_1, D_2, and D_4 measurements and direct measurements for all methods. A statistically significant difference was found between only D_3 (buccolingual) measurement and direct measurement for conventional tomography, which is similar to the results of Peltola et al.[30]

The measurement error is generally required to be less than 1 mm on images made for implant treatment.[1] In studies[11,40] using cadaver mandibles, measurement error was found to be less than 1 mm in 94% of cases for computerized tomography, in 39%

of cases for conventional tomography, in 53% of cases for intraoral radiography, and in 17% of cases for panoramic radiography. In the present study, the measurement error was less than 1 mm in 80% of panoramic images, 77.7% of linear tomographic images, and 96.9% of computerized tomographic images, which is similar to the results of Hanazawa et al.[20] The differences between studies may be a result of differences in the areas measured, the researchers, the equipment used, and positioning.

CONCLUSION

The measurements obtained from computerized tomographic images were more consistent with direct measurement than the measurements obtained from panoramic radiography or conventional tomography. The advantages and disadvantages of different imaging methods for preoperative dental implant planning should be evaluated in further studies.

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REFERENCES

1. Wyatt CC, Pharoah MJ. Imaging techniques and image interpretation for dental implant treatment. Int J Prosthodont 1998;11:442–452.
2. Iplikcioglu H, Akca K, Cehreli MC. The use of computerized tomography for diagnosis and treatment planning in implant dentistry. J Oral Implantol 2002;28:29–36.
3. Engelman MJ, Sorensen JA, Moy P. Optimum placement of osseointegrated implants. J Prosthet Dent 1988;59:467–473.
4. Scaf G, Lurie AG, Mosier KM, Kantor ML, Ramsby GR, Freedman ML. Dosimetry and cost of imaging osseointegrated implants with film-based and computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;83:41–48.
5. Stella JP, Tharanon W. A precise radiographic method to determine the location of the inferior alveolar canal in the posterior edentulous mandible: Implications for dental implants, Part 1: Technique. Int J Oral Maxillofac Implants 1990;5:15–22.
6. Frederiksen NL, Benson BW, Sokolowski TW. Effective dose and risk assessment from film tomography used for dental implant diagnostics. Dentomaxillofac Radiol 1994;23:123–127.
7. Reiskin AB. Implant imaging status, controversies and new developments. Dent Clin North Am 1998;42:47–56.
8. Sunden S, Grondahl K, Grondahl HG. Accuracy and precision in the radiographic diagnosis of clinical instability in Brånemark dental implants. Clin Oral Implants Res 1995;6:220–226.
9. Todd A, Gher M, Quintero G, Richardson A. Interpretation of linear and computed tomograms in the assessment of implant recipient sites. J Periodontol 1993 63; 1243-1249.
10. Schropp L, Wenzel A, Kostopoulos L. Impact of conventional tomography on the prediction of the appropriate implant size. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001; 92:458–463.
11. Bolin A, Eliasson S, von Beetzen M, Jansson L. Radiographic evaluation of mandibular posterior implant sites: Correlation between panoramic and tomographic determinations. Clin Oral Implants Res 1996;7:354–359.
12. Akdeniz BG, Oksan T, Kovanlikaya I, Genc I. Evaluation of bone height and bone density by computed tomography and panoramic radiography for implant recipient sites. J Oral Implantol 2000;26:114–119.
13. Lindh C, Petersson A, Klinge B. Visualization of the mandibular canal by different radiographic techniques. Clin Oral Implants Res 1992;3:90–97.
14. Bou Serhal C, van Steenberghe D, Bosmans H, Sanderink GC, Quirynen M, Jacobs R. Organ radiation dose assessment for conventional spiral tomography: A human cadaver study. Clin Oral Implants Res 2001;12:85–90.
15. Preda L, Di Maggio EM, Dore R, et al. Use of spiral computed tomography for multiplanar dental reconstruction. Dentomaxillofac Radiol 1997;26:327–331.
16. Serhal CB, van Steenberghe D, Quirynen M, Jacobs R. Localisation of the mandibular canal using conventional spiral tomography: A human cadaver study. Clin Oral Implants Res 2001; 12:230–236.
17. Yang J, Cavalcanti MG, Ruprecht A, Vannier MW. 2-D and 3-D reconstructions of spiral computed tomography in localisation of the inferior alveolar canal for dental implants. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;87: 369–374.
18. ten Bruggenkate CM, Krekeler G, Kraaijenhagen HA, Foitzik C, Nat P, Oosterbeek HS. Hemorrhage of the floor of the mouth resulting from lingual perforation during implant placement: A clinical report. Int J Oral Maxillofac Implants 1993;8: 329–334.
19. Naitoh M, Kawamata A, Iida H, Ariji E. Cross-sectional imaging of the jaws for dental implant treatment: Accuracy of linear tomography using a panoramic machine in comparison with reformatted computed tomography. Int J Oral Maxillofac Implants 2002;17:107–112.
20. Hanazawa T, Sano T, Seki K, Okano T. Radiologic measurements of the mandible: A comparison between CT-reformatted and conventional tomographic images. Clin Oral Implants Res 2004;15:226–232.
21. Horton RA, Ludlow JB, Webber RL, Gates W, Nason Rh Jr, Reboussin D. Detection of peri-implant bone changes with axial tomosynthesis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996;81:124–129.
22. Batenburg RH, Stellingsma K, Raghoebar GM, Vissink A. Bone height measurements on panoramic radiographs. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;84:430–435.
23. ten Bruggenkate CM, van Der Linden LW, Oosterbeek HS. Parallelism of implants visualized on the orthopantomogram. Int J Oral Maxillofac Surg 1989;18:213–215.
24. Klinge B, Petersson A, Maly P. Location of the mandibular canal: A comparison of macroscopic findings, conventional radiography, and computed tomography. Int J Oral Maxillofac Implants 1989;4:327–332.
25. Sonick M, Abrahams J, Faiella RA. A comparison of accuracy of the periapical, panoramic, and computerized tomographic radiographs in locating the mandibular canal. Int J Oral Maxillofac Implants 1994;9:455–460.

26. Lindh C, Petersson A, Klinge B. Measurements of distances related to the mandibular canal in radiographs. Clin Oral Implants Res 1995;6:96–103.
27. Tyndall DA, Brooks SL. Selection criteria for dental implant site imaging: A position paper of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:630–637.
28. Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State of the art on cone beam CT imaging for preoperative planning of implant placement. Clin Oral Invest 2006;10:1–7.
29. Harris D, Buser D, Dula K, et al. E.A.O. Guidelines for the use of diagnostic imaging in implant dentistry. A consensus workshop organized by the European Association for Osseointegration in Trinity College Dublin. Clin Oral Implants Res 2002; 13;566–570.
30. Peltola JS, Mattila M. Cross-sectional tomograms obtained with four panoramic radiographic units in the assessment of implant measurements. Dentomaxillofac Radiol 2004;33: 295–300.
31. Frei C, Buser D, Dula K. Study on the necessity for cross-section imaging of the posterior mandible for treatment planning of standard cases in implant dentistry. Clin Oral Implants Res 2004;15:490–497.
32. Naitoh M, Katsumata A, Kubota Y, Okumura S, Hayashi H, Ariji E. The role of objective plane angulation on the mandibular image using cross-sectional tomography. J Oral Implantol 2006;32:117–121.
33. Jacobs R, Mraiwa N, van Steenberghe D, Sanderink G, Quirynen M. Appearance of mandibular incisive canal on panoramic radiographs. Surg Radiol Anat 2004;26:329–333.
34. Cavalcanti MG, Rocha SS, Vannier MW. Craniofacial measurements based on 3D-CT volume rendering: Implications for clinical applications. Dentomaxillofac Radiol 2004;33:170–176.
35. Reddy MS, Mayfield-Donahoo T, Vanderven FJ, Jeffcoat MK. A comparison of the diagnostic advantages of panoramic radiography and computed tomography scanning for placement of root form dental implants. Clin Oral Implants Res 1994;5: 229–238.
36. Greenstein G, Tarnow D. The mental foramen and nerve: Clinical and anatomical factors related to dental implant placement: A literature review. J Periodontol 2006;77:1933–1943.
37. Besimo C, Lambrecht JT, Guindy JS. Accuracy of implant treatment planning utilizing template-guided reformatted computed tomography. Dentomaxillofac Radiol 2000;29:46–51.
38. Sakakura CE, Loffredo Lde C, Scaf G. Diagnostic agreement of conventional and inverted scanned panoramic radiographs in the detection of the mandibular canal and the mental foramen. J Oral Implantol 2004;30:2–6.
39. Potter BJ, Shrout MK, Russell CM, Sharawy M. Implant site assessment using panoramic cross-sectional tomographic imaging. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;84:436–442.
40. Petrikowski CG, Pharoah NJ, Schmitt A. Presurgical radiographic assessment of implants. J Prosthet Dent 1989;61:59–64.