A Comparison of the Accuracy of Periapical, Panoramic, and Computerized Tomographic Radiographs in Locating the Mandibular Canal

Michael Sonick, DMD/James Abrahams, MD/Robert A. Faiella, DMD, MMSc

A customized acrylic-resin template with gutta percha markers was fabricated for a human cadaver mandible. Twelve measurements were made between gutta percha markers and between the markers and known mandibular anatomic locations. Periapical, panoramic, and computerized tomographic radiographs were taken of the mandible and stent. Similar readings were recorded from the radiographs. The average amount of distortion for the periapical, panoramic, and computerized tomographic radiographs was 1.9, 3.0, and 0.2 mm respectively. The average distortion for the periapical, panoramic, and computerized tomographic radiographs, as a percentage, was 14%, 23.5%, and 1.8% respectively. The computerized tomogram was the most accurate radiograph. (INT ORAL MAXILLOFAC IMPLANTS 1994;9:455-460)

Key words: computerized tomographic radiograph, endosseous implantation, mandibular canal, panoramic radiograph, periapical radiograph, posterior mandible

The placement of implants in the posterior mandible has become an increasingly common practice, particularly in partially edentulous patients.[1] This surgical procedure is complicated by a need to accurately locate the implant site relative to several important anatomic structures, particularly the neurovascular bundle of the mandibular canal. This renders preoperative planning for implant surgery in the posterior mandible more complicated than for most other implant sites. Trauma to this structure may result in hemorrhage and/or paresthesia.[2,3,4] In addition, to maximize the potential for implant success, longer lengths of implants are desirable over shorter lengths.[5] For these reasons, it is essential that the position of the mandibular canal be known, both before and during implant placement.

The introduction of computerized tomography has enabled the visualization of the mandible in three dimensions.[6-12] Prior to this technology, presurgical assessment was primarily accomplished through periapical and panoramic radiographs.[13,14] While conventional radiographic techniques are still widely used in presurgical planning, they are limited in that the information they provide is only two-dimensional. Assessments from such radiographs alone do not allow accurate determination of the buccolingual position of the mandibular canal, thus complicating decisions regarding implant placement and size prior to surgery.

Given the three-dimensional advantages which computerized tomographs provide, it would be expedient to know that they are accurate as well as comprehensive. The aim of this study was to provide a comparison of the differences in accuracy which may exist between the periapical radiograph, the panoramic radiograph, and the computerized tomographic radiograph, as tested by measuring along known distances between reference points.

Materials and Methods

To provide a common basis for comparison between the three radiographic technologies, a human mandible was obtained and alginate impressions were made. Stone casts were poured and an acrylic-resin template was fabricated. Four rectangular grooves were cut bilaterally on the template. Gutta percha markers were then fixed with acrylic resin bilaterally into the grooves (Figs 1a and 1b). Following this arrangement, periapical, panoramic, and computerized tomographic radiographs were taken of the acrylic-resin template in position on the mandibular teeth with standard technique and diagnostic quality.

Measurements were made between the gutta percha markers on the template, and also between the markers and certain anatomic landmarks directly on the mandible. Calipers were used to make six bilateral measurements, providing 12 data points as a basis for comparison with those obtained from the three radiograph images. The six measurements taken on the right side were:

A: Vertical length of the mesial aspect of the gutta percha rectangle.

B: Vertical length from the inferior border of the gutta percha rectangle to the inferior lip of the mental foramen.

C: The horizontal length of the inferior aspect of the gutta percha rectangle.

D: Vertical length of the distal aspect of the gutta percha rectangle.

E: Horizontal length of the superior aspect of the gutta percha rectangle.

F: Vertical length from the superior border of the gutta percha rectangle to the inferior lip of the mental foramen (Fig 2).

Similar measurements A′, B′, C′, D′, E′, and F′, were also taken on the left side.

Once these measurements had been obtained directly from the mandible and template, they were obtained from each of the three radiographic images. Periapical radiographs of the mandible with the template in place were obtained by using a long-cone paralleling technique with a film holder (Rinn, Elgin, IL) attached to the tube of a dental X-ray machine at 70 kVp (GX-77, Gendex, Milwaukee, WI). Ultraspeed DF-57 (Eastman Kodak Company, Rochester, NY) film was used for all periapical images (Fig 3).

Panoramic radiographs of the mandible with the template in place were taken using a Syntex Panoramic machine. Kodak X-Omat panoramic film was used. For this test, the mandible was fixed in a position which corresponded to that of a normal patient.

In the third test, computerized tomography was performed, with the plane of the inferior border of the mandible positioned parallel to the plane of the axial cuts. All scans were performed on a GE 9800 CT scanner (GE Medical Systems, Milwaukee, Wl). Axial slices were acquired parallel to the alveolar process using a bone algorithm, dynamic mode, 15 FOV × 512 matrix, and slice thickness of 1.5 mm with a 0.5-mm overlap. Data were then reformatted with the DentaScan software (GE Medical Systems) (Fig 4)

The caliper measurements taken directly from the mandible and template were recorded and used as the basis for comparing the radiographic techniques. Each set of radiographic measurements was interpreted independently by a periodontist and a neuro-radiologist. In no instance were differences in measurement greater than 1 mm.

Results

Twelve different sets of measurements made by calipers were recorded from the template and mandible, ranging from 5.5 to 23.0 mm in length. These measurements were then repeated using the periapical, panoramic, and computerized tomographic images, yielding a total of 48 measurements for comparison (Table 1).

The differences between the actual caliper measurements and the radiographic measurements were then tabulated and averaged (Table 2). It was found that the differences between the periapical measurements and the actual caliper distances varied from 0.5 to 5.5 mm, with an average disparity of 1.9 mm. The panoramic radiographic measurements varied from the caliper distances in a range of 0.5 to 7.5 mm, with an average variance of 3.0 mm. The computerized tomographic images varied from the actual measurement in a range of 0 to 0.5 mm, with an average variance of 0.2 mm.

The percentage radiographic distortion for each measurement was also calculated by subtracting the difference in measurement for each image from the actual caliper distance and dividing by the actual caliper measurement (Table 3).

Radiographic distortion could be expressed mathematically as follows:

$$\text{Radiographic Distortion} = \frac{(\text{Radiographic}) - (\text{Actual})}{(\text{Actual})} \times 100$$

The degree of distortion existing between the actual caliper measurements and the periapical radiographs varied from 8 to 24%, with an average distortion of 14%. The distortion from the panoramic radiographs varied from 5 to 39%, with an average distortion of 23.5%. The distortion from the computerized tomographs varied from 0 to 8%, with an average of 1.8%.

These data show that of the three radiographic images, the most accurate measurements were obtained by using the computerized tomograph. The panoramic radiograph proved to be the most inaccurate image, exhibiting the greatest amount of distortion. The periapical radiograph yielded accuracies between those of the panoramic and computerized tomographic radiographs.

Discussion

The results of this investigation demonstrate that the computerized tomogram is superior to the periapical and panoramic radiographs in its ability to accurately measure the height of available bone. Two previous comparison studies have demonstrated the computerized tomogram to be superior to the panoramic image in locating the position of the mandibular canal. However, those authors did not compare differences in linear assessment.[15,16] This study demonstrated that the accuracy of the computerized tomographic radiograph was within 0.5 mm of the caliper measurement in every reading taken; and in 8 out of the 12 readings, there was no distortion of the computerized tomographic measurements. In contrast, the panoramic radiograph showed extreme variability, with errors in measurement up to 7.5 mm and an average error of 3.0 mm. The periapical radiograph proved slightly more accurate, but still displayed errors of 5.5 mm, with an average error of 1.9 mm.

Without exception, all periapical radiographs were distorted so that the distances measured appeared greater than what they actually were. In no instance was less distance measured from the periapical radiograph than could be directly measured from the template and mandible. The tendency among the panoramic radiograph readings was also towards enlargement. However, in several instances a diminution of the actual distance occurred. It should be noted that panoramic images may be further affected by the technique and equipment used to obtain images. In contrast to the other images, the computerized tomographic radiograph was rarely found to distort its measurements. When distortion did occur, it was of small magnitude (0.5 mm or less) and may be clinically insignificant.

The ramifications of measurement error in implant surgery in the posterior mandible are significant. During presurgical planning, it is essential that the position of the mandibular canal be located in an corono-apical direction. This study shows that the computerized tomogram demonstrates this information accurately. The placement of an implant in close proximity to the inferior alveolar nerve may result in vascular trauma to the inferior alveolar artery neurovascular bundle, with resultant paresthesia of the lip and mentalis muscle area.[2-4] Another advantage of knowing the exact distance from the alveolar ridge to the mandibular canal is the ability to maximize the use of available bone. With minimal distortion of the image, the clinician is able to confidently plan longer implant placement, which may offer a better long-term prognosis than that offered by shorter implants.[5]

The computerized tomogram can also reveal the mandibular canal and its surrounding bone in three dimensions.[3,4,6-12,16] The canal passes through the body of the mandible in a posterior-anterior direction. Yet its position in a buccolingual direction varies with each patient.[6,9] The computerized tomographic radiograph accurately reveals the position of the nerve and its canal along their entire course through the mandible.[4,6,17,18] By using data from this image, the clinician can circumvent the canal on either the buccal or lingual side, if adequate bone exists in these areas.[9,16] The computerized tomogram also provides data on bone density, another prognosticating factor in implant success.[20-22]

The possibility of an image portraying greater bone than actually exists between the alveolar ridge and the mandibular canal is obvious. Since distortion is not predictable, extrapolations cannot be made with certainty. This experiment was performed on a defleshed cadaver mandible with a mandibular canal that was clearly visible with all three radiographic modalities. Thus, image quality may be quite variable from patient to patient. Changes might also be noted depending upon patient positioning, radiographic processing, and among different radiographic technicians.

It should also be noted that this study was performed with a single set of images and that variability may exist when multiple images are obtained. Also, conventional axial tomographic techniques may also provide accurate data regarding bone height, width, and density, as well as position of the mandibular canal, and may be as accurate as computerized tomographic techniques. Conventional tomograms were not used in this study, and additional investigation is needed to evaluate the accuracy of data obtained from such images.

Conclusions

Preoperative planning for dental implants is crucial to their long-term success; radiographic examination is an essential component of the planning process. When considering dental implants in the posterior mandible, the computerized tomogram demonstrates accuracy superior to that of conventional periapical and panoramic radiographs. In addition to imaging the mandible in three dimensions, this study demonstrates accuracy to within 0.5 mm of direct measurements. This accuracy may indicate the selection of a computerized tomographic image over conventional periapical or panoramic images for presurgical planning of implant placement in the posterior mandible.

Michael Sonick

Assistant Clinical Professor of Surgery, Yale University School of Medicine, New Haven, Connecticut; Assistant Clinical Professor of Periodontics, University of Connecticut School of Dental Medicine, Farmington, Connecticut.

James Abrahams

Assistant Professor of Diagnostic Radiology, Section of Neuroradiology, Yale University School of Medicine, New Haven, Connecticut.

Robert A. Faiella

Research Associate, Orthopedic Research Laboratories, Massachusetts General Hospital,

Boston, Massachusetts.

FIGURES

Figure 1a

Fig. 1a Human cadaver mandible is shown with the fabricated acrylic-resin template. A rectangle of gutta percha was embedded into the resin bilaterally so that fixed measurements could be obtained.

Figure 1b

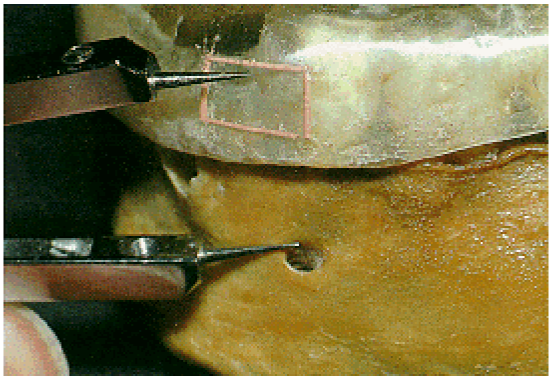

Fig. 1b Magnified view of the template and mental foramen. A caliper was used to perform the measurements both between the gutta percha markers and the mental foramen.

Figure 2

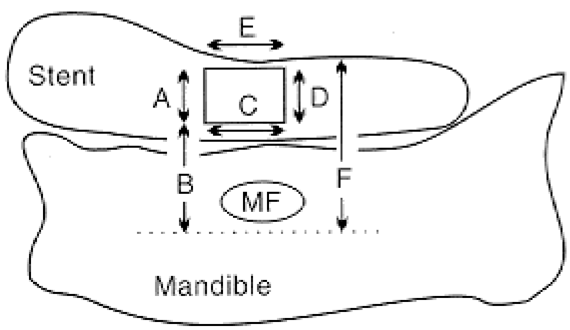

Fig. 2 Diagrammatic illustration of the six measurements taken of the actual cast and the radiographs bilaterally. They are represented as follows: A, vertical length of the mesial aspect of the gutta percha rectangle; B, vertical length from the inferior border of the gutta percha rectangle to the inferior lip of the mental foramen; C, the horizontal length of the inferior aspect of the gutta percha rectangle; D, vertical length of the distal aspect of the gutta percha rectangle; E, horizontal length of the superior aspect of the gutta percha rectangle; and F, vertical length from the superior border of the gutta

percha rectangle to the inferior lip of the mental foramen.

Figure 3

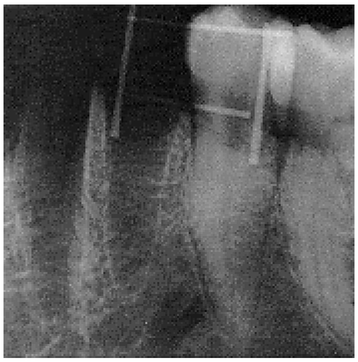

Fig. 3 Periapical radiograph of the gutta percha markers and mandibular teeth. The mental foramen is noted interproximally between the premolar and the extraction site.

Figure 4

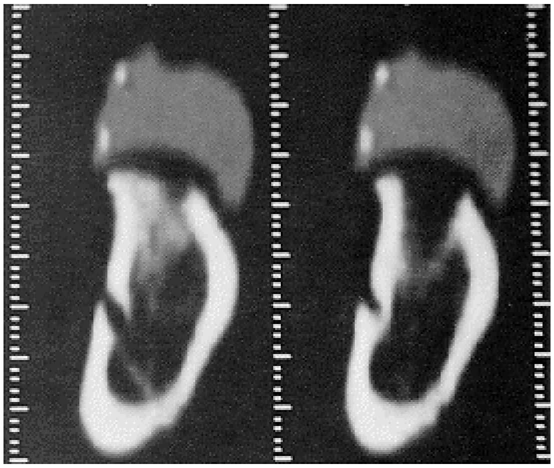

Fig. 4 Computerized tomographic radiograph of two oblique slices through the posterior mandible with the gutta percha embedded acrylic stent in place. A cross-sectional image of the superior and inferior horizontal markers can be seen, as well as the mental foramen. From this one view, it is possible to measure the vertical length from the inferior border of the gutta percha to the inferior lip of the mental foramen (B) and the vertical length from the superior border of the gutta percha to the inferior lip of the mental foramen (F).

TABLES

Table 1

Table 1 Measurement Recorded from Actual Cast and Periapical, Panoramic, and Computerized Tomographic Radiographs

	Actual cast (mm)	Periapical radiograph (mm)	Panoramic radiograph (mm)	Computerized tomographic radiograph (mm)
A	5.5	6.0	6.5	6.0
B	15.5	18.0	20.0	15.5
C	21.0	25.0	27.5	20.5
D	6.0	6.5	7.0	6.0
E	10.0	11.0	9.5	10.0
F	10.0	11.0	9.0	10.0
A'	6.0	7.0	8.0	6.5
B'	16.5	20.5	23.0	16.0
C'	23.0	28.5	30.5	23.0
D'	6.5	7.5	8.0	6.5
E'	10.0	11.0	7.5	10.0
F'	10.0	11.0	8.0	10.0

Table 2

Table 2 Differences Between Actual and Radiographic Measurements of Cast

	PA-Act* (mm)	Pan-Act† (mm)	CT-Act‡ (mm)
A	0.5	1.0	0.5
B	2.5	4.5	0
C	4.0	6.5	(0.5)+
D	0.5	1.0	0
E	1.0	(0.5)+	0
F	1.0	(1.0)+	0
A'	1.0	2.0	0.5
B'	4.0	6.5	(0.5)+
C'	5.5	7.5	0
D'	1.0	1.5	0
E'	1.0	(2.5)+	0
F'	1.0	(2.0)+	0
Total	23.0	36.5	2.0
Average	1.9	3.0	0.2

+ signifies a lesser distance measurement radiographically than measured directly from the mandible and template.
*Difference between actual measurements from cast and periapical radiograph.
†Difference between actual measurements from cast and panoramic radiograph.
‡Difference between actual measurements from cast and computerized tomographic radiograph.

Table 3

Table 3 Percentage Difference of Radiographic Distortion Between Actual and Radiographic Measurements of Cast

	PA-Act (%)	Pan-Act (%)	CT-Act (%)
A	9	18	9
B	16	29	0
C	19	31	2
D	8	16	0
E	10	5	0
F	10	10	0
A'	17	33	8
B'	24	39	3
C'	24	33	0
D'	15	23	0
E'	10	25	0
F'	10	20	0
Total	172	282	22
Average	14	23.5	1.8

A Comparison of the Accuracy of Periapical, Panoramic, and Computeriz

1. Jemt T, Lekholm U, Adell R. Osseointegrated implants in the treatment of partially edentulous patients: a preliminary study on 876 consecutively placed fixtures. Int J Oral Maxillofac Implants 1989;4:211-217.
2. Day R. Microneurosurgery: the diagnosis and management of trigeminal nerve injuries associated with implant therapy. Presented at the Eighth Annual Meeting of Academy of Osseointegration, March 6,1993, San Diego, California:43.
3. Lindh C, Peterson A, Klinge B. Visualization of the mandibular canal by different radiographic techniques. Clin Oral Implant Res 1992;3:90-97.
4. Williams M, Mealey B, Hallmon W. The role of computerized tomography in dental implantology. Int J Oral Maxillofac Implants 1992;7:373-380.
5. Lekholm U. The Brånemark implant technique: A standardized surgical procedure under continuous development. In: Laney WR, Tolman DE (eds). Tissue Integration in Oral, Orthopedic and Maxillofacial

Reconstruction. Chicago: Quintessence, 1992:194-199.

6. Schwarz MS, Rothman SLG, Rhodes ML, Chafetz N. Computerized tomography: Part I. Preoperative assessment of the mandible for endosseous implants surgery. Int J Oral Maxillofac Implants 1987;2:137-141.

7. Rothman SLG, Chafetz N, Rhodes ML, Schwarz MS. CT in the preoperative assessment of the mandible and maxilla for endosseous implant surgery. Radiology 1988;168:171-175.

8. McGivney GP, Haughton V, Strandt JA, et al. A comparison of computer-assisted tomography and data-gathering modalities in prosthodontics. Int J Oral Maxillofac Implants 1986;1:55-68.

9. Schwarz MS, Rothman SLG, Chafetz N, Rhodes ML. Computed tomography in dental implantation surgery. Dent Clin N Am 1989;33:555-597.

10. Wishan MS, Bahat O, Krane M. Computed tomography as an adjunct in dental implant surgery. Int J Periodont Rest Dent .1988;8:30-47.

11. Abrahams JJ, Levine B. Expanded application of DentaScan (multiplanar computerized tomography of the mandible and maxilla). Int J Periodont Rest Dent 1990;10:465-471.

12. Abrahams JJ. CT Assessment of dental implant planning. Oral Maxillofac Surg Clin N Am 1992;4:1-18.

13. Strid K-G. Radiographic results. In: Brånemark P-I, Zarb G, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:187-198.

14. Hobo S, Ichida E, Garcia L. Osseointegration and Occlusal Rehabilitation. Tokyo: Quintessence, 1989:64-65.

15. Klinge B, Petersson A, Maly P. Location of the mandibular canal: Comparison of macroscopic findings, conventional radiography, and computed tomography. Int J Oral Maxillofac Implants 1989;4:327-332.

16. Lindh C, Petersson A. Radiologic examination for location of the mandibular canal: a comparison between panoramic radiography and conventional tomography. Int J Oral Maxillofac Implants 1989;4:249-253.

17. Casselman JW, Quirynen M, Lemahieu SF, Baert AI, Bonte J. Computerized tomography in the determination of the anatomic landmarks in the perspective of endosseous oral implant installation. J Head Neck Pathol 1988;7:255-264.

18. Quirynen M, Lamoral Y, Dekeyser C, Peene P, van Steenberghe D, Bonte J, et al. The CT scan standard reconstruction technique for reliable jaw bone volume determination. Int J Oral Maxillofac Implants 1990;5:384-389.

19. Langer B, Sullivan D. Osseointegration: its impact on the interrelationship of periodontics and restorative dentistry. Part I. Int J Periodont Rest Dent 1989;9:84-105.

20. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone: A 5 year analysis. J Periodontol 1991;62:2-4.

21. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark P-I, Zarb G, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence 1985:202-208.

22. van Steenberghe D. Periodontal aspects of osseointegrated oral implants ad modum Brånemark. Dent Clin North Am 1988;32:355-370.