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Perioperative validation of localisation of the mental foramen

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Aim: To assess the accuracy of panoramic radiography and spiral or computed tomography for the localisation of the mental foramen.
Materials and methods: The distance from the alveolar crest to the mental foramen was measured from panoramic radiographs, spiral tomograms and CT scans. The same distance was measured during implant surgery using a specially designed caliper.
Results: Panoramic radiography showed more deviation (+0.6 mm) from the perioperative measurements than either spiral or computed tomography (+0.4 and −0.3 mm respectively). The difference was significant ($P<0.05$). In general, distances were overestimated on the panoramic radiographs.
Conclusions: Cross-sectional imaging techniques are recommended for the pre-operative planning of implants in the posterior mandible.
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Introduction

In planning of oral implants, information on the quantity and quality of bone available is acquired mainly from the radiographic examination.[1] An important aspect to consider is the localisation of anatomical landmarks in the area of the potential implant since this determines its dimensions and the axes.

Localisation of important anatomical structures is related among other factors to the image quality, in particular the accuracy and precision of the chosen technique. Cross-sectional imaging, such as conventional spiral and computed tomography, have been recommended for the pre-operative planning in numerous reports.[2–12]

Several studies have been reported assessing the accuracy and feasibility of alternative imaging techniques. Measurement errors have been calculated *in vitro*.[2,3,5,7,8,13–22] *In vivo* studies would reflect the clinical situation better, but are far more difficult to realise. The limitation of those studies that have attempted this approach is the lack of objective *in vivo* criteria.[2,6,23–25] Such an approach is only achievable by making the measurements during surgery. To the best of our knowledge this has not yet been attempted. The aim of the present study was therefore to compare radiographic measurements of the distance from the upper border of the alveolar crest to the mental foramen on cross-sectional as well as panoramic images and to compare these with perioperative findings.

Materials and methods

This study was based on eighteen either fully or partially edentulous patients (mean age 54 years, range 38–73; 10 males), who had implants placed in the mandibular premolar region at the Department of Periodontology of the University Hospital of the Catholic University Leuven. The 18 patients had a total of 22 available sites (10 right and 12 left).

Preoperative radiographic planning was carried out using panoramic (PAN) and cross-sectional images (conventional spiral tomography (ST) or computed tomography (CT)). The imaging technique was selected on the basis of the clinical situation (single or multiple sites) and the radiation dose. CT was chosen for cases of full rehabilitation of the lower jaw.[26,27]

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Eighteen patients were examined by PAN allowing measurements of all 22 sites. Eight sites in five patients were examined by ST and eight in seven patients by CT. No radiographic examinations supplementary to the standards were required for this study and all examinations formed a part of a routine clinical protocol. The six remaining patients, who had two implants placed in left canine-premolar region did not require additional radiography since sufficient information was obtained from the clinical examination. Panoramic radiography and spiral tomography were performed using a Cranex TOME® multimodal X-ray machine (Soredex Orion Corporation, Helsinki, Finland). The exposure settings for the panoramic radiography were 70 kV, 6.4–8 mA and 15 s. For tomography, the 'dental tomo' program for the lower jaw was selected and four cuts were obtained at the region of the mental foramen with a 2 mm layer thickness. The exposure parameters were 60–63 kV, 1.3–2 mA and 56 s with aperture number 3. Storage phosphor plates (15 × 30 cm) (Agfa-Gevaert N.V., Mortsel, Belgium) were used for both panoramic radiography and tomography and were read out using an Agfa ADC Solo® system. The images were printed with an Agfa Drystar 2000® dye sublimation printer.

Spiral computed tomography was performed using a Somatom Plus S® scanner (Siemens, Erlangen, Germany). A slice thickness of 1 mm (1 mm/s table feed) was used at 120 kV and 85 mA. The number of axial slices needed depended on the height of the jaw. Data was reformatted using Dental CT® software (Siemens, Erlangen, Germany) and images were printed on Agfa Scopix LT 2B® films with a Matrix LR 3300® printer (Agfa-Gevaert N.V., Mortsel, Belgium). The reformatted cross-sectional slice corresponding the best to the location of the mental foramen was used for measurements.

Radiographic measurements

The distance between the highest point of the upper border of the mental foramen and the alveolar crest was measured parallel to the buccal plate (Figure 1). One observer repeated the measurements twice at an interval of 2 weeks using a sliding caliper made to the nearest 0.5 mm. When measuring from the ST and CT images, the image showing the widest and sharpest cross-section of the mental foramen was selected.

In vivo *measurements*

The surgical procedures varied according to the number of implants and the extent of the edentulous area. Access to the mental foramen was obtained by carefully raising a mucoperiosteal flap. Once the mental foramen was located, the distance to the alveolar crest was measured with an especially designed caliper (Figure 2). The caliper was made using 0.9 mm diameter wires (Dentaurum, Ispringen, Germany) to form a horizontal arm connected to two vertical sliding tubes. The latter were graduated between 7 and 15 mm in 1 mm steps. The horizontal tips were rounded to avoid any damage to the tissues. To measure the distance between the mental foramen and the alveolar crest, the lower end of the caliper was carefully slid downwards under the upper border of the mental foramen (Figure 3). Great care was taken not to push it into the foramen. The upper horizontal arm was then adjusted until it touched the alveolar crest. The vertical part of the caliper was held parallel to the buccal plate.

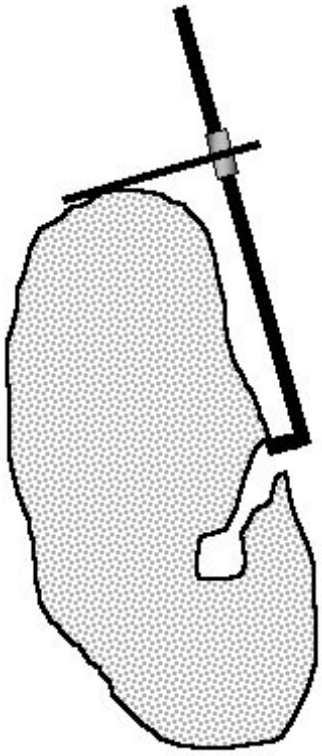

Figure 1 The vertical part of the caliper was oriented parallel to the buccal plate.

The precision of the caliper was first tested on a dry mandible. Test-retest reliability yielded variations in the measurements of less than 1%. All radiographic measurements were repeated twice by the same observer and the mean of both measurements was used for comparison. The perioperative distances, however, were measured only once by the surgeon in order to minimise tissue manipulation.

Data and statistical analysis

The Statistica software 5.1® (StatSoft, Tulsa, OK, USA) package was used for all the analyses. The mean values of the repeated measurements on the panoramic radiographs and the tomograms were corrected for the corresponding magnification factors of 1.3 and 1.5 respectively (as provided by the manufacturer). A *t*-test

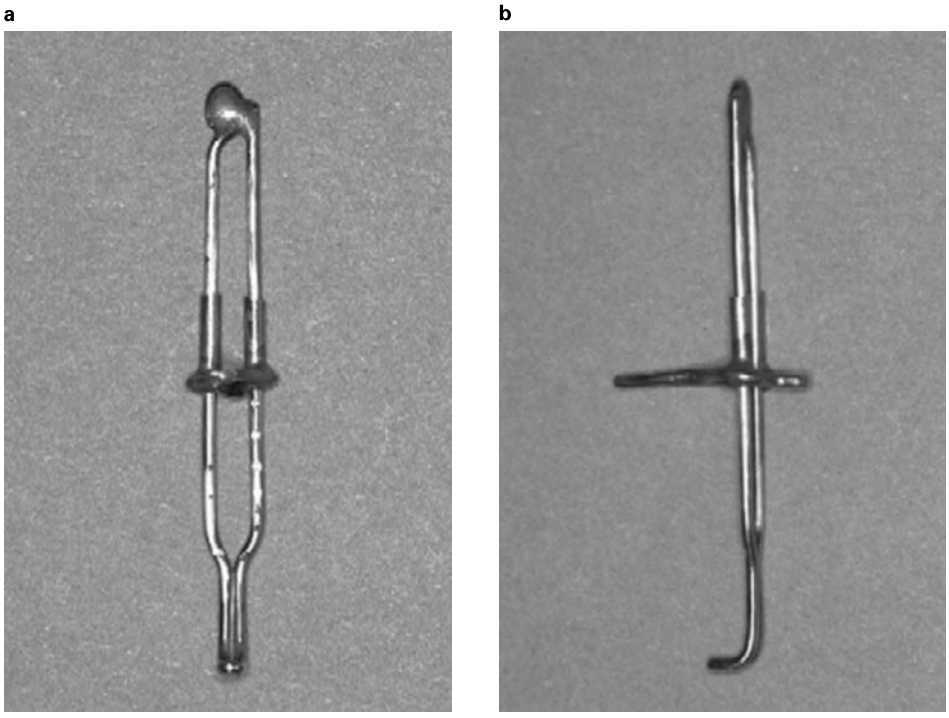

Figure 2 The specially constructed caliper for increasing the distance from the alveolar crest to the mental foramen shown from the front (left) and side (right).

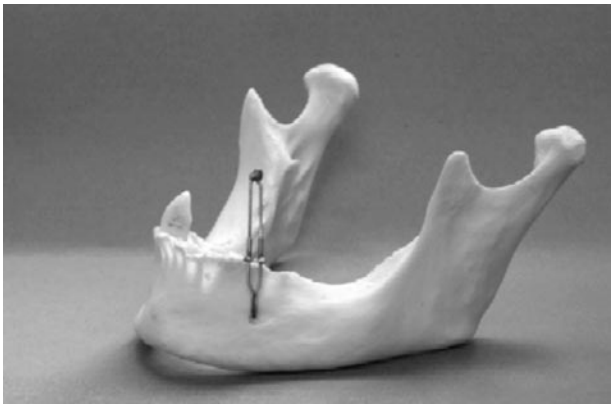

Figure 3 For measurements, the lower tip of the caliper is brought in contact with the upper border of the mental foramen. The horizontal arm of the caliper is moved down to contact the alveolar crest. The distance can then be recorded.

for dependent samples was applied to compare the perioperative measurements with those on panoramic radiographs ($n=22$), tomograms ($n=8$) or CT scans ($n=8$).

The intra-observer reproducibility of the measurements on the radiographs was assessed using the coefficient of variation (CV%) where (CV% = $(S_i/X_{mean}) \times 100$).[27] S_i is the error of the method expressed by the formula $\sqrt{\sum(X_1-X_2)^2/2n}$. X_1 being the first and X_2 the second measurement of the distance to the mandibular canal (MC), the bone height (BH) or the bone width (BW). X_{mean} is the mean value of all the $(X_1+X_2)/2$ and n is the number of observations $(3\times6=18)$.

Results

Table 1 shows results of the radiographic and perioperative measurements. The measurements on the panoramic radiographs were significantly different from both the perioperative measurements and those based on cross-sectional images ($P<0.05$). ST and CT however showed no significant difference from the perioperative measurements. PAN showed, on average an +0.6 mm overestimation of the distances, while ST and CT differed by +0.4 mm and −0.3 mm, respectively. Panoramic radiography (CV% = 3) also showed more intra-observer variation (−2.62 to 1.86 mm) than ST (CV% = 2.5) (−0.97 to 0.10 mm) and CT (CV% = 2.2) (−0.11 to 0.82 mm). All values were less than 4%.

Discussion

To our knowledge, no previous studies have compared the localisation of the mental foramen in particular and anatomical landmarks in general, between radiographs and the patients. *In vivo* measurements are the most appropriate gold standard. In the present study, we achieved this with a specially designed caliper.

Table 1 Results of radiographic (PAN: panoramic; ST: spiral tomography, CT: computed tomography) and surgical measurements (peroperative) at the 22 sites in 18 patients

Measurement (mm)	*n*	*Mean*	*Minimum*	*Maximum*	*SD*
PAN	22	11.5	7	14	2.3
ST	8	10	7.5	14	2.1
CT	8	12	10	14	1.2
Perioperative	22	11	6	14	2.4

Two to six implants are usually placed in the anterior mandible to support either an overdenture or a fixed bridge. For the latter, it is desirable to place the most distal implant as close to the mental foramen as possible[29] to obtain a maximum spreading of the load. In localising the mental foramen, one should keep in mind that the mental foramen is generally located higher than the mandibular canal.[28,29] This can be clearly seen on the cross-sectional images from conventional tomography and CT. In addition, the mandibular canal may have a so-called anterior loop[30,31] or may form a curve during its course mesial to the mental foramen.[28] Such variations can be identified and avoided by carefully observing adjacent cross-sectional slices, mesially and distally to the foramen but may be hard to identify on panoramic images alone.

Panoramic radiography was supplemented in the majority of patients by cross-sectional imaging. The present study showed that this should be a routine indication for implant placement in the posterior mandible, since PAN showed a significant mean overestimation. Although low, such overestimates are potentially dangerous, or on the other hand, CT had a negative mean error. This may be explained by the absence of magnification, which may reduce the error, and also better control of patient positioning by means of the scout view.

These errors with each type of imaging may have a considerable influence on the outcome. Errors may be also related to image quality and the diagnostic ability. Errors in the panoramic measurements may be due to patient positioning and also the ability to locate the foramen. On the other hand, the measurement errors on the ST and CT images may mainly be related to faulty positioning of the patient's head so that the cross-sectional images are not absolutely perpendicular to the lower border of the mandible. In such cases, the distance to the mental foramen would be greater. Another possible source of error is the way measurements are performed. In the present study, we tried to ensure the calipers were parallel to the buccal plate.

The use of only one observer may also have influenced the results. The surgical measurements could only be done once in order to reduce the risk of damage. The radiographic measurements were repeated in order to calculate the intra-observer error.

Cavalcanti and his coworkers[21] have performed a similar study on human cadavers. Using spiral CT, they reported differences of, on average, 0.9 mm. Most values in the literature comparing the accuracy of differing radiographic techniques are derived from locating the mandibular canal. An average difference of 0.9 mm has been reported for CT,[5,8,13,17,21] 1 mm for ST[8,12] and 3 mm for PAN.[17] With spiral CT, this figure falls to 0.6 mm. In general, larger differences have been reported for locating the mandibular canal compared with bone height and width. This can be explained by the fact that the mandibular canal may be more difficult to identify on radiographs, since it is not always corticated.[32,33] The same may apply to locating the mental foramen. In addition, the foramen is located on the edge of the cross-sectional image, which makes it easier to identify. Therefore, it is more appropriate to compare the differences found in the present study to measurements of bone height. Kim and Park[8] reported very similar values in an *in vitro* study, 0.06 mm for ST and 0.07 mm for CT.

In conclusion, cross-sectional imaging proved to be more accurate than panoramic radiography for measuring the distance from the alveolar crest to the mental foramen. Overestimation of the distance on panoramic radiographs may lead to serious complications. Therefore, we recommend the use of cross-sectional imaging for preoperative planning in the posterior mandible.

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References

1. Jacobs R, van Steenberghe D. Radiographic planning and assessment of endosseous oral implants. Berlin: Springer-Verlag, 1998; Chapter 1, pp 7–30.
2. Petrikowski CG, Pharoah MJ, Schmitt A. Presurgical radiographic assessment for implants. *J Prosthet Dent* 1989; **61:** 59–64.
3. 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* 1990a; **5:** 15–22.

4. 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: Clinical application. *Int J Oral Maxillofac Implants* 1990b; **5:** 23 – 29.
5. Quirynen M, Lamoral Y, Dekeyser C, Peene P, van Steenberghe D, Bonte J, Baert A. The CT scan standard reconstruction technique for reliable jaw bone volume determination. *Int J Oral Maxillofac Implants* 1990; **5:** 384 – 389.
6. Gröndahl K, Ekestubbe A, Gröndahl H-G, Johnsson T. Reliability of hypocycloidal tomography for the evaluation of the distance from the alveolar crest to the mandibular canal. *Dentomaxillofac Radiol* 1991; **19:** 200 – 204.
7. Lindh C, Petersson A, Klinge B. Measurements of distances related to the mandibular canal in radiographs. *Clin Oral Impl Res* 1995; **6:** 96 – 103.
8. Kim KD, Park CS. Reliability of spiral tomography for implant site measurement of the mandible compared with DentaScan computed tomography. In: Farman AG, Ruprecht A, Gibbs SJ, Scarfe WC (eds). *Advances in Maxillofacial Imaging*. Amsterdam: Elsevier Science B.V. 1997; pp 119 – 126.
9. Preda L, Di Maggio EM, Dore R, La Fianza A, Solcia M, Schifino MR, Campani R, Preda EG. Use of spiral computed tomography for multiplanar dental reconstruction. *Dentomaxillofac Radiol* 1997; **26:** 327 – 331.
10. Ekestubbe A, Gröndahl K, Gröndahl H-G. Quality of preimplant low-dose tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999; **88:** 738 – 744.
11. Bou Serhal C, Jacobs R, Persoons M, Hermans R, van Steenberghe D. The accuracy of spiral tomography to assess bone quantity for the preoperative planning of implants in the posterior maxilla. *Clin Oral Impl Res* 2000; **11:** 242 – 247.
12. Bou Serhal C, van Steenberghe D, Quirynen M, Jacobs R. Localisation of the mandibular canal using conventional spiral tomography: a human cadaver study. *Clin Oral Impl Res* 2001; **12:** 230 – 236.
13. Casselman JW, Quirynen M, Lemahieu SF, Baert AL, Bonte J. Computed tomography in the determination of anatomical landmarks in the perspective of endosseous oral implant installation. *J Head Neck Pathol* 1988; **7:** 255 – 264.
14. Klinge B, Petersson A, Maly P. Location of the mandibular canal: comparison of macroscopic findings, conventional radiography, and computed tomography. *Int J Oral Maxillofac Impl* 1989; **4:** 327 – 332.
15. Lindh C, Petersson A, Klinge B. Visualisation of the mandibular canal by different radiographic techniques. *Clin Oral Impl Res* 1992; **3:** 90 – 97.
16. Todd AD, Gher ME, Quintero G, Richardson AC. Interpretation of linear tomography and computed tomograms in the assessment of implant recipient sites. *J Periodontol* 1993; **64:** 1243 – 1249.
17. Sonick M, Abrahams J, Faiella R. A comparison of the accuracy of periapical, and computerised tomographic radiographs in locating the mandibular canal. *Int J Oral Maxillofac Impl* 1994; **9:** 455 – 460.
18. Mayfield-Donahoo TL, Stokely EM, Jeffcoat MK. Blur reduction of conventional film-based tomograms for presurgical evaluation of potential mandibular implant sites. *J Periodontol* 1997; **68:** 362 – 368.
19. Butterfield KJ, Dagenais M, Clokie C. Linear tomography's clinical accuracy and validity for presurgical dental implant analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1997; **84:** 203 – 209.
20. Potter B, Shrout M, Russell C, Sharawy M. Implant site assessment using panoramic cross-sectional tomographic imaging. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1997; **84:** 436 – 442.
21. Cavalcanti MG, Yang J, Ruprecht A, Vannier MW. Validation of spiral computed tomography for dental implants. *Dentomaxillofac Radiol* 1998; **27:** 329 – 333.
22. Cavalcanti MG, Yang J, Ruprecht A, Vannier MW. Accurate linear measurements in the anterior maxilla using orthoradially reformated spiral computed tomography. *Dentomaxillofac Radiol* 1999; **28:** 137 – 140.
23. Lindh C, Petersson A. Radiologic examination for location of the mandibular canal: A comparison between panoramic radiography and conventional tomography. *Int J Oral Maxillofac Impl* 1989; **4:** 249 – 253.
24. Ekestubbe A, Gröndahl H-G. Reliability of spiral tomography with the Scanora® technique for dental implant planning. *Clin Oral Impl Res* 1993; **4:** 195 – 202.
25. Kaeppler, G. Localization of the mandibular nerve and the impacted lower third molar on transversal tomograms. In: Farman AG, Ruprecht A, Gibbs SJ, Scarfe WC (eds). *Advances in Maxillofacial Imaging*. Amsterdam: Elsevier Science B.V. 1997; pp 189 – 196.
26. Dula K, Mini R, van der Stelt PF, Buser D. The radiographic assessment of implant patients: decision-making criteria. *Int J Oral Maxillofacl Impl* 2001; **16:** 80 – 89.
27. Bou Serhal C, Jacobs R, Bosmans H, Hermans R, Quirynen M, van Steenberghe D. Absorbed doses from conventional and computed spiral tomography: a phantom vs. cadaver study. *Clin Oral Impl Res* 2001 (In press).
28. Bavitz JB, Harn SD, Hansen CA, Lang M. An anatomical study of mental neurovascular bundle-implant relationships. *Int J Oral Maxillofac Impl* 1993; **8:** 563 – 573.
29. Fishel D, Buchner A, Hershkowith A, Kaffe I. Roentgenologic study of the mental foramen. *Oral Surg Oral Med Oral Pathol* 1976; **41:** 682 – 686.
30. Bolin A, Eliasson S, von Beetzen M, Jansson L. Radiographic evaluation of mandibular posterior implant sites: correlation between panoramic and tomographic determinations. *Clin Oral Impl Res* 1996; **7:** 354 – 359.
31. Arzouman MJ, Otis L, Kipnis V, Levine D. Observations of the anterior loop of the inferior alveolar canal. *Int J Oral Maxillofac Impl* 1993; **8:** 295 – 300.
32. Rosenquist B. Is there an anterior loop of the inferior alveolar nerve? *Int J Periodont Rest Dent* 1996; **16:** 41 – 45.
33. Gowgiel JM. The position and course of the mandibular canal. *J Oral Impl* 1992; **18:** 383 – 385.