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Direct and tomographic dimensional analysis of the inter-radicular distance and thickness of the vestibular cortical bone in the parasymphyseal region of adult human mandibles

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Abstract

We calculated the inter-radicular distances between the canine, and first and second premolars, of human mandibles and the thickness of the cortical bone at adjacent sites using computed tomographic (CT) imaging, and assessed the precision of the dimensional assessment made by CT compared with the same measurement made directly with calipers. We examined 100 adult cadaveric dentate human hemimandibles. At the level at which monocortical screws are inserted to place miniplates according to the current technique used to treat mandibular fractures, points A, B, and C referred to the canine, and first and second premolars, and were marked to calculate the level of the CT slice and as the reference for sectioning of the hemimandible. Our findings showed that there was no significant difference in the inter-radicular distance or in the thickness of cortical bone between the sides of the mandible. The vestibular cortical bone was less than 3.0 mm thick in 91 of the samples. In 98 of the samples the inter-radicular distance between the canine and the first and second premolars was more than 2 mm. There was no significant difference in micrometric precision between the dimensional assessment on CT and direct measurement using a caliper. In the region of the mental foramen the screws have cortical bone less than 3 mm thick in which to be anchored. The inter-radicular distance suggests that there is a minimal risk of radicular injury when miniscrews are inserted between the alveolar structures. CT is a reliable tool for measuring the inter-radicular distance and the thickness of mandibular cortical bone.

Keywords: Morphometry; Mandible; Inter-radicular space; Monocortical screws; Computed tomography

Introduction

Given its dimensions, shape, and location in the human body, the mandible is a bone that is often subject to trauma that can result in fractures. The technique for their treatment that was developed by Michelet[1] and modified by Champy[2–7] comprises the use of malleable, miniature plates placed in strategic anatomical sites on the mandible to counteract functional forces and promote monocortical, subapical, and non-compressive osteosynthesis. Based on the tension band principle the ideal place to put miniplates is adjacent to dental roots and nerve branches, but these are potentially subject to irreversible damage when the miniplates are screwed to the

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mandible. The successful application of miniplates, therefore, relies on knowing the actual thickness of the vestibular layer of cortical bone of the mandible, and how much room there is between adjacent dental alveoli where miniscrews are inserted so that safe anchoring of the miniplate can be achieved without irreversible physiological damage.[5–8]

We have used computed tomographic (CT) analysis and direct measurement with calipers to investigate the thickness of the vestibular cortical bone and the inter-radicular distance in the mental region, which is where System 2.0™ monocortical miniscrews and miniplates are inserted by Champy's technique. This is a contribution to safe, complication-free osteosynthesis of parasymphyseal mandibular fractures, and also to the safety of other procedures. A further aim was to experiment with CT dimensional analysis to improve safety in dental treatments that involve the insertion of miniplates.

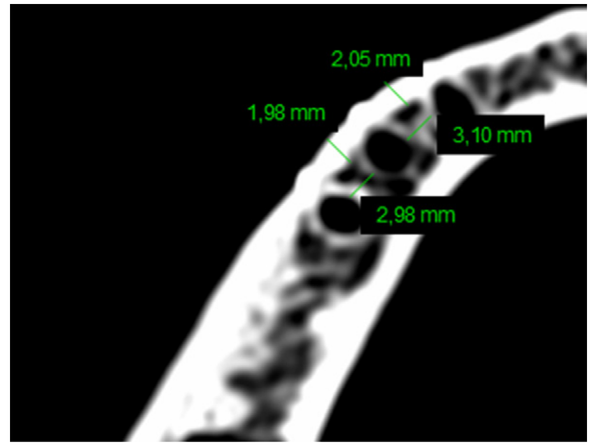

Fig. 1. Axial computed tomogram showing measurements of the inter-radicular distance and thickness of the vestibular cortical bone.

Materials and methods

We examined 102 normal, dry, tooth-bearing hemimandibles from adult cadavers aged 33–87 (mean 53) years old. All aspects of the study were approved by the Institutional Review Board of the State University of Bahia - Brazil.

Initially we located a point (P) 1.25 mm above the median point of the upper margin of the mandibular mental foramen (right side P′ and left side P″). This distance corresponds to half the width of the titanium miniplate System 2.0™, which is used above the mental foramen in the Champy technique to treat a mandibular fracture, and aims to eliminate the tension zones.[3,4] Point P also corresponds to the lowest point at which local bone is normally at its thickest, and drilling would not affect the roots of the teeth.[2–6] The distance of 1.25 mm corresponds to the exact site where the screw is implanted to anchor the miniplate. After point P had been calculated, the mandible was placed on a horizontal acrylic base where, using a reference mechanical arm, the points A′, B′, C′ (right side) and A″, B″, C″ (left side), corresponding to the canine, first, and second premolars, were measured at the same height as P.

At each of the points A, B and C, perforations were made using a high speed dental device (DENTEC™ 405N) and a 1 mm surgical drill. The holes were filled with radiopaque material to provide reference points when we assessed CT slices. Axial tomographic imaging of slices 1 mm thick at the level of point P were obtained using a dual-slice Spirit (SIEMENS™) tomographic scanner. The measurements of the thickness of the vestibular cortical bone and the inter-radicular distance in the mental region were measured on these images using the software UniViewer.exe, version 1.0.0.1™. These measurements, which corresponded to the inter-radicular distance (idtc) and thickness of the interalveolar vestibular cortical bone (tc), and referred to the canine (A), first premolar (B), and second premolar (C), were made bilaterally.

After we had obtained CT images, the hemimandibles were prepared for direct measurements. Using an ultrathin diamond saw blade, a horizontal section through points P, A, B, and C was cut on the hemimandibles followed by 2 additional cross-sections on the lower part of the samples, one adjoining the most proximal flank of the canine and the second adjoining the most distal flank of the second premolar. The measurements of the study variables were, therefore, made on the lower segments of the hemimandibles that contained the apical alveolar structures of the canine and the first and second premolars. All measurements were made twice by the same person with digital micrometer calipers (Model No. 500–144B, Mitutoyo Corp.) sensitive to 0.001 mm.

The thickness of the vestibular layer of cortical bone with both CT imaging (tc) and the direct method (t) was measured at the midpoint between adjacent dental alveoli, and identified as tc1.r and tc1.l, and t1.r and t1.l for the right and left pair canine-first premolar, and tc2.r and tc2.l, and t2.r, t2.l for the right and left pair first-second premolars, respectively. The inter-radicular distance, identified as idtc and id for tc and direct methods, respectively, and as idtc1.r and id1.r, and idtc1.l and id1.l for left and right, was the distance between canine and first premolar on the right and left hemimandible, respectively; idtc2.r and id2.r, and idtc2.l and id2.l indicated the inter-radicular distance between the first and second premolars on the right and left hemimandible, respectively (Fig. 1).

Data were summarised using descriptive statistics. Inferential statistics were not calculated because the sample design was a convenience sample and the SE could not be estimated properly. A cutoff of 2 mm was used for inter-radicular distance and 3 mm for cortical thickness. The proportions above and below those cutoffs were calculated and presented as boxplots. The reliability of the CT was evaluated using Pearson's correlation test and was introduced through the scattergram.

Results

The statistical analysis of data about the thickness of vestibular cortical bone showed no significant differences between

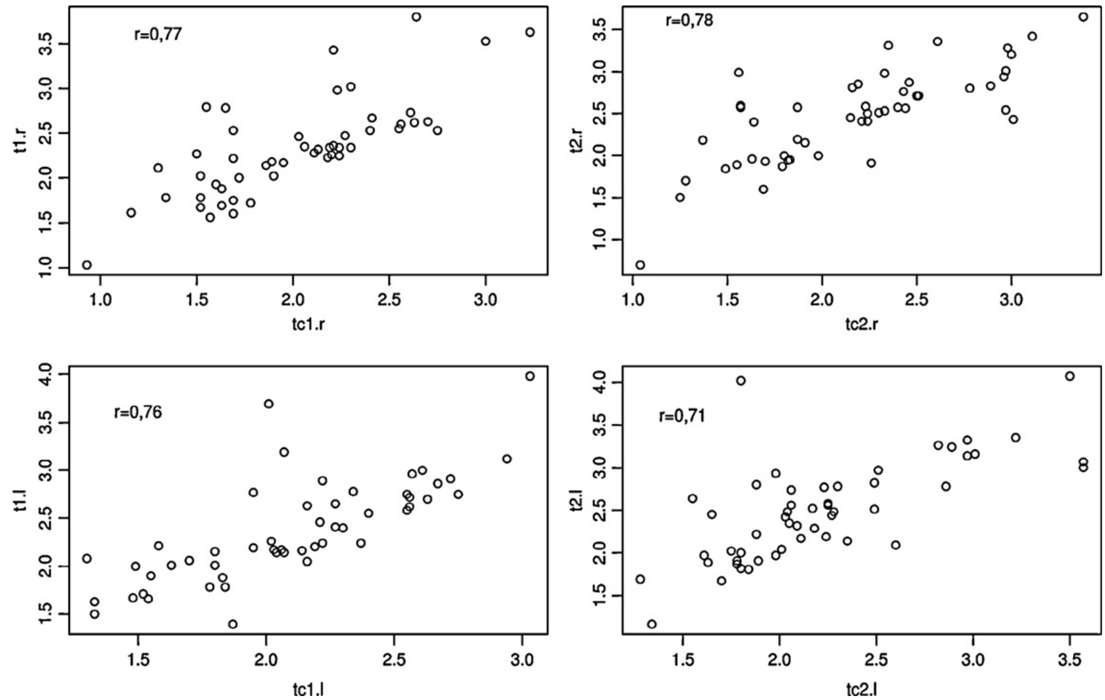

Fig. 2. Mandibular cortical thickness: scattergrams and linear correlation between computed tomography and direct measurement. The thickness of the vestibular layer of cortical bone in computed tomographic (tc) images identified as tc1.r and tc1.l for the right and left pair of canine-first premolars, and tc2.r and tc2.l for the right and left pair of first-second premolars.

CT imaging and direct measurement (Fig. 2). Inter-radicular distances of more than 2.0 mm (screw diameter) were found in 97 and 100 on the right and 93 and 100 on the left between the canine and first premolar. Between the first premolar and second premolar the numbers were 97 and 100 on the right and 100 and 100 on the left side. The mean inter-radicular distances at all study sites and for both methods of measuring were more than 3 mm, which provided a reasonable safety margin in which to insert 2.0 mm screws (Fig. 3).

Similar results were found for the thickness of vestibular cortical bone (Fig. 4). We found that the thicknesses of the vestibular cortical bone were less than 3.0 mm on both CT and direct measurements between the canine and first premolar (98 and 90 of the measurements, respectively, on the right

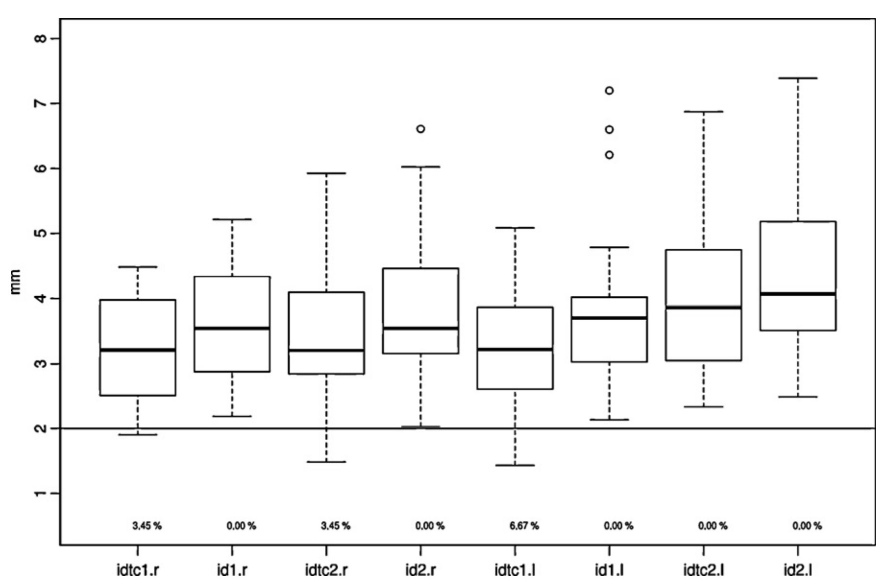

Fig. 3. Box-plot showing inter-radicular distance using computed tomography and direct measurement according to the side. The inter-radicular distance in computed tomographic images is identified as idtc1.r and idtc1.l, between canine and first premolar on the right and left hemimandible, respectively, and as idtc2.r and idtc2.l between the first and second premolars, respectively. The corresponding figures for direct measurement are id1.r, id1.l, id2.r, and id2.l.

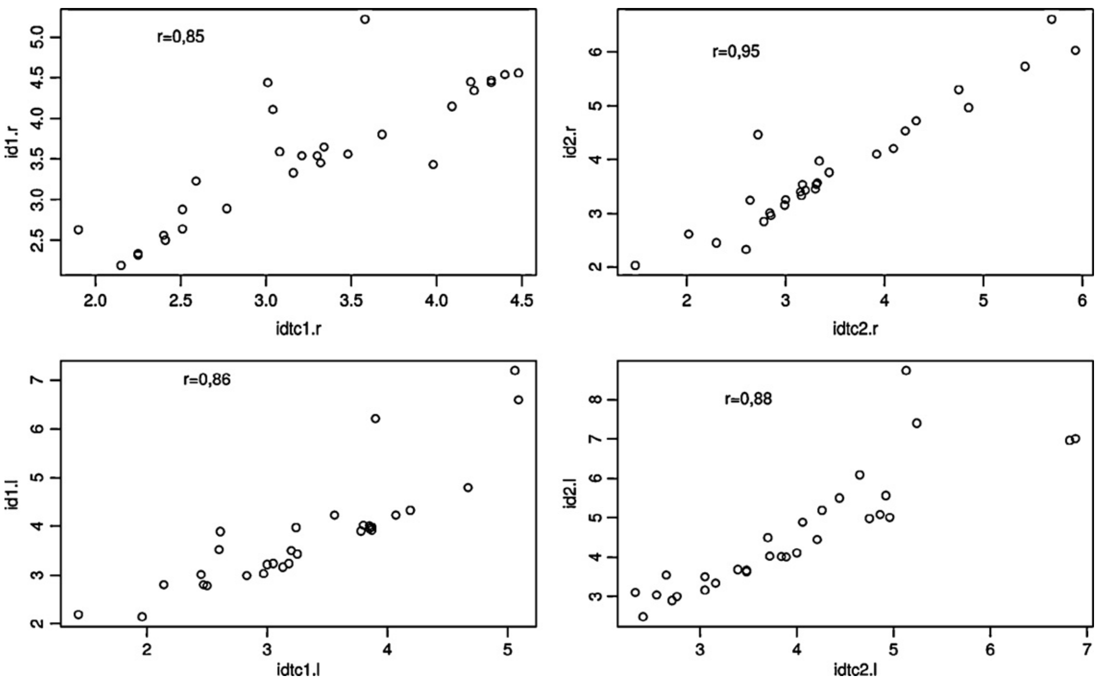

Fig. 4. Inter-radicular distance: scattergrams and linear correlation between computed tomography and direct measurement. The inter-radicular distance in computed tomographic images is identified as idtc1.r and idtc1.l between canine and first premolar on the right and left hemimandible, respectively, and as idtc2.r and idtc2.l between the first and second premolars, respectively.

side and 98 and 92, respectively, on the left side) and between the first and second premolars (94 and 84 of measurements, respectively, on the right side; and 90 and 82, respectively, on the left side) (Fig. 5).

The analysis of the data confirmed that there was no significant variation in either the thickness of cortical bone or inter-radicular distance regardless of the different sites or sides studied.

Discussion

CT imaging is a preoperative assessment tool generally used by surgeons to plan reduction of fractures.[9] We did not examine the significance of dimensional differences between male and female specimens, as previous research work had reported that there were none.[10–13]

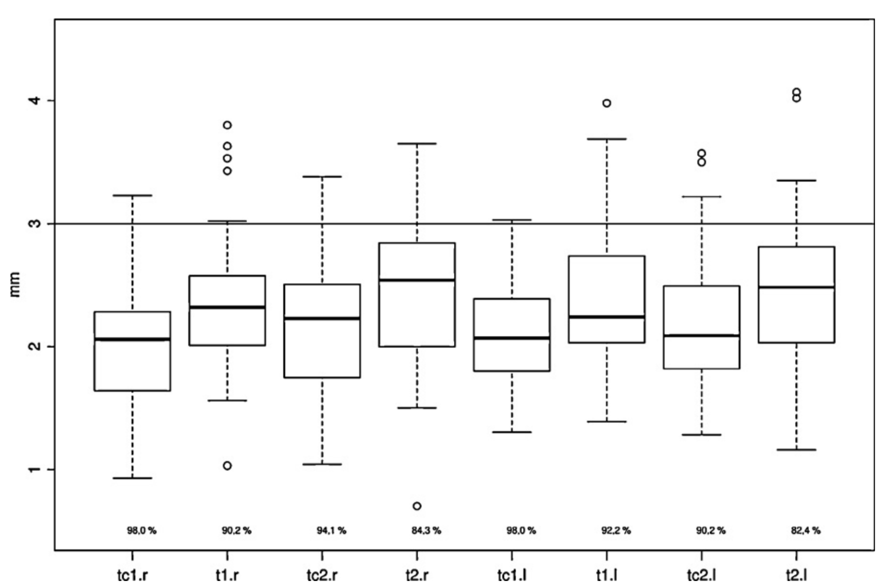

Fig. 5. Box-plot showing mandibular cortical thickness by computed tomography and direct measurement according to the side. Comparison of the thickness of the vestibular layer of cortical bone shown on computed tomographic (tc) images and on direct measurement (t) between the right and left canine-premolars (tc1.l, tc1.r, t1.l, and t1.r) and the right and left first and second premolars (tc2.l, tc2.r, t2.l, and t2.r).

According to protocols, screws 5.0 and 7.0 mm long with a diameter of 2.0 mm are used to anchor plates to stabilise mandibular fractures adequately. Ideally fixation of a fracture should neutralise dispersion forces, but this can lead to misalignment of bony fragments. Normally the recommended site to promote initial osteosynthesis with the application of miniplates involves drilling close to the dental roots and the inferior alveolar and mental nerves. Studies that have reported on the thickness of the subapical vestibular cortical bone are therefore relevant to safe and adequate fixation.[12,14,15]

We assessed the inter-radicular distance at the level of insertion of monocortical screws, 1.25 mm above the mental foramen, a place where fractures are common and where there are major anatomical structures. Because there are roots of teeth at this level, this increases the risk of injury to those roots. However, according to Champy, the miniplates are indicated for dentate patients and should be placed as high as possible yet below the roots of the teeth. In his studies, this site is called "subapical". However, the anchorage of a subapical plate in the area adjacent to the mental foramen can result in injury to the mental and incisive nerves.[5]

Our findings are similar to those of Hu et al.[10] who reported mean distances between the canine and first pre-molar, and between the first and second pre-molars, of 3.9 and 3.7 mm, respectively, at the level of the apex of the tooth, and are also similar to those of Lee et al.,[13] who studied the distances between the roots of adjacent teeth and reported distances of more than 3 mm.

Even though the level of the mandible on which we focused (1.25 mm above the mental foramen, and half the width of the miniplate applied to the upper border of the mental foramen according to standard recommendations) is usually considered to be subapical, alveolar structures of the left and right canines and first and second pre-molars were found at this level in all 51 mandibles (102 hemi-mandibles) studied. Alveolar structures were also found by Fernandes et al.,[16] who studied the same level and region of the mandible. Such findings suggest that special attention should be given to this problem.

To do a mandibular, monocortical, non-compressive osteosynthesis next to the alveolus the surgeon must be aware of the mandibular anatomy, particularly of the thickness of the vestibular cortical bone.[15,17] This bone is strong, particularly where it is wider, in the oblique external line, and in the mental foramen. It is a dense bone and provides stable fixation for miniscrews to anchor miniplates for osteosynthesis.[11,18,19] Miniplate-aided osteosynthesis is the approach most often used to treat mandibular fractures, particularly those of the mandibular body, which are the most common.[12,18–20]

According to Champy et al.[5] the thickness of the vestibular cortical bone in the mandible varies from 3.0 to 3.3 mm, which would allow the application of only 3 complete turns to the miniscrew. They concluded that the vestibular cortex of the mandible is sufficiently solid to resist the tension and shearing forces that are exerted on it through the screws when physiological forces act on the mandible. Fernandes et al.[16] studied the thickness of cortical bone in mandibles at the same sites as we did, and obtained results similar to ours. As the mean reported thickness of vestibular cortical bone was less than that referred to in previously published papers as being the minimum necessary to provide stability for the fixation of screws, our findings indicate the need for further studies to confirm whether the proposed minimum should prevail or whether a smaller value could still provide secure anchorage of miniplates, and therefore be adopted.

When requirements for stability are not met, complications such as dehiscence, infection, malunion of the fragments, and inadequate consolidation of the fracture may result. We have calculated thicknesses at the site of choice for the insertion of miniscrews below the minimum recommended. Supplementary studies are needed not only to promote improvements in the biomechanical characteristics of the material used, but also to improve knowledge of the anatomy of the region where this material will be used, making the technique safer. It is important to minimise the risk of damage to the roots of teeth or to nerves, and the amount of titanium in human tissues.

Finally, although CT measurement showed values slightly higher than those found on direct measurement, it is a reliable way to assess the inter-radicular distance and the thickness of vestibular cortical bone in the mandible.

References

1. Arzouman MJ. Observations of the anterior loop of the inferior alveolar canal. *Int J Oral Maxillofac Implants* 1993;**8**:295–300.
2. Bolourian R, Lazow S, Berger J. Transoral 2.0-mm miniplate fixation of mandibular fractures plus 2 weeks' maxillomandibular fixation: a prospective study. *J Oral Maxillofac Surg* 2002;**60**:167–70.
3. Champy M, Lodde JP, Jaeger JH, Wilk A. Biomechanical basis of mandibular osteosynthesis according to the F X Michelet method. *Rev Stomatol Chir Maxillofac* 1976;**13**:248–51 (in French).
4. Champy M, Lodde JP, Jaeger JH, Wilk A, Gerber JC. Mandibular osteosynthesis according to the Michelet technique. Justification of a new material. Results. *Rev Stomatol Chir Maxillofac* 1976;**76**:252–5 (in French).
5. Champy M, Lodde JP, Schmitt P, Jaeger JH, Muster D. Mandibular osteosynthesis by miniature screwed plates via a bucal approach. *J Maxillofac Surg* 1978;**6**:14–21.
6. Champy M, Pape HD, Gerlach KL, Lodde JP. Mandibular fracture. The Strasbourg miniplate osteosynthesis. In: Kruger E, Schilli W, editors. *Oral and maxillofacial traumatology*. Chicago: Quintessence; 1986. p. 19–43.
7. Champy M. Microplates in maxillofacial surgery. *Rev Prat* 1992;**42**:321–3 (in French).
8. Davies BW, Cederna JP, Guyuron B. Noncompression unicortical miniplate osteosynthesis of mandibular fractures. *Ann Plast Surg* 1992;**28**:414–9.
9. Yang J, Cavalcanti MG, Ruprecht A, Vannier MW. 2-D and 3-D reconstructions of spiral computed tomography in localization of the inferior alveolar canal for dental implants. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999;**87**:369–74.
10. Hu KS, Kang MK, Kim TW, Kim KH, Kim HJ. Relationships between dental roots and surrounding tissues for orthodontic miniscrew installation. *Angle Orthod* 2009;**79**:37–45.

11. Jackson IT, Somers PC, Kjar JG. The use of Champy miniplates for osteosynthesis in craniofacial deformities. *Plastic Reconstr Surg* 1986;**77**:729–36.
12. 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**:327–32.
13. Lee KJ, Joo E, Kim KD, Lee JS, Park YC, Yu HS. Computed tomographic analysis of tooth-bearing alveolar bone for orthodontic miniscrew placement. *Am J Orthod Orthop* 2009;**135**:486–94.
14. Heidemann W, Gerlach KL. Clinical applications of drill free screws in maxillofacial surgery. *J Craniomaxillofac Surg* 1999;**27**:252–5.
15. Saka B. Mechanical and biomechanical measurements of five currently available osteosynthesis systems of self-tapping screws. *Br J Maxillofac Surg* 2000;**38**:70–5.
16. Fernandes AC, Rossi MA, Schaffner IS, Machado LA, Sampaio AA. Lateral cortical bone thickness of human mandibles in region of mental foramen. *J Oral Maxillofac Surg* 2010;**68**:2980–5.
17. Worthington P, Champy M. Monocortical miniplate osteosynthesis. *Otolaryngol Clin North Am* 1987;**20**:607–20.
18. Mardinger O, Chaushu G, Arensburg B, Taicher S, Kaffe I. Anterior loop for the mental canal: an anatomical–radiologic study. *Implant Dent* 2000;**9**:120–5.
19. Renton TF, Wiesenfeld D. Mandibular fracture osteosynthesis: a comparison of three techniques. *Br J Oral Maxillofac Surg* 1996;**34**: 166–73.
20. Rosenquist B. Is there an anterior loop of the inferior alveolar nerve? *Int J Periodontics Restorative Dent* 1996;**16**:40–5.