Assessment of the anterior loop of the inferior alveolar nerve using reformatted computed tomography imaging: a retrospective cohort study

Vladimir S. Todorovic [1, 2], DDS, MSc, PhD

Thomas C. Postma [3], BChD, MChD, PhD

Andre W. van Zyl [4], BChD, MChD

[1]ITI Scholar, National Research Foundation Assistant, Department of Periodontics and Oral Medicine, School of Dentistry, University of Pretoria, South Africa

[2]Research Associate, School of Dental Medicine, University of Belgrade, Serbia

[3]Senior Lecturer, Department of Dental Management Sciences, School of Dentistry, University of Pretoria, South Africa

[4]Professor, Head of the Department of Periodontics and Oral Medicine, School of Dentistry, University of Pretoria, South Africa

Corresponding Author: Vladimir S. Todorovic,

Department of Periodontics and Oral Medicine,

School of Dentistry, University of Pretoria

PO Box 1266, Pretoria 0001, South Africa

Tel.: +27 123 192 336

Fax: +27 123 263 375

E-mail: todent@yahoo.com

ABSTRACT

Purpose: The anterior loop of the inferior alveolar nerve (IAN) is an important landmark to consider during dental implant surgery in the anterior mandible. The purpose of this study was to determine the prevalence and length of IAN loops using reformatted computed-tomography (CT) scans.

Materials and Methods: CT scans of 188 consecutive patients, complying with inclusion criteria, were reformatted using specialized software. The prevalence and length of IAN loops were assessed for dentate subjects.

Results: Eighty four per cent of cases had at least one anterior loop present; 59% of cases had bilateral loops. The mean length of the loops in third quadrant (Q3) was 1.4 mm (SD: 0.7; 95% CI: 1.3-1.6; Minimum: 0.3; Maximum: 4.0). The mean length of the loops in fourth quadrant (Q4) was 1.5 mm (SD: 0.9; 95% CI: 1.4-1.6; Minimum: 0.3; Maximum: 5.5). In total 21% of cases had loops greater than 2 mm, in both the Q3 and Q4.

Conclusions: CT images, reformatted with specialized software may be a useful to identify IAN loops, especially in settings where recent CBCT devices are not freely available. The prevalence of IAN loops is high while the length of the loop remains variable, requiring meticulous individual assessment prior to implant placement.

Key words: Anterior loop; Mandibular nerve; Multi-slice computed tomography; Dental implant surgery

INTRODUCTION

The placement of endosseous dental implants to replace lost teeth has become an extremely predictable treatment modality, with success rates in excess of 95%. [1] Dental implant placement has become the standard of care for tooth loss in the anterior mandible (inter-foraminal area) [2] and it is generally regarded as a safe procedure. [3] However, there are anatomical risks in the anterior mandible that should be considered, such as the possible damage to the anterior loop of the inferior alveolar nerve (IAN) just before it emerges through the mental foramen. [4]

The terminal portion of the IAN may pass forward of the anterior rim of the mental foramen, before curving back to exit the mental foramen as the mental nerve. The portion of IAN anterior to the mental foramen is termed the anterior loop of the IAN. [5] In the treatment of the edentulous mandible, a full arch implant-supported restoration involving 4 to 5 implants in the inter-foraminal area is a viable option. The implant closest to the mental foramen is the key factor for increasing the anterior-posterior spread and reducing distal cantilever. [6] When preparing this most distal site, the drill may come into contact with the anterior loop of the inferior alveolar nerve and result in iatrogenic damage to the nerve. This may present as anaesthesia, paraesthesia, dysthesia or even overt pain in the area innervated by the mental nerve. [4] The mental nerve supplies sensation to the labio-mental area and the gingiva from midline up to the mandibular second premolar. [7] Altered sensation in this region may impede the ability to perform routine activities such as eating, speaking, kissing, shaving, applying make-up and even tooth brushing. [4] In order to avoid such devastating consequences it is essential that adequate pre-operative planning be done. It also requires a sound knowledge of the anatomy of this area. [8]

Reported data on the prevalence of the anterior loop and its length varies amongst different studies. [3, 5, 7, 9, 10] Methods to investigate the anterior loop consisted of panoramic radiography, dissected cadavers, computed tomography (CT) scans and cone beam computed tomography (CBCT) scans. In order to avoid iatrogenic injury to the mental nerve during the implant installation, clinicians have advocated safety margins of 1-6 mm from the mental foramen. [5, 11-14] It is clear from previous studies with differetnt methodologies used to assess the anterior loop that there is still no consensus regarding the dimensions of the anterior loop. [3, 10, 11, 15, 16, 17] Therefore, the intention of this study was to use the accurate modality of multi-slice CT`s, reformatted with specialized software, to improve the accuracy of assessing this important anatomical landmark. If multi-slice CT`s, reformatted with specialized software could render similar results as CBCT it could validate CBCT in this setting.

The objectives of the present study were therefore to:

- Determine the prevalence and dimensions of the anterior IAN loops in a South African population by means of reformatted multi-slice CT`s.
- To make clinical recommendations regarding dental implant surgery involving the anterior mandible.

MATERIAL AND METHODS

Study approval (Ethics Reference No. 341/2013) was obtained by the Ethics Committee of the Faculty of Health Sciences, University of Pretoria. The sample population consisted of 200 consecutive patients, sent for multi-slice CT examination due to different reasons (this was performed before CBCT became freely available in South Africa) for the period 2008 to 2010.

For a scan to be included in this study, the mandible had to be included in the volume with all teeth present up to the second premolar in the arch. Exclusion criteria included cases with radiographic signs of pathology, trauma or surgery in the mandible, a history of systemic disease, and absent teeth in the premolar area.

All CT scans were performed by the same radiologist using the same 64-slice CT unit (Brilliance CT, Philips, Netherlands). The protocol employed by the radiologist was identical for all patients. The CT unit was set to take 1 mm slice thickness with 0.5 mm overlap. The kV was standardised at 120, collimation 64 x 0.624, pitch 0.579, rotation time 0.5 s, filter set on "detail" and window set to C:200 and W:2000. The average radiation dosage per scan was between 300 to 400 microSV. CT scans were reformatted by preparing industry-standard DICOM datasets on the CT scanner and importing it into Simplant Master Software (Dentsply, USA). Surface rendering with realistic shading was applied to generate three-dimensional (3-D) views of the mandibular structures. In all cases, bone reconstruction algorithms and slice thicknesses of 0.5 mm and slice increments of 0.5 mm or less were used. All datasets were prepared by a reformatting center. Although measurements on the 3-D image are possible, all measurements were done using two-dimensional (2-D) images, as 3-D images are influenced by various software settings, such as triangle reduction and smoothing factors.

All measurements were initially performed by one observer, the senior resident at the Department of Periodontics and Oral Medicine. In order to ensure reproducibility, an independent examiner (the first author) re-examined 20 randomly selected scans, without having access to any of the previous markings or measurements.

Measurements

Using the software the Alpha-plane was placed to align with the anterior-most aspect of the mental foramen. The anterior-most aspect of the mental foramen was first identified using the 3-D window in full screen mode for increased accuracy. Once the plane had been drawn, this was verified on the axial view for correctness (see Figure 1a).

The Beta-plane was drawn parallel to the Alpha-plane and touching the anterior most aspect of the loop of the IAN. To determine where the anterior-most aspect of the anterior loop was, all the available views were utilised by scrolling through the reconstructions. Once satisfied that the anterior-most aspect of the anterior loop had been identified, the Beta-plane was confirmed. The distance between the Alpha- and Beta-planes constituted the length of the loop (see Figure 1b). If anterior to the Alpha-plane a loop could not be identified, those cases were considered as with no loop existing.

Statistical analysis

The statistical analysis was conducted with Statistical Package for Social Sciences (SPSS for Windows, version 24.0; SPSS Inc., Chicago, IL, USA).

Inter-examiner agreement

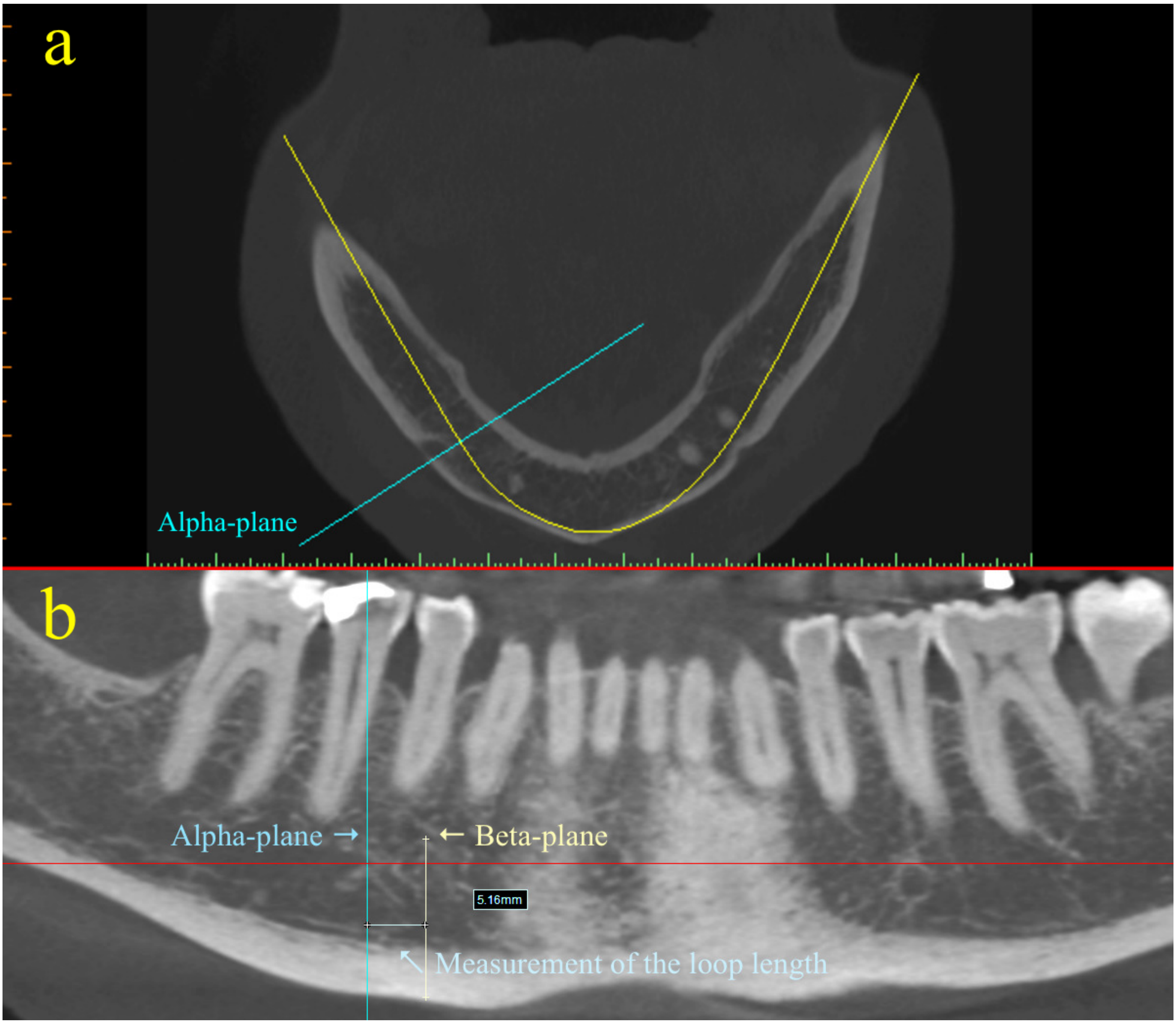
The level of inter-observer agreement was calculated with the interclass correlation (ICC) test, using a two-way random absolute agreement model.

Prevalence of the IAN loop

The prevalence of the IAN loop was calculated per case for the total sample, as well as for males and females, using the following criteria:

- IAN loop present in either quadrant three (Q3) or quadrant four (Q4) of the mouth;
- IAN loop present bilaterally (in both Q3 and Q4);

Figure 1. Verification of the Alpha-plane on the axial view (a); Alpha-plane, Beta-plane and measurement of the anterior loop length (b)



- IAN loop present unilaterally in Q3 and Q4, respectively.

A Pearson Chi^2 test was used to examine the difference in the prevalence of the IAN loop between males and females.

Length of the IAN loop

The mean length and measurement range of the IAN loops was descriptively analysed and compared between males and females, using the independent samples T-test.

The mean length of the IAN loop in Q3 and Q4 was compared with a dependent samples paired t-test accounting for the non-prevalent loops as being 0 mm in length. Initial testing of the correlation between age and length of the loop through scatter plots (r^2=0.05) did not reveal any correlation whatsoever, and “age” as a variable was hence excluded from any further comparisons.

RESULTS

Characteristics of the sample

Eventually, 188 of the 200 cases complied with the inclusion criteria. Twelve cases were excluded due to edentulism in the premolar area. Seventy subjects (37.2%) were male while 118 (62.8%) were female, aged from 15 to 87 years (Mean: 51.19; Standard Deviation (SD): 12.30). The racial mix was not recorded according to the obtained Ethics approval.

Inter-rater agreement

The ICC test indicated a high degree of agreement (ICC=0.94 (95% CI: 86-98%) between the measurements taken by the two independent raters. The difference in measurements ranged between 0.0 mm and 0.6 mm in Q3 and between 0.0 mm and 0.7 mm in Q4. With a high level of agreement expected, the sample size of 10% for the ICC test was deemed adequate based on calculations. [18]

Prevalence of anterior loops

IAN loops were prevalent in either Q3 or Q4 in 84.0 % (n=158) of cases (Table 1). Males had 92.9 % IAN loops present in either Q3 or Q4 in comparison to the 78.8% for females. This difference was statistically significant (Chi^2: $P<0.05$).

Table 1. Prevalence of the IAN loop

	Total sample n (%)	Female n (%)	Male n (%)
IAN loop present in either Q3 and Q4			
Not prevalent	30 (16.0)	25 (21.2)*	5 (7.1%)*
Prevalent	158 (84.0)	93 (78.8)*	65 (92.9)*
IAN loop present in both Q3 and Q4 (bilateral)			
Not prevalent	77 (41.0)	56 (47.5)*	21 (30.0)*
Prevalent	111 (59.0)	62 (52.5)*	49 (70.0)*

*Chi^2: $P<0.05$

IAN loops were prevalent bilaterally in 111 (59.0%) of cases in the total sample. IAN loops occurred bilaterally in 70.0 % of males and 52.5 % of females. Again the gender difference was statistically significant (Chi^2: $P<0.05$) (Table 1).

Only 19 (10.1 %) and 27 (14.4 %) IAN loops occurred unilaterally in Q3 and Q4, respectively. Thirteen of the unilateral loops in Q3 occurred in females and 6 in males while 18 of the unilateral loops in Q4 occurred in females and 9 in males.

Length of the IAN loops

The descriptive statistics for the length of the IAN loops are displayed in Table 2. The mean length of the IAN loops present in Q3 was 1.4 mm (SD: 0.7) while the mean length of the IAN loop present in Q4 was 1.5 mm (SD: 0.7). No statistical difference could be detected (using a dependent samples paired t-test) between length of the IAN loop in Q3 and Q4.

The percentage distribution of the IAN loops is displayed in Figure 2. The shortest loop in Q3 was 0.3 mm and the longest 4.0 mm, while the shortest loop in Q4 was 0.3 mm and the longest 5.5 mm (Table 2 and Figure 2). The highest number of loops was slightly shorter than 1 mm in Q3 and slightly longer than 1 mm in Q4 (Figure 2). The length of the loop only differed significantly for Q3 with males having a slightly longer loop (independent samples T-Test: $P<0.05$) (Table 2).

DISCUSSION

This study examined the prevalence and length of the IAN loop in a South African population using multi-slice CT images, reformatted with specialized software to improve image quality.

Prevalence

The current study's finding of a prevalence of 84.0% IAN loops is very similar to one recent CT study, which accounted for an 83.1% prevalence [16] and two other recent CBCT studies that, respectively, estimated the prevalence at 84.0% [3] and 85.2%. [17] It therefore appears as if the use of more sophisticated technologies such as multi-slice CT (with or without special reformatting) and CBCT are now increasingly being able to identify the presence of IAN in a fairly consistent way.

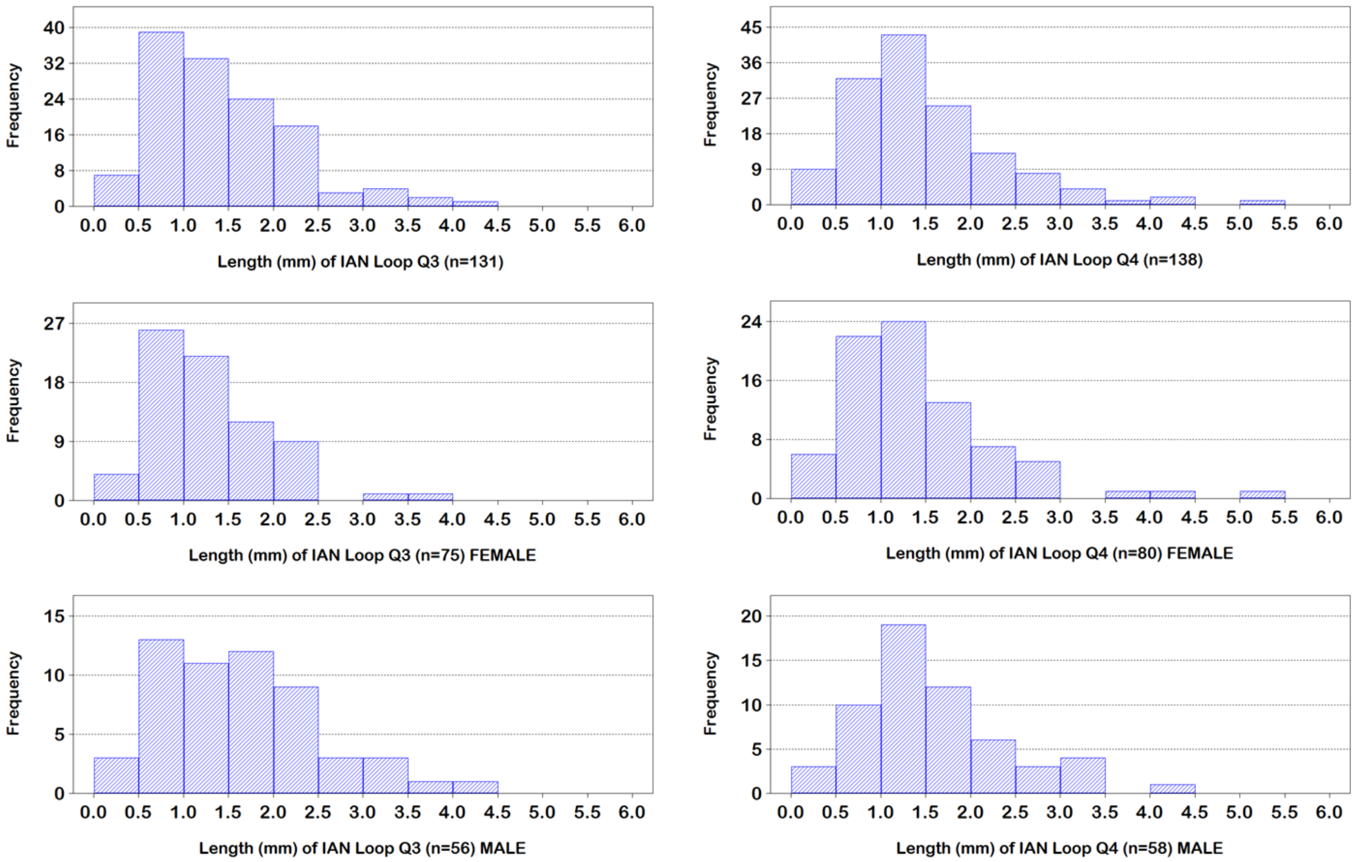
The combined results of the above-mentioned studies [3, 16, 17] suggest a very high prevalence of IAN loops. The current study showed that the prevalence of the IAN

Table 2. Length of present IAN loops

	Total sample		Males		Females	
	Q3 (n=131) (mm)	Q4 (n=138) (mm)	Q3 (n=56) (mm)	Q4 (n=58) (mm)	Q3 (n=75) (mm)	Q4 (n=80) (mm)
Mean	1.4	1.5	1.6	1.6*	1.3	1.4*
Stand Dev	0.7	0.9	0.8	0.8	0.6	0.9
Minimum	0.3	0.3	0.4	0.4	0.3	0.3
Maximum	4.0	5.5	4.0	4.4	3.6	5.5

*Independent samples T-Test: $P<0.05$

Figure 2: Frequency distribution of the length of present IAN loops (mm)



loop was as high as 92.9 % in males and that the loop occurred bilaterally in 70 % of male cases. Although the numbers for females were significantly (Chi^2: $P<0.05$) lower in the current study it could still be regarded as high at a prevalence rate of 78.8 %. The gender differences found in the current study is in contrary to other studies [5, 9, 14, 17, 19] where no significant difference was reported between males and females in terms of prevalence of the IAN loop.

Having established that the prevalence of the IAN loops is high it could be argued that the risk of traumatic injury should rather be estimated based on the length of IAN loops for each individual case.

Length of the IAN loop

The mean length of the anterior loop varies considerably in the literature from 0.1 mm [11] to 6.9 mm. [20] In our view these differences might be due to a substantially different methodology used to measure the length of the loop, using cadaver dissection and different diagnostic imaging techniques.

The mean length of loops that were present in our study was 1.4 in Q3 and 1.5 mm in Q4, while the longest loop measured was 5.5 mm. A recent CT study by Li et al. [16] showed a slightly longer mean loop length of 2.09 mm, ranging from 0 to 5.31 mm. A recent CBCT study showed a mean IAN loop length of 1.16 mm, ranging up to 5.6 mm [21] while another study showed a mean loop length of 1.9 mm ranging from 0 to 9.00 mm [19]. The longest loop in the literature of 11.0 mm was reported by Neiva et al. [22]

Several studies showed that the loop in Q4 might be longer [5, 23-25] than in Q3. In contrast to these studies Uchida et al. did not support this hypothesis of a side-specific dominance of the loop, [9, 19] which is in accordance with the results in our study. Although the current study found statistically significant differences in the length of the IAN loop between males and females (T-test: $P<0.05$) in Q3 these findings may not be of clinical relevance, as the mean difference in IAN loop length was only 0.2 mm. However, using CBCT, Uchida et al showed a 0.7 mm mean difference between males and females. [19]

If the length of the loop is used to establish risk then it is clear that the length of the loop is unpredictable and variable in its range. This supports previous suggestions [21] that no "safe zone" can be recommended anterior of the mental foramen. This in turn implies that all cases must be subjected to proper diagnostic scrutiny to accurately determine locations where implant can be placed without causing harm to the IAN.

CONCLUSIONS

CT images, reformatted with specialized software may be a useful tool to identify the IAN loop that poses a risk to implant surgery. This may be particularly relevant in situations where modern CBCT scanners are not freely available.

The prevalence of IAN loops are very high and the length of the IAN is variable corroborating previous suggestions that no “safe zone” exists and that each individual case should be meticulously assessed for prevalent IAN loops before implant placement.

ACKNOWLEDGEMENTS

Authors would like to express their gratitude to Nickie Schroeder and Stephanie Burgess for assistance with Simplant software, as well as to Anthony Reynolds BA, MSc, PhD, for assistance with scanning protocol.

CONFLICT OF INTEREST: None.

ETHICS APPROVAL: Study approval (No. 341/2013) was obtained by the Ethics Committee of the Faculty of Health Sciences, University of Pretoria.

PATIENT PERMISSION/CONSENT: Not applicable.

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