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Original Article

Risks of angled implant placement on posterior mandible buccal/lingual plated perforation: A virtual immediate implant placement study using CBCT

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Complication;
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Abstract *Background/purpose:* Immediate implant placement has been considered to be a successful treatment procedure. The bone plate perforation (BPP) may be one of severe complication and potentially life-threatening situation. The aim of this virtual study is to evaluate the influences of angled implant insertion on BPP during immediate implant installation in the posterior mandible.
Materials and methods: Cone beam computed tomography images of 488 posterior teeth from 61 patients were selected. Virtual immediate implant placement (VIIP) was performed at each posterior tooth following the appropriate axis with the prosthetic-driven planning and different deviation angles of 3-, 6-, or 9-degree. BPP was then examined from cross-sectional images obtained. Furthermore, the relation of lingual bony morphology and BPP were also determined.
Results: The incidence of buccal and lingual BPP increased as the deviation angle increased in posterior mandible area. Incidence of lingual BPP was significantly influenced by angular deviation and type of lingual bony morphology after adjusting for age, gender, tooth type, and right/left side. An increase in incidence odds of over 6-fold (OR = 6.583) was noted for

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placements angled by 9° compared with placements made without angulation, and an increase in incidence odds of over 3-fold (OR = 3.622) was noted for teeth with the undercut-type lingual morphology compared with the other types.
Conclusion: The present Results indicate that accurate selection of the implant insertion angle and full awareness of the bony anatomy at the implant recipient site are essential to prevent BPP in the posterior mandible.

Introduction

Immediate implant placement into fresh extraction sockets has been documented to be a predictable treatment modality, particularly in regions such as the posterior mandible teeth where aesthetics is not a primary concern.[1,2] Under proper pre-surgical planning, immediate implants have given several promising Results on clinical benefits, including shorter treatment time along with reduced surgical intervention,[1,2] preservation of soft tissue,[2,3] conservation of bony structures,[4] and ensuring higher patient comfort and satisfaction.[1,2] However, certain complications or unusual sequelae may still occur during dental implantation.[5–13] In the posterior mandible region, several studies have present that implant placement beyond the alveolar housing may result in bone plate perforation (BPP).[9–13] Besides, the BPP may further lead to post-surgical infection, ultimate loss of the implant,[8] severe hemorrhages of the floor of the mouth and even life-threatening events.[14]

Ideal implant position and angulation is a crucial determinant of esthetic and functional success, and that can be achieved by proper case selection, use of surgical guides, adequate site preparation, prosthetic-driven design, and appropriate surgical experience.[15–19] However, despite the use of drilling supports and precise preparation techniques, an aberration from the planned ideal implant axis can frequently be seen after implant placement. According to a meta-analytic review,[16] the average angular deviation of an implant during implantation is 3.89° when a computer-assisted surgical guide is used; in this case, mean angular deviations ranging from 1.49 to 8.54° may be observed from the accepted clinical studies. Molars as implant recipient sites also show greater deviations of implant angle than incisors or premolars.[20] In addition, the study further demonstrated that implantation in the mandible is more likely to develop axial deviation than implantation in the maxilla.[20] Therefore, the deviation of dental implantation in the posterior mandibular region needs to be carefully studied to prevent BPP.

In addition, the lingual alveolar bone morphology of the mandible has been carefully examined.[10,11,15] The cross-sectional information of mandible has been recognized as part of diagnosis and pre-surgical planning as it provides anatomical information ensuring optimal alignment of immediate implants. Three types of alveolar ridges, including the undercut- (U), convergent- (C), and parallel- (P) type ridge, have been classified and assessed according to the cross-sectional morphology in CBCT images.[21] The predicted incidence of lingual BBP was more frequently occurred in sites with U-type ridge.[11] Although the information concerning immediate implant placement and the significance of the lingual concavity in posterior mandible regions. However, limited information is available on the potential impact of BPP if the implant is placed with the buccal or lingual direction. The present study aims to evaluate the influence of angled implant insertion on BPP using virtual immediate implant placement (VIIP) with cone beam computed tomography (CBCT) of posterior mandibular premolars and molars and to determine whether the presence of lingual concavity is related to a higher risk of BPP.

Materials and methods

Patient pool and imaging system

This study received institutional review board approval from the Buddhist Tzu Chi general hospital (04-XD35-102). The CBCT images used in this work were taken from patients with dental implant needs at the dental department of Taipei Tzu-Chi General Hospital from July 2007 to September 2012. The CBCT images used in this study were obtained from a clinically available imaging system (i-CAT Next Generation®, Imaging Sciences International, Hatfield, PA, USA). The scan parameters were: gantry rotation time of 7.0 s, tube voltage of 120 kV, and the tube current of 35 mA. At voxel size of 0.25 mm, a slice interval of 0.25 mm, and a slice thickness of 0.25 mm were obtained from the apex of the mandibular symphysis to the mandibular condyle. Following CBCT scanning, images were viewed independently and saved to DICOM files using i-CATVision software (Imaging Sciences International, Hatfield, PA, USA).

Images selected for this study had to fulfill the following inclusion criteria (1) all posterior mandibular teeth, except third molars, with the complete eruption and proper alignment (no crowding or ectopic eruption) and (2) the presence of opposing maxillary teeth to provide information for implant location and angulation. (3) Each tooth had to have fully formed apexes. (4) Each tooth had to be normally positioned. The imaginary line connecting the cusp tip of canines, central grooves of premolars, and molars was generally smooth.[10,11] The exclusion criteria included (1) presence of bone pathological imaging or periapical radiolucency; (2) images were unclear because of scattering or beam-hardening artifacts; (3) mandibular premolar/molar was not fully erupted and not in the normal position.

Virtual immediate implant placement and bone plate perforation evaluation

Selected CBCT scans were reconstructed using an implant planning software (ImplantMax, Saturn imaging Inc, Taipei, Taiwan). The posterior teeth of mandibular (from 1st premolar to 2 nd M) were the sites of interest. Based on the inclusion and exclusion criteria, images were selected by two independent examiners (T-Y Wang and P-J Kuo) in this study. The disagreements in the selection of CBCT scan were resolved through discussion. The root-form implant implants were virtually immediate placed into the posterior teeth of the mandible.

The virtual implant was first placed based on the original morphology of crown, which represents the further restoration, without considering buccao-lingual alveolar boundaries. Mesio-distally, the center of implant platform was positioned along an imaginary line passing through the center of the original crown and fulfills 2 mm away from the root of the adjacent tooth. Bucco-lingually, the center of the implant platform was positioned along an imaginary line passing through the central fossa of the adjacent teeth. Apico-coronally, the implant platform was placed at the crestal level. The angulation of the implant depended on the curvature of the mandibular occlusal plane and the long axis of the opposing maxillary tooth. The implant was placed so that its long axis was in line with that of the opposing tooth. In addition, the functional cusps of the opposing teeth were positioned at the center of the implant.

The diameter of the virtual implant was set to 4 mm, and its length was set to 4 mm plus the length of the root to simulate the clinical need for apical anchorage during immediate implant placement.[9,22] The original position was defined as angulation of 0°, and three deviation angulations, including 3, 6, or 9°, against the long axis of the tooth were placed either buccally or lingually.

BPP was determined when the virtual implant apical outline was crossover the alveolar bony border from the cross-sectional CBCT images of mandibles (Fig. 1) at each posterior mandibular tooth, including the first premolar (PM1), second premolar (PM2), first molar (M1), and second molar (M2). Moreover, the presence of a C—, P—, or U-type cross-sectional mandibular morphology was assessed based on the lingual concavity and shape of the alveolar ridge of the mandibular bone 2 mm above the inferior alveolar canal.[11,21,22]

Buccal/lingual BPP caused by VIIP at the posterior mandibular area was evaluated from the CBCT images two independent examiners (T-Y Wang and P-J Kuo). An intra-examiner calibration based on the anatomic diagnosis of CBCT images was performed to assess data reliability. After intra-examiner calibration, the two examiners separately evaluated the images, and any disagreement in the interpretation of images was discussed until a consensus was reached.

Statistical analysis

All of the collected data were analyzed using SPSS (version 15.0, IBM, Chicago, IL). The χ^2 test, the Cochran-Armitage trend test, and the generalized estimation equation (GEE) were used to examine the potential risk factors of BPP.

Results

A total of 527 CBCT images were identified. After reviewing, 122 hemi-mandibles obtained from 61 CBCT images of the clinical patients, consisting of 29 males and 32 females were selected. The patients' ages ranged from 21 years to 66 years, and their mean age was 39.3 $\pm$ 12 years.

Lingual bone plate perforation

The incidences of virtual lingual BPP at mandibular posterior teeth varied from 0.8% to 19.7% (Fig. 2, white bars) when the implants were placed without angular deviation. The incidence of lingual BPP at M2 (19.7%) was significantly higher than those at any other tooth. The second incidence of lingual BPP was at PM2 (4.1%). Lingual BPP tended to increase as the deviation angle increased (from 0 to 9°),

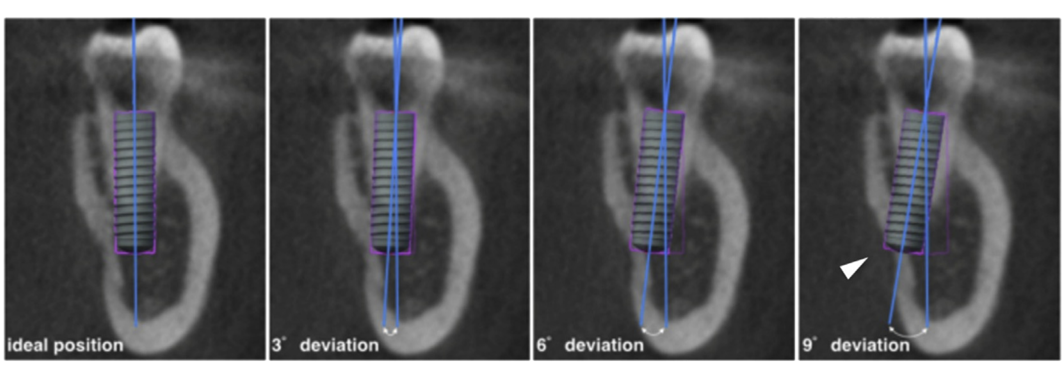

Figure 1 CBCT images of virtual immediate implant placement (VIIP) at the ideal implant position or lingual angulations of 3, 6, or 9 degrees. Lingual bone plate perforation was noted in VIIP at a 9-degree deviation. The bone plate perforation (BPP) was assessed and identified when the virtual implant apical outline was cross over the border of alveolar bone (the white arrow head).

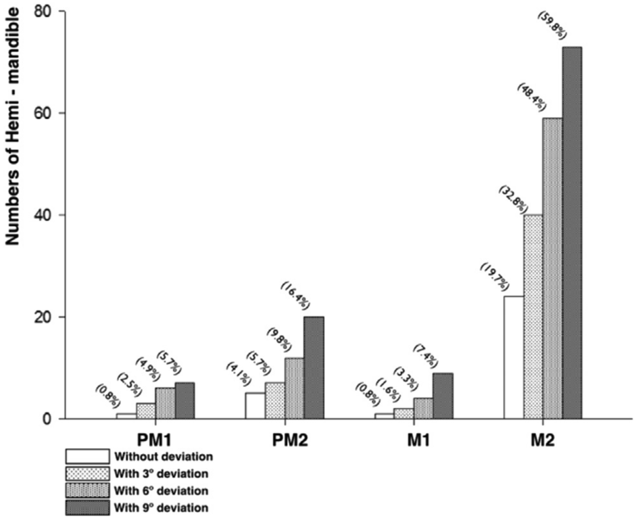

Figure 2 Incidences of lingual BPP after VIIP with and without lingual deviation at each posterior mandibular tooth The parenthesis indicates the incidence of perforation: $p = 0.02$, 0.004, 0.031, and 0.001 at PM1, PM2, M1, and M2, respectively, as determined by the Cochran-Armitage Trend test. PM1 = first premolar, PM2 = second premolar, M1 = first molar, and M2 = second molar.

regardless of the tooth examined ($p = 0.02$, 0.004, 0.031, and <0.0001 for PM1, PM2, M1, and M2, respectively).

The incidence of a C−, P−, or U-type lingual cross-sectional morphology varied among the different tooth types (Fig. 3) in VIIP. The U-type lingual morphology was the dominant morphology at M2 (95 out of 122), and 23 of the 95 U-type M2 (24.2%) showed lingual BPP when the VIIP was placed without deviation. In all of the examined teeth, the incidence of lingual BPP with the U-type morphology (15.7%) was significantly higher than that in teeth with the P-type (1.3%) or C− (0.0%) type (Fig. 3). GEE analysis indicated that the incidence of lingual BPP of VIIP was significantly influenced by tooth type, insertion angulation, and lingual cross-sectional morphology type but not by gender, right/left side, or age (Table 1). The incidence of lingual BPP was significantly higher at PM2 or M2 compared with that at PM1 (OR = 2.528 and 11.764 in PM2 and M2, respectively) and significantly higher when the implant was inserted with angulations of 3, 6, or 9° compared with that without any angulation (OR = 1.977, 3.891, and 6.583 for 3, 6, and 9°, respectively). BPP incidence was significantly higher in teeth with the U-type lingual morphology than in teeth with the C-type morphology (OR = 3.622).

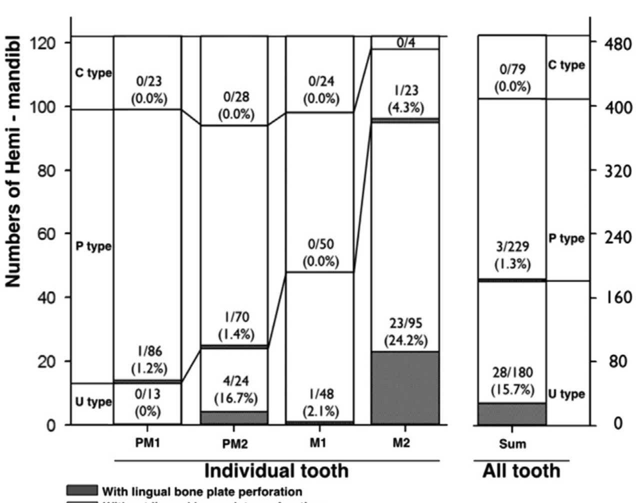

Figure 3 Distribution of the incidence of lingual BPP after VIIP without lingual deviation according lingual morphology type in 122 CBCT hemi-mandible images PM1 = first premolar, PM2 = second premolar, M1 = first molar, and M2 = second molar; C type = convergent type, P type = parallel type, U type = undercut type.

Buccal bone plate perforation

The incidences of virtual buccal BPP at PM1, PM2, M1, and M2 were 4.9%, 1.6%, 2.5%, and 0%, respectively, when VIIP was inserted according to the prosthetic-driven design (Fig. 4). The incidence of buccal BPP in VIIP with angulation (3, 6, or 9°) significantly increased compared with that without angulation. GEE analysis demonstrated that the incidence of buccal BPP was significantly influenced by tooth type and deviation angle but not by lingual bone morphology, gender, right/left side, or age (Table 2). The incidence of buccal BPP at PM2, M1, and M2 was significantly lower than that at PM1 (OR = 0.399, 0.301, and 0.051 for PM2, M1, and M2, respectively) but significantly

Table 1 Effect of tooth type, deviation angle, lingual cross-sectional bone morphology, gender, right/left side, and age on the incidence of lingual BPP, as estimated by an adjusted logistic model utilizing the generalized estimating equation (GEE).

	Odds ratio	95C%CI		*p*-value
		Lower	Upper	
Tooth type				
PM1	1			
PM2	2.528	1.207	5.294	0.014
M1	0.632	0.233	1.713	0.367
M2	11.764	3.999	34.609	0.000
Lingual Deviation Angle				
0 Degree	1			
3 Degree	1.977	1.439	2.716	0.000
6 Degree	3.891	2.595	5.834	0.000
9 Degree	6.583	4.239	10.224	0.000
Cross-sectional Morphology				
C type	1			
P type	1.309	0.308	1.893	0.561
U type	3.622	1.106	6.922	0.012
Gender				
Female	1			
Male	0.481	0.226	1.023	0.057
R/L side				
Right	1			
Left	0.980	0.632	1.520	0.927
Age	1.001	0.975	1.208	0.922

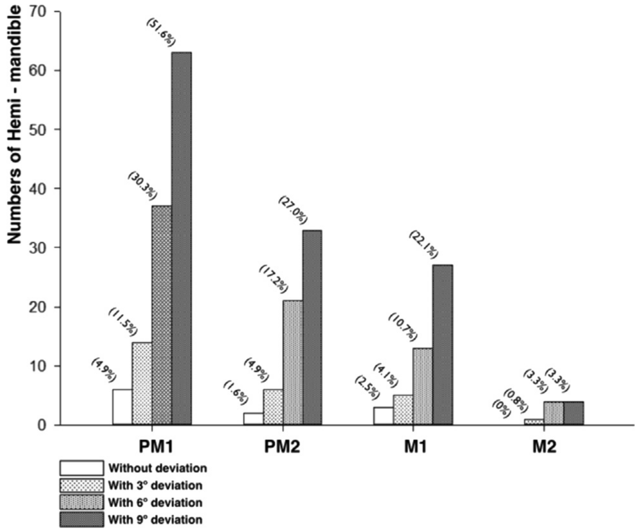

Figure 4 Incidences of buccal BPP after VIIP with and without buccal deviation at each posterior mandibular tooth; the parenthesis indicates the incidence of perforation: $p < 0.0001$ at PM1, PM2, and M1, respectively, and $p = 0.0275$ at M2, as determined by the Cochran-Armitage Trend test. PM1 = first premolar, PM2 = second premolar, M1 = first molar, and M2 = second molar.

Table 2 Effect of tooth type, deviation angle, lingual cross-sectional bone morphology, gender, right/left side, and age on the incidence of buccal BPP, as estimated by an adjusted logistic model utilizing the generalized estimating equation (GEE).

	Odds ratio	95C%CI		*p*-value
		Lower	Upper	
Tooth type				
PM1	1			
PM2	0.399	0.254	0.627	0.000
M1	0.301	0.151	0.600	0.001
M2	0.051	0.017	0.164	0.000
Buccal Deviation Angle				
0 Degree	1			
3 Degree	2.494	1.598	3.893	0.000
6 Degree	8.675	4.168	18.059	0.000
9 Degree	18.310	8.271	40.535	0.000
Cross-sectional Morphology				
C type	1			
P type	1.385	0.407	1.775	0.162
U type	1.543	0.498	2.506	0.101
Gender				
Female	1			
Male	0.970	0.428	2.196	0.941
R/L side				
Right	1			
Left	0.902	0.632	1.286	0.568
Age	1.008	0.981	1.035	0.576

higher in VIIP with deviated angulation compared with that without angulation (OR = 2.494, 8.675, and 18.310 for 3, 6, and 9°, respectively).

Discussion

In the present study, the incidence of buccal or lingual BBP in posterior mandibular teeth after VIIP with varying insertion angles was examined using CBCT images. The incidence of lingual BPP when implants were placed with prosthetic-driven planning without deviation in this study varied from 0.8% to 19.7%, depending on the tooth type (Fig. 2), and was slightly lower than the Results reported in a previous study (7%, 9%, and 31% at PM2, M1, and M2, respectively).[9] The exact reason for this difference in findings is uncertain, but different ethnic populations and experimental designs may contribute to the variations observed. Studies, including several case reports, have reported that perforation of lingual bone plate may lead to serious complications, such as sublingual bleeding, hematoma, or infection.[6,7] Therefore, the clinician must be aware of the risk of BPP during implant placement.

The Results demonstrated that BPP incidence increased as the deviation of the insertion angle increased regardless of tooth type or buccal/lingual bone plate examined (Figs. 2 and 4). At M2, for example, the incidence of lingual BPP was 59.8% if the immediate implant was inserted at 9° but 19.7% if the implant was inserted at 0-degree. After adjustment and examination with GEE, the incidence of lingual and buccal BPP was confirmed to be significantly influenced by the deviation angle during implant insertion (Tables 1 and 2). Furthermore, studies lend support to select the deviation angles in this study, in term of clinical accuracy, the mean angular deviation ranged from 1.49 to 8.54° under the l854 implants measurement with computer-guided surgery.[16] Moreover, the Guided implant placement showed a statistically superior accuracy when compared with freehand placement after osteotomy. The data indicated that deviation between the planned ideal implant axis and clinical implant placement could be more severe.[23,24]

In order to test the hypothesis that the lingual cross-sectional morphology of the mandible is a confounding factor of VIIP-caused BPP, the morphology type at each posterior tooth was identified and the influence of each morphology on the incidence of BPP was further analyzed (Fig. 3, Tables 1 and 2). The cross-sectional bone morphology has been previously classified according to the presence of lingual concavity and shape of the alveolar ridge, and the C, P, and U ridge types were assessed.[21] In the present study, the incidence of C−, P−, and U-type morphologies varied among the tooth types studied (Fig. 3). The P-type morphology was dominant in PM1 (70.5%), PM2 (57.4%), and M1 (41.0%), but the U-type morphology was dominant in M2 (77.9%). Similar findings showing that the P-type morphology is the most common in PM2 (40.3%) and that the U-type morphology is the most common in M1 (57.5%) and M2 (62.3%) have been reported.[10]

Our Results demonstrated that the incidence of lingual BPP was significantly higher in teeth with a U-type lingual morphology than in teeth with other morphologies if not considering the individual tooth (Fig. 3). At M2, for example, 23 out of 95 U-type (24.2%) ridges presented with lingual perforations, whereas only 1 out of 23 (4.3%) P-type ridges showed lingual perforations. After adjustment with

GEE, the incidence of lingual perforation during VIIP was observed to be significantly influenced by the cross-sectional mandibular morphology (Table 1). The probability of developing lingual BPP in teeth with the U-type morphology was over 3-fold higher (OR = 3.622) than that of developing lingual BPP in teeth with the C-type morphology (Table 1).

In the present study, we further evaluated the incidence of BPP in VIIP when the insertion angulation deviated buccally and observed the highest incidence of buccal BPP without angular deviation at PM1 (Fig. 4). As the angular deviation increased, the incidence of buccal BPP also increased, regardless of tooth type. After adjustment with GEE, buccal BPP incidence was found to be significantly influenced by confounding factors such as tooth type and deviation angle but not by type of lingual bone morphology (Table 2). Bone dehiscence or fenestration on the buccal surface of the implant has been previously examined, and perforation was found to be mainly located in the maxillary anterior regions.[25–27] Assessment of the types of lingual bone morphology was based on the presence of lingual concavity and shape of the alveolar ridge because no classification for buccal bone morphology is currently available. Therefore, a suitable classification system may be necessary to examine the association between buccal bone morphology and risk of implant BPP further. However, the regeneration procedure performed to repair BPP may be challenged clinically by anatomical and access limitations, such as apical location, muscle attachment, and cross-sectional morphology.

In this study, CBCT images were selected and used. CBCT provides three-dimensional data, including the cross-sectional morphology of the mandible that cannot be observed during traditional periapical film and panoramic radiography, which only offer two-dimensional data.[28,29] The use of CT prior to surgery allows surgeons to inspect the details of the surgical area; thus, the wider application of CT has been assessed and analyzed.[30] The accuracy of CBCT and traditional periapical films in preventing implant-caused injury of the inferior alveolar nerve was compared in a cadaver model.[31] Damage of the mandibular inferior alveolar nerve was detected in 7 out of 22 (31.8%) final implant drills placed by periapical radiography but only 1 (4.5%) final drills placed by CBCT. Considering these findings, CBCT images were selected in this study to evaluate the influence of angled implant placement on BPP in the posterior mandible. In order to minimum implant diameter required to support the occlusal load in the posterior mandible, the diameter of diameter virtual implant was set at 4 mm in this study.[9,32,33] The BPP incidence may be higher when the large diameter implant was used. In addition, the previous study claimed that the narrow implant (3.7 mm) should be considered in the posterior mandible region to avoid lingual BPP.[12]

This study demonstrates that deviation of implant insertion could statistically increase the risk of buccal/lingual BPP in VIIP of the posterior mandibular region. The incidences of BPP of the buccal site at PM1 and lingual site at M2 were 4.9% and 19.7%, respectively, when the VIIP were inserted without any deviation. These incidences increased to 51.6% and 59.8%, respectively, if the insertion with a 9-degree deviation. The cross-sectional lingual bone morphology also influenced the incidence of lingual BPP. This suggested that the incident of BPP cab be decreased through pre-surgical analysis and well control the angulation of implant during surgery in the posterior mandible regions.

Declarations of interest

The authors report no conflicts of interest related to this study.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jds.2019.03.005.

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