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Research Paper
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Comparison of posterior alveolar canal location measured on computer tomography scan with cadaveric measurement of posterior superior alveolar foramen in Japanese samples

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Abstract. The aim of this study was to analyse anatomical characteristics of the most posterior alveolar canal (PAC) on computed tomography (CT) images and the posterior superior alveolar foramen (PSAF) physically identified in cadaveric samples, to avoid injuring the posterior superior alveolar artery (PSAA) during surgery in the maxillary tuberosity region. The study included 125 hemi-heads of 64 Japanese cadavers. Simple CT data of the maxillary bone region of the samples were obtained and analysed using measurement software. The alveolar crest (AC) and the PAC were identified to calculate the shortest distance between the AC and the PAC (AC-PAC). Then the samples were dissected to measure physically the shortest distance between the AC and the PSAF (AC-PSAF). The data were analysed statistically. The mean value and standard deviation were 20.7 ± 4.2 mm for AC-PAC and 20.7 ± 4.3 mm for AC-PSAF. The intraclass correlation coefficient between AC-PAC and AC-PSAF was 0.98. The CT-measured PAC locations were found to be almost identical to the PSAF positions identified physically in the samples. Preoperative CT localization of the PAC aids in avoiding injury to PSAA, while preoperative CT evaluation is important for each case due to significant individual variability in the anatomical PAC and PSAF locations.

Key words: Posterior superior alveolar artery; posterior superior alveolar foramen; posterior alveolar canal; bleeding; maxillary tuberosity.

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In oral and maxillofacial surgery, an injury to the posterior superior alveolar artery (PSAA), a branch of the maxillary artery, can cause serious haemorrhage. Inappropriate periosteal exfoliation or location of osteotomy in the maxillary tuberosity region during Le Fort I osteotomy may injure the PSAA causing unexpected bleeding to compromise visibility in the surgical field[1,2]. In 2017, we performed a study focusing on critical sites for implant placement in the pterygomaxillary region. It included 46 Japanese cadavers (78 hemiheads) with all molars missing and a distance of ≤10 mm between the alveolar crest (AC) and the sinus floor (SF) in the molar region. The relevant distances and angles in the pterygomaxillary region were measured using CT images as well as directly on the samples. The results showed that the measurement values, including the distance between the AC and the PSAA, varied significantly between samples[3]. Massive haemorrhage cases have been reported in extraction of the maxillary second or third molar also, due to injury to the PSAA[4,5]. Therefore, accurate data on the location of the posterior superior alveolar foramen (PSAF) where the PSAA enters, are critical for surgery in the maxillary tuberosity region. However, the simple computed tomography (CT) does not offer sufficient anatomical landmarks, and the number of clinical anatomical studies comparing physical and CT measurements regarding the PSAF is limited.

This study aimed to find the anatomical characteristics of the most posterior alveolar canal (PAC) obtained from CT images, and the PSAF measured physically, using cadaveric samples from Japanese specimens. In addition, the PAC was evaluated to determine the feasibility of using it as an anatomical landmark for the PSAF by clarifying the locational relationship between the PAC and the PSAF.

Table 1. Distribution of cadaver specimens by age and sex.

Age (Yr)	Male	Female	Both
45–59	3 (6)	0 (0)	3 (6)
60–69	10 (18)	3 (6)	13 (24)
70–79	12 (24)	2 (4)	14 (28)
80–89	10 (20)	3 (6)	13 (26)
90–99	7 (14)	10 (19)	17 (33)
100–103	1 (2)	2 (4)	3 (6)
All	43 (84)	20 (39)	63 (123)

Note: Number of hemiheads in each group is given in parentheses.

Materials and methods

Materials

Approval from the Ethics Committee of Saga Medical School was obtained before conducting this study (approval number 28-70.) One hundred and twenty-five hemiheads (males: 86, females: 39) were used from 64 Japanese cadavers owned by the Department of Anatomy of Saga Medical School for this study (Table 1). Sixty-one cadavers provided both the right and left hemi-heads, i.e. two hemi-heads per individual. The mean age at the time of death was 79.9 years (range 46–103 years), excluding one cadaver (two hemi-heads) (male) with unknown age at the time of death (Table 1). Forty-nine hemi-heads had one or more maxillary molars (molar dentate group) including 35 hemi-heads that retained the maxillary second molars, and 76 had no molars at all (molar edentulous group.) All the specimen had been fixed in a 10% neutral formalin solution. The head was detached from the neck.

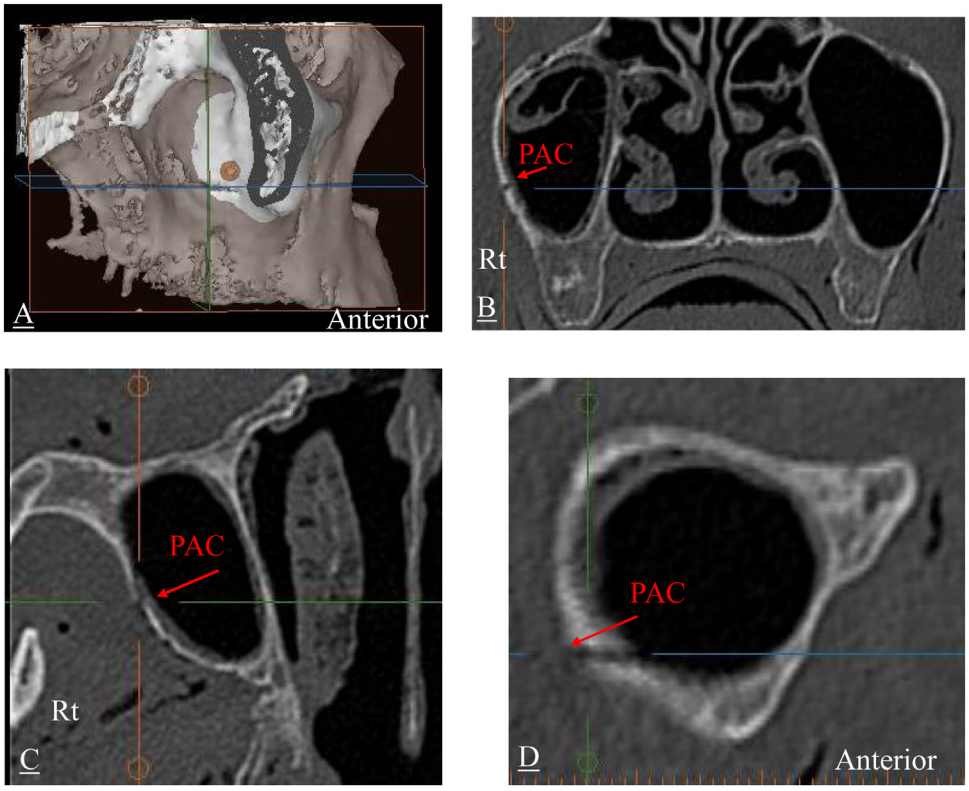

Fig. 1. Images of the maxillary tuberosity region, including the most posterior alveolar canal (PAC): (A) three-dimensional view, (B) coronal view, (C) axial view, and (D) sagittal view. Rt, right.

Methods

CT measurements

A multi-slice CT system (MSCT, SOMATOM Scope 16-slice configuration, Siemens, Germany) was used for CT imaging. The parameters were as follows: tube potential 130 kV, tube current 75–120 mA, scan time 0.8 s, gantry tilt 0°, slice thickness 0.6 mm, beam pitch 1.2, reconstruction interval 0.6 mm, and reconstruction function H90 s very sharp. The field of view (FOV) was set at 200 mm, and the voxel size was 0.39 mm for the *x*- and *y*-axes, and 0.6 mm for the *x*-axis. The scan range was between the superior orbital margin and the maxillary bone. The mid-sagittal plane was aligned with the mid-longitudinal axis of the gantry for scanning via parallel alignment of the scan and the Frankfort (FH) planes. The CT data were saved as DICOM (Digital Imaging and Communication in Medicine) files.

The CT data were analysed using measurement software (LAND marker Direct, Version 7.50; iCAT, Osaka, Japan). Three-dimensional, coronal, axial, and sagittal images of the maxillary tuberosity region were generated using the FH plane as reference on the personal computer display (Fig. 1). In the image, the most posterior alveolar canal of the maxillary bone was defined as the 'PAC' (Fig. 1). Where there were multiple PACs, the largest one was selected. In coronal view, the shortest distance between the AC and the PAC in the maxillary tuberosity region was defined as AC-PAC (Fig. 2), and the shortest distance between the maxillary sinus floor (SF) and the PAC in the maxillary tuberosity region was defined as SF-PAC (Fig. 2). Both the distances were measured. In samples retaining the maxillary second molar, the shortest distance between the highest second molar root apex (R) and the PAC was defined as R-PAC, and measured in sagittal view (Fig. 3). The PAC could be identified in the maxillary tuberosity region, in the coronal view, in all samples, while the SF was not identified in two samples (four sides) due to metal artefacts in the maxillary SF region. Similarly, the R was not identified in two sides due to metal artefacts. In the SF-PAC measurement, the position of the PAC above the SF was indicated by a positive number, while that below the SF was indicated by a negative number.

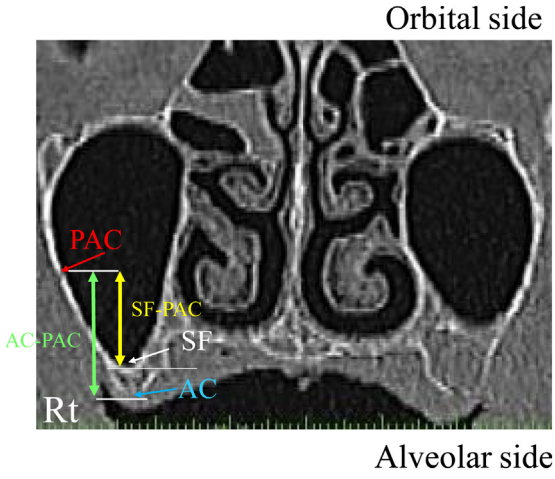

Fig. 2. Coronal view of the maxillary tuberosity region. The blue arrow indicates the alveolar crest (AC), the red arrow indicates the most posterior alveolar canal (PAC), the white arrow indicates the maxillary sinus floor (SF), the green double-headed arrow indicates AC-PAC, and the yellow double-headed arrow indicates SF-PAC. Rt, right.

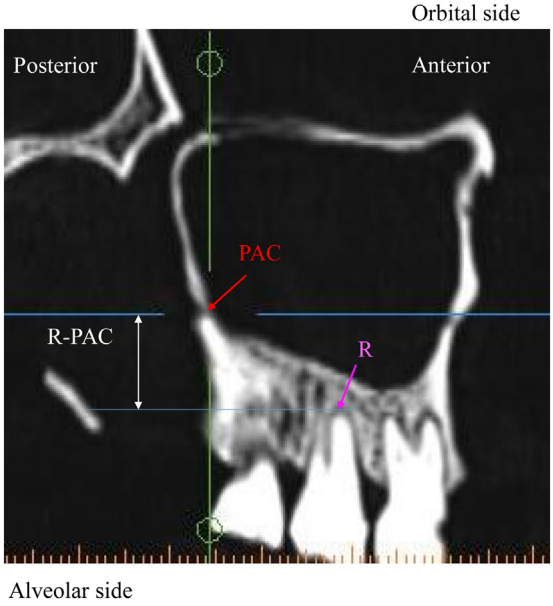

Fig. 3. Sagittal view of the maxillary second molar region. The pink arrow indicates the maxillary second molar root apex (R), the red arrow indicates the most posterior alveolar canal (PAC), and the white double-headed arrow indicates R-PAC.

Physical measurements

Using a lateral approach, a fan-shaped incision was made on the lateral part of the head of each sample to remove the temporal and masseter muscles. The zygomatic arch was then dissected at both ends of the masseter muscle, turned downwards with the zygomatic arch, and removed. The mandibular ramus above the mandibular foramen was dissected, and the temporal muscle was turned upwards to identify the maxillary artery. Then, the PSAAs peripheral to the maxillary artery were dissected to identify the PSAF. When there were multiple PSAFs, the largest one was selected. Each sample was placed on a flat experimental table with the FH plane parallel to the table surface. The shortest distance between the AC and the PSAF (AC-PSAF) in the maxillary tuberosity region was measured directly using a caliper (N10S; Mitutoyo Corporation, Kanagawa, Japan) (Fig. 4).

All the CT and physical measurements were performed by a single expert examiner.

Statistical analysis

All statistical analyses were conducted using Excel 2002 (Microsoft Corporation, Redmond, WA, USA) and SPSS (Ver.

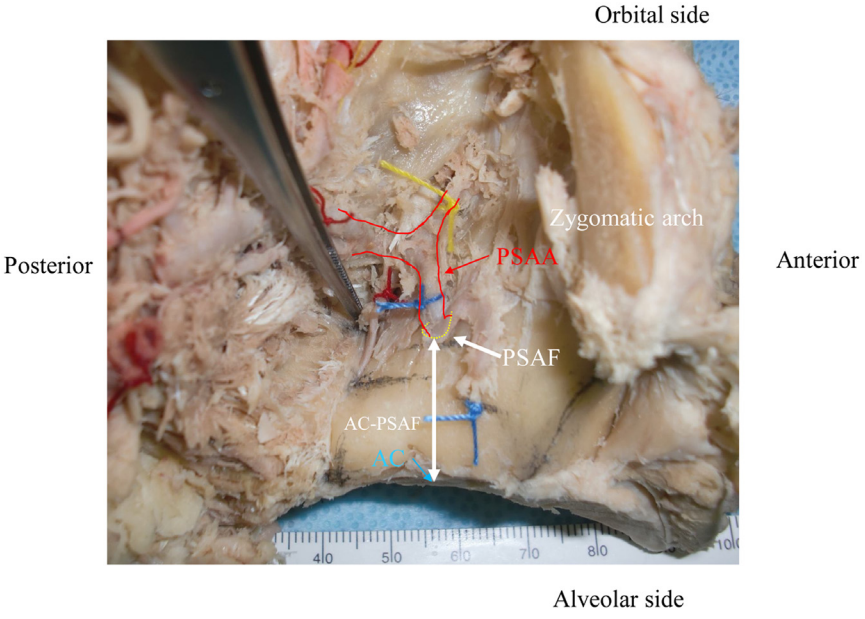

Fig. 4. Lateral view of a sample showing the region of the maxillary bone to the pterygoid process of the sphenoid. The red contours indicate the maxillary artery (upper red thread); the posterior superior alveolar artery (PSAA, indicated by the upper blue thread and red arrow) that branches from the maxillary artery; and the infraorbital artery (yellow thread). The blue arrow indicates the alveolar crest (AC), the white arrow indicates the posterior superior alveolar foramen (PSAF), and the white double-headed arrow indicates AC-PSAF.

11.0J; SPSS, Tokyo, Japan.) *P*-values of <0.05 were considered statistically significant. Descriptive statistics of AC-PAC, AC-PSAF and SF-PAC were calculated for all samples, the right and left sides, the male and female groups, both the age groups, and the molar dentate and molar edentulous groups. Descriptive statistics of the R-PAC were calculated for all samples, the male and female groups, and the age groups. A paired *t*-test was used for comparison between the right and left sides, and an unpaired *t*-test, for comparison between the sexes, age groups, and dental statuses. The age groups for comparison were defined as <80 years and ≥ 80 years because the mean age of all samples was 79.9 years. Additionally, the intraclass correlation coefficient was calculated between CT-based AC-PAC and physically measured AC-PSAF.

Results

Descriptive statistical values of respective measurements are shown in Tables 2–4.

The mean AC-PAC and AC-PSAF for all samples, including both sides, both sexes, and both age groups, was approximately 21 mm (Table 2). Based on the dental status, the mean AC-PAC and AC-PSAF were approximately 22 mm in the molar dentate group and approximately 20 mm in the molar edentulous group, indicating statistical significance ($P < 0.05$). However, the mean AC-PAC and AC-PSAF did not show a statistical significance with respect to any other parameter (side, sex, age group). Standard deviations (SDs) were approximately 4–5, and the maximum value was two- to four-times larger than the minimum value of all groups.

The mean values of SF-PAC were in the range of 7–10 mm for all samples and samples under the respective conditions (Table 3). Sex-based comparison showed significant statistical difference, with approximately 10 mm for male and approximately 7 mm for female ($P < 0.05$). The

Table 2. Descriptive statistical values of respective measurements of AC-PAC and AC-PSAF.

Group	AC-PAC					AC-PSAF				
	Mean	SD	Minimum	Maximum	*P*-value	Mean	SD	Minimum	Maximum	*P*-Value
All (n = 125)	20.7	4.2	7.4	31.8		20.7	4.3	7.4	31.7	
Side										
Right (n = 61)	20.7	4.3	7.4	31.8		20.7	4.3	7.4	31.7	
					0.60					0.53
Left (n = 61)	21.0	3.9	10.4	29.1		21.1	3.9	10.5	29.0	
Sex										
Male (n = 86)	20.5	4.5	7.4	31.8		20.5	4.6	7.4	31.7	
					0.48					0.46
Female (n = 39)	21.1	3.6	12.0	29.1		21.0	3.6	12.0	29.0	
Age										
<80 (n = 58)	21.1	4.3	10.0	31.8		21.0	4.5	10.0	31.7	
					0.41					0.59
≥80 (n = 65)	20.5	4.1	7.4	29.1		20.5	4.1	7.4	29.0	
Dental status										
Molar dentate (n = 49)	22.1	3.9	11.7	31.8		21.9	4.1	11.6	31.7	
					0.002*					0.007*
Molar edentulous (n = 76)	19.8	4.2	7.4	29.1		19.8	4.2	7.4	29.0	

Legend:
SD: standard deviation.
AC: the alveolar crest in the maxillary tuberosity region.
PAC: the most posterior alveolar canal.
PSAF: the posterior superior alveolar foramen.
n= numbers of hemi-maxillae.
* $P < 0.05$.

Table 3. Descriptive statistical values of respective measurement of SF-PAC.

Group	SF-PAC				
	Mean	SD	Minimum	Maximum	*P*-value
All (n = 121)	9.1	6.0	−4.7	24.8	
Side					
Right (n = 59)	9.7	6.4	−4.7	23.7	0.18
Left (n = 59)	8.8	5.4	−1.4	24.8	
Sex					
Male (n = 82)	9.9	6.5	−4.7	24.8	0.01*
Female (n = 39)	7.4	4.4	−3.5	19.5	
Age					
<80 (n = 54)	9.9	6.4	−1.4	24.8	0.18
≥80 (n = 65)	8.4	5.6	−4.7	21.8	
Dental status					
Molar dentate (n = 49)	10.0	5.5	−1.4	21.6	0.17
Molar edentulous (n = 72)	8.5	6.3	−4.7	24.8	

Legend
SD: standard deviation.
PAC: the most posterior alveolar canal.
SF: the maxillary sinus floor in the maxillary tuberosity region.
n= numbers of hemi-maxillae.
* $P < 0.05$.

Table 4. Descriptive statistical values of respective measurements of R-PAC.

Group	R-PAC				
	Mean	SD	Minimum	Maximum	*P*-value
All (n = 33)	15.3	3.1	9.5	23.8	
Sex					
Male (n = 24)	15.7	3.1	9.5	23.8	0.23
Female (n = 9)	14.3	2.8	10.6	19.5	
Age					
<80 (n = 19)	16.0	3.2	10.5	23.8	0.12
≥80 (n = 12)	14.2	2.9	9.5	19.5	

Legend
SD: standard deviation.
PAC: the most posterior alveolar canal.
R: the highest the maxillary second molar root apex.
n= numbers of hemi-maxillae.

mean SF-PAC did not show a statistical significance regarding any other parameter (side, age group, dental status). SF-PAC showed SDs of approximately 4–7 and differences between the maximum and minimum values of approximately 23–30 mm for each group.

The mean values of R-PAC were in the range of 14–16 mm for all samples and samples under the respective conditions (Table 4). No statistical significance was observed regarding any parameter (sex, age group). R-PAC showed SD of approximately 3, and the maximum value was approximately 1.8- to 2.5-times higher than the minimum value for each group.

The intraclass correlation coefficient between AC-PAC and AC-PSAF was 0.98 for all samples.

Discussion

AC-PAC and AC-PSAF

Behnia et al.[6] used intraclass correlation coefficient to assess the degree of conformity between the direct and CT measurement results. We used the same method and found that the CT and physical measurement values matched highly. This indicated that the PSAF location could be estimated from the PAC located on the preoperative CT data.

Ide et al. described the mean vertical distance between the AC and the PAC in the maxillary tuberosity region as 18.8 mm, on CT-based measurement of 118 maxillary sinuses of dentate and edentulous cases with no clarification on racial type[7]. Hur et al. conducted an anatomical measurement on 42 Korean, dentate hemi-heads and reported that the mean height (vertical distance) between the AC and the intraosseous branch of the PSAA was 23.3 mm in the maxillary tuberosity region[8]. Our previous study, using 21 Japanese hemi-heads with no maxillary molar, showed that the mean AC-PSAA was 19.7 mm[3]. These mean values reported in previous studies are similar to the mean AC-PAC and AC-PSAF values measured in this study, suggesting a certain tendency in the anatomical locations of the PAC and the PSAF.

We have previously reported significant individual variations in the locations of the pterygomaxillary fissure and the PSAA in the pterygomaxillary region[3]. The PAC and the PSAF measured this time are also located in the pterygomaxillary region, showing significant locational variation. Therefore, the anatomical location of the PAC must be confirmed in each case by preoperative CT, to avoid injuring the PSAA during surgery in the maxillary tuberosity region. Both AC-PAC and AC-PSAF were significantly shorter in the molar edentulous group than in the molar dentate group. This finding may be explained by alveolar bone resorption due to missing teeth.

SF-PAC

Hur et al. also reported that the mean height (same as vertical distance) between the maxillary SF and the intraosseous branch of the PSAA was 9.5 mm in the maxillary tuberosity region[8]. Apostolakis et al. reported the mean vertical distance between the maxillary SF and the PAC to be 9.6 mm in the maxillary tuberosity region, by measurement from cone-beam CT data of 255 maxillary sinuses in 156 samples with no clarification of the race and dental status[9]. The values obtained in this study were similar to those reported in the past. The SF-PAC, AC-PAC, and AC-PSAF also revealed a certain tendency, but the variation was substantial.

Contrary to the results of studies by Kang et al.[10], Yang et al.[11] and Kurt et al.[12], our study indicated statistically significant differences between male and female samples. This discrepancy should be further analysed using more samples in the future.

R-PAC

All the above three measurements, and the R-PAC showed a certain tendency, but the variation was substantial.

In Le Fort I osteotomy, the osteotomy line is defined usually at 5 mm above the

maxillary second molar root apex[13], therefore, attention should be directed to the PAC located approximately 9–11 mm above this line, in the maxillary tuberosity region.

This study was performed using only Japanese cadaveric samples. We plan to evaluate the racial differences and characteristics by using a similar study design and analysis, but withother racial samples.

In conclusion, the results obtained from this study indicated that the CT-based PAC locations corresponded with high reliability to the anatomically confirmed PSAF locations. This proved the usefulness of the preoperative CT-measured PAC location, as an anatomical landmark to avoid injuring the PSAA. Although the PAC and the PSAF show a certain tendency in the anatomical locational relationship, preoperative CT evaluation is still essential owing to significant differences between individuals. The materials used in this study were cadavers whose ages should be higher than those of clinical surgery cases. This fact should be considered during clinical application of the data obtained in this study.

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None.

Competing interests

None.

Ethical approval

Ethical Approval was provided by the Ethics Committee at Saga Medical School (approval number 28-70).

Patient consent

Not required.

References

1. Rahpeyma A, Khajehahmadi S. Alveolar antral artery: review of surgical techniques involving this anatomic structure. *Iran J Otorhinolaryngol* 2014;**26**:73–8.
2. Pandharbale AA, Gadgil RM, Bhoosreddy AR, Kunte VR, Ahire BS, Shinde MR, Joshi SS. Evaluation of the posterior superior alveolar artery using cone beam computed tomography. *Pol J Radiol* 2016;**81**:606–10.
3. Uchida Y, Yamashita Y, Danjo A, Shibata K, Kuraoka A. Computed tomography and anatomical measurements of critical sites for endosseous implants in the pterygomaxillary region: a cadaveric study. *Int J Oral Maxillofac Surg* 2017;**46**:798–804.
4. Benazzou S, Cheynet F, Brignol L, Guyot L, Chossegros C. Third molar extraction with massive hemorrhage treated by embolization. *J Craniofac Surg* 2009;**20**:575–6.
5. Bertram AR, Rao AC, Akbiyik KM, Haddad S, Zoud K. Maxillary tuberosity fracture: a life-threatening haemorrhage following simple exodontia. *Aust Dent J* 2011;**56**:212–5.
6. Behnia H, Motamedian SR, Kiani MT, Morad G, Khojasteh A. Accuracy and reliability of cone beam computed tomographic measurements of the bone labial and palatal to the maxillary anterior teeth. *Int J Oral Maxillofac Implants* 2015;**30**:1249–55.
7. Ide Y, Iwata H, Yamada M, Takamori H, Yosue T. Position of the posterior alveolar canal based on CT. *J Jpn Soc Oral Implantol* 2009;**22**:115–21.
8. Hur MS, Kim JK, Hu KS, Bae HE, Park HS, Kim HJ. Clinical implications of the topography and distribution of the posterior superior alveolar artery. *J Craniofac Surg* 2009;**20**:551–4.
9. Apostolakis D, Bissoon AK. Radiographic evaluation of the superior alveolar canal: measurements of its diameter and of its position in relation to the maxillary sinus floor: a cone beam computerized tomography study. *Clin Oral Implants Res* 2014;**25**:553–9.
10. Kang SJ, Shin SI, Herr Y, Kwon YH, Kim GT, Chung JH. Anatomical structures in the maxillary sinus related to lateral sinus elevation: a cone beam computed tomographic analysis. *Clin Oral Implants Res* 2013;**24** (Suppl. A100):75–81.
11. Yang SM, Kye SB. Location of maxillary intraosseous vascular anastomosis based on the tooth position and height of the residual alveolar bone: computed tomographic analysis. *J Periodontal Implant Sci* 2014;**44**:50–6.
12. Kurt MH, Kurşun E.Ş., Alparslan YN, Öztaş B. Posterior superior alveolar artery evaluation in a Turkish subpopulation using CBCT. *Clin Dent Res* 2014;**38**:12–9.
13. Cortese A. Le Fort I Osteotomy for Maxillary Repositioning and Distraction Techniques. In: Waddell JP, editor. *The Role of Osteotomy in the Correction of Congenital and Acquired Disorders of the Skeleton*. London, UK: In Tech; 2012. p. 29.

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