



ORIGINAL ARTICLE

Analyses of anatomical relationship between mandibular third molar roots and variations in lingual undercut of mandible using cone-beam computed tomography



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KEYWORDS

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Abstract *Background/purpose:* Anatomical features of the lingual undercut region is a potential factor that might increase the risk of displacement of a tooth or fragment. The aim of this study was to report the normal anatomical relationship of impacted lower third molar roots to the lingual cortex and soft tissues of mandible and anatomical variations of lingual balcony in the impacted third molar region.

Materials and methods: One hundred impacted third molars (54 males, 46 females) from 65 (31 men, 34 women) patients were evaluated for this study using cone-beam computed tomography. Three measurements [bone thickness, angle (Ang) 1 and Ang 2] were recorded on the coronal section slices of cone-beam computed tomography images; in these images, the impacted third molar root was closest to the lingual soft tissues.

Results: The average distance between the tooth root and the lingual outer cortical bone layer (bone thickness) was 1.03 mm. The averages of Ang 1 and Ang 2 were 140.61° and 153.44°. Ang 1 and Ang 2 of female patients were larger than those of male patients.

Conclusion: The narrow angulation of the lingual balcony region and the relationship between roots and lingual soft tissues should be noted to avoid undesirable complication of

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displacement of a tooth or fragment into sublingual, submandibular, and pterygomandibular spaces. There was no relation in the floor of the mouth between the position of the impacted third molar roots and different lingual undercut angulation variations.

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Introduction

Third molar extraction, a common procedure in oral and maxillofacial surgery, is rarely associated with complications.¹ However, the complications of mandibular third molar surgery include alveolar osteitis, secondary infection, nerve dysfunction, hemorrhage, and displacement of the tooth into adjacent structures.² The most common sites of dislodgement of an impacted mandibular third molar fragment are the sublingual, submandibular, and pterygomandibular spaces.³ Distal version and curved roots may increase the risk of displacement of a tooth or fragment.⁴

In this study, anatomical features of the lingual undercut region was questioned as a potential factor that might increase the risk of displacement of a tooth or fragment. Cone-beam computed tomography (CBCT) was used to evaluate the proximity of impacted mandibular third molar roots to lingual soft tissues and to determine the anatomical features of the lingual undercut region related to impacted mandibular third molars.

The main purpose of this study was to report the normal anatomical relationship of impacted lower third molar roots to the lingual cortex and soft tissues of mandible and anatomical variations of lingual balcony in the impacted third molar region.

Materials and methods

This study followed the Declaration of Helsinki on medical protocol and ethics and the regional Ethical Review Board of Medipol University Non-invasive Clinical Research Ethics Committee (no:2015/328) approved the study.

Until reaching the number of 100 impacted mandibular third molar teeth in inclusion criteria assessed in this study, 185 archived CBCT images that had been taken for various needs (indication, preoperative or postoperative control, follow-up, treatment planning) were reanalyzed. Patients with a history of trauma and/or surgery involving the maxillofacial region, systemic diseases affecting growth and development, or clinical and/or radiographic evidence of developmental anomalies/ pathologies affecting the maxillofacial region were excluded from the study. After also excluding third molars with pathology, incomplete root formation, and lingual version, 100 impacted third molars (54 males, 46 females) from 65 patients (31 men, 34 women) were evaluated. The evaluation was performed independently by one trained oral and maxillofacial surgeon and one trained oral and maxillofacial radiologist who were experienced in the radiographic evaluation of maxillofacial anatomy. Then,

the average of the two measurements was calculated and evaluated.

The CBCT examinations were performed using a ProMax 3D Mid machine (Planmeca Oy, Helsinki, Finland). The ProMax 3D Mid was operated at 90 kVp and 10 mA with a 16 cm × 16 cm field of view. Assessment of CBCT scans was performed directly on a monitor screen (58-cm Acer, 1920 × 1080 pixels, HP Reconstruction PC). The MIMICS software (ver. 14.0; Materialise Europe, Leuven, Belgium) was used to measure the distance and angulation parameters. Measurements were recorded on 2× zoomed-in images to provide more accurate and detailed data. Collected data were categorized under classes of right–left sides, vertical–mesioangular–horizontal–distoangular versions, Emes⁵ A–B–C relation types (Figure 1), and Chan⁶ U–P–C morphology types (Figure 2).

In addition, three measurements were recorded on the coronal section slices of CBCT images; in these images, the impacted third molar root was closest to the lingual soft tissues. If there were multiple roots, the root closest to the lingual soft tissues was selected for evaluation.

- 1) Bone thickness (BT): lingual BT between the tooth root and the lingual outer cortical bone layer (Figure 3). Relationship type C values, in which the root does protrude into the soft tissues, by the Emes classification,⁵ were entered with the data as negative rational values.
- 2) Angle 1 (Ang 1): the angle between (1) the most superior point of the lingual alveolar bone; (2) the most prominent point of the lingual alveolar bone; and (3) the deepest point of the lingual balcony (Figure 4).
- 3) Angle 2 (Ang 2): the angle between (1) the most prominent point of the lingual alveolar bone; (2) the deepest point of the lingual balcony; and (3) the most inferior point of the mandibular basis (Figure 5).

Statistical analysis

All statistical analyses were performed using SPSS software (version 22.0; SPSS, Chicago, IL, USA). Results were evaluated with the Shapiro–Wilk test, and a normal distribution of the parameters was detected. Results are expressed as means ± standard deviation. Differences between groups were evaluated using a one-way ANOVA test or Student *t* test, as appropriate. Student *t* test was used for the comparison of the quantitative data that does achieve two independent group's parametric test possibilities. One-way ANOVA test was used for the comparison of the quantitative data that does achieve three or more independent group's parametric test possibilities. A *P* value < 0.05 was considered to indicate statistical significance.

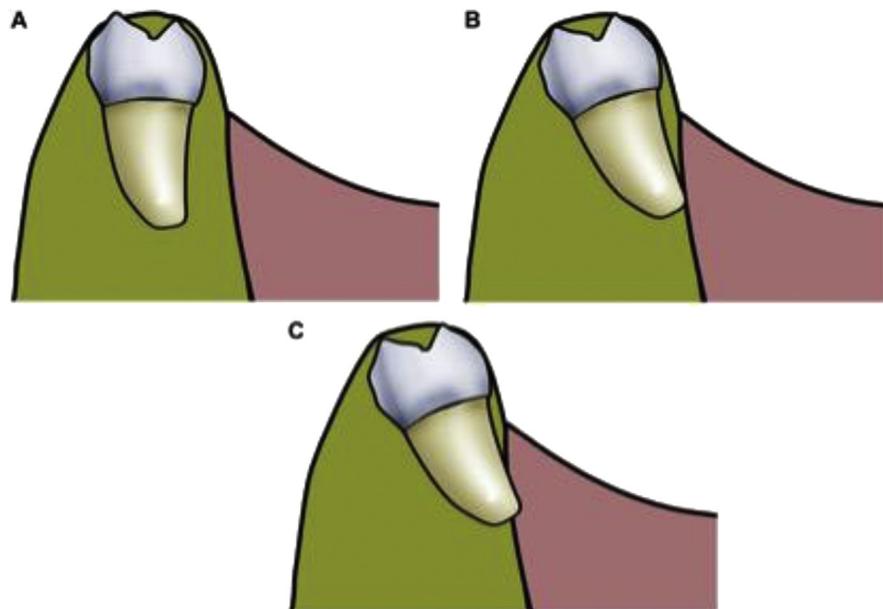


Figure 1 (A) Type A relation, in which there is bone between the root and the floor of the mouth. (B) Type B relation, in which the root communicates with but does not protrude into the floor of the mouth. C, Type C relation, in which the root does not protrude into the soft tissues.⁵

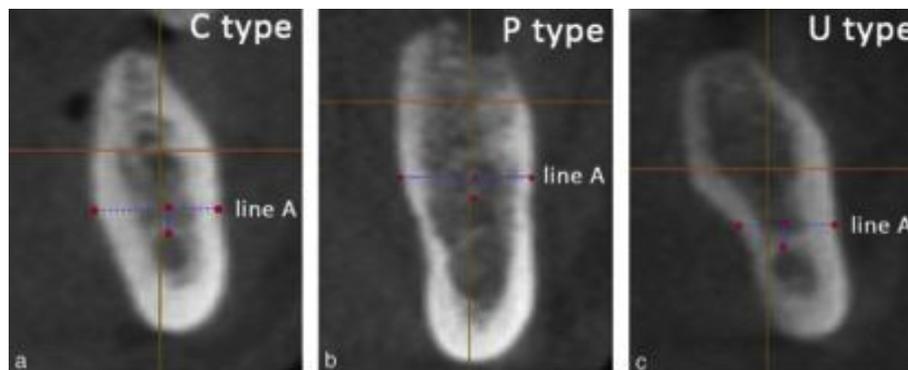


Figure 2 Three types of lingual undercut morphology according to Chan et al⁶: convex (C), parallel (P), and undercut (U).

Results

In total, 100 impacted third molars (54 males, 46 females) from 65 (31 men, 34 women) patients were evaluated. The average age of patients was 31.97 ± 7.36 years (range, 18–47 years). Of the 100 impacted third molars, 54 were right and 46 were left. There were 56 vertically, 23 mesioangular, 16 horizontal, and five distoangular positioned third molars. Of these 100 teeth, 74 were classified as type A under the Emes classification,⁵ 16 were type B, and 10 were type C. Detailed data on the position of the teeth and the Emes classification relations are provided in Table 1.

Lingual balcony morphology was classified under the Chan classification⁶ criteria, and 100% of subjects were found to be type U (undercut).

The average distance between the tooth root and the lingual outer cortical bone layer (BT) was 1.03 mm (range, –3.09 mm to 4.4 mm). The averages of Ang 1 and Ang 2

were 140.61° and 153.44° with ranges of 105.08 – 168.21° and 120.57 – 177.51° , respectively (Table 2).

There were no statistically significant sex differences between the BTs of the groups. However, Ang 1 and Ang 2 of female patients were statistically significantly larger than those of male patients (Table 3). There were no statistically significant differences between the BTs or Ang 1 and Ang 2 of the groups according to right or left side (Table 4). There was a statistically significant difference between BTs according to the Emes classification⁵ among types A, B, and C, but there were no statistically significant differences in Ang 1 or Ang 2 (Table 5). There were no statistically significant differences between the BTs or among the groups' Ang 1 and Ang 2 according to the position of the teeth (Table 6).

Discussion

Many cases with displacement of the third molar into the surrounding facial spaces have been reported since the first



Figure 3 Bone thickness lingual bone thickness between the tooth root and the lingual outer cortical bone layer.

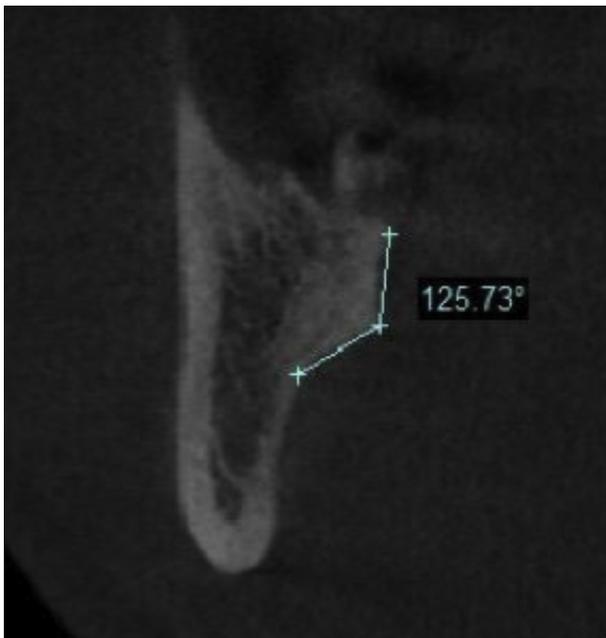


Figure 4 Angle 1 (Ang 1): the angle between (1) the most superior point of the lingual alveolar bone; (2) the most prominent point of the lingual alveolar bone; and (3) the deepest point of the lingual balcony.

case was reported by Howe.⁷ The affected sites were primarily in the infratemporal, submandibular, pterygomandibular, lateral pharyngeal, and sublingual spaces.^{1,2-4,7-12} Although displacement of teeth or tooth fragments during surgery into the surrounding tissues is a rare complication, it has been suggested that these complications may be underreported because practitioners retrieve their own displaced fragments and do not report doing so.¹³

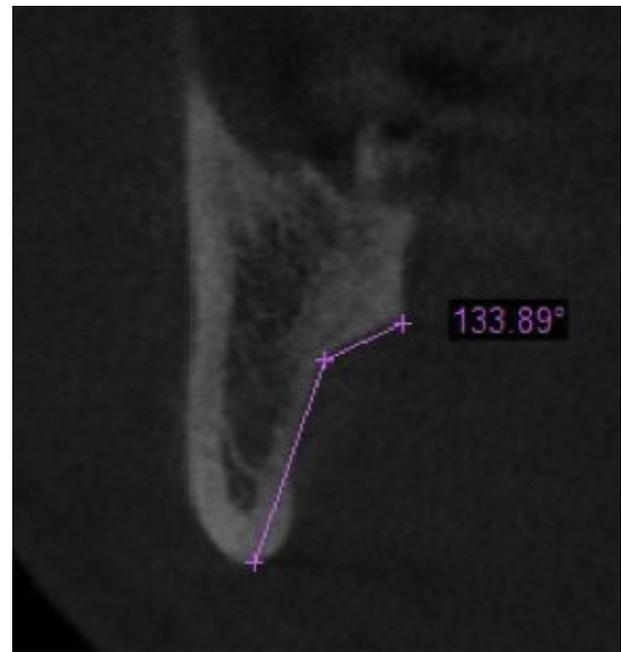


Figure 5 Angle 2 (Ang 2): the angle between (1) the most prominent point of the lingual alveolar bone; (2) the deepest point of the lingual balcony; and (3) the most inferior point of the mandibular basis.

Cases with atypical anatomical considerations, such as a distolingual tooth inclination or a thin or no lingual cortex or curved roots, can displace the fragments to the soft tissues.^{4,12} Inadequate clinical and radiographic examinations and incorrect technique are risk factors for displacement of the mandibular third molars into the adjacent anatomical spaces.^{14,15} Some authors have reported fractures of the lingual plate of the alveolar bone because of a thin lingual plate or an improperly applied force vector by the practitioner during surgery as the major reason of dislocation of the lower third molars to the adjacent anatomical spaces.^{5,10,12,16} We think less angulation values of Ang 1 and Ang 2 would allow an improper surgical application of force vector on nonadvantageous lingual morphology.

The size and morphology of the mandible and the location of the mandibular canal were determined clearly using cross-sectional computed tomography images.¹⁷ The usefulness of CBCT has been described in endodontology, implantology, periodontology, and oral surgery.¹⁸⁻²¹ In oral surgery practice, CBCT images are used mostly for evaluating the mandibular canal and third molar or dental implant relationships.^{6,17,19,22-26} Efficiency and financial costs of CBCT instead of panoramic radiographs for assessment of impacted mandibular third molars were discussed in previous studies and their conclusion were that CBCT scans for routine third molar extractions might be unnecessary.²⁷⁻²⁹ The discussed parameter was mostly tooth-mandibular canal relations. As panoramic radiographs could be an alternate to CBCT for this parameter, anatomical variations of lingual undercut could only be noticed and evaluated by CBCTs.

Studies of implant positioning and bone morphology have mentioned lingual undercuts at a point.^{17,30-32} These

Table 1 Incidence of position versus Emes classification.

Position/Emes	Vertical	Mesioangular	Horizontal	Distoangular	Total
A	41.00	18.00	10.00	5.00	74
B	11.00	3.00	2.00	0.00	16
C	4.00	2.00	4.00	0.00	10
Total	56	23	16	5	

Table 2 Total bone thickness (BT), angle 1, and angle 2.

Total (n = 100)	Mean ± SD	Min	Max
BT (mm)	1.03 ± 1.09	-3.09	4.4
Angle 1 (°)	140.61 ± 12.70	105.08	168.21
Angle 2 (°)	153.44 ± 13.64	120.57	177.51

Values are presented as mean ± standard deviation (SD).

Table 3 Comparison of bone thickness (BT), angle 1 and angle 2 measurements by sex.

		Male/female (n = 100)		
		Mean ± SD	Min	Max
BT (mm)	Male (n = 54)	1.12 ± 0.88	-1.08	3.53
	Female (n = 46)	0.93 ± 1.3	-3.09	4.4
	P	0.379		
Angle 1 (°)	Male (n = 54)	138.25 ± 13.35	105.08	167.71
	Female (n = 46)	143.37 ± 11.42	114.46	168.21
	P	0.044*		
Angle 2 (°)	Male (n = 54)	150.5 ± 13.39	120.57	174.4
	Female (n = 46)	156.88 ± 13.26	131.08	177.51
	P	0.019*		

Student *t* test. Values are presented as mean ± standard deviation (SD).

Values of *P* < 0.05 were considered to indicate statistical significance. * *P* < 0.05.

Table 4 Comparison of bone thickness (BT), angle 1 and angle 2 measurements by right and left side.

		Right/left (n = 100)		
		Mean ± SD	Min	Max
BT (mm)	Right (n = 54)	1.01 ± 1.12	-3.09	4.4
	Left (n = 46)	1.06 ± 1.07	-1.25	3.53
	P	0.829		
Angle 1 (°)	Right (n = 54)	139.69 ± 12.78	105.08	167.71
	Left (n = 46)	141.68 ± 12.67	106.06	168.21
	P	0.438		
Angle 2 (°)	Right (n = 54)	154.13 ± 13.74	120.57	177.51
	Left (n = 46)	152.63 ± 13.63	130.71	177.44
	P	0.586		

Students *t* test. Values are presented as mean ± standard deviation (SD).

Values of *P* < 0.05 were considered to indicate statistical significance. * *P* < 0.05.

Table 5 Comparison of bone thickness (BT), angle 1 and angle 2 measurements by Emes classification.

		Emes A–B–C (n = 100)		
		Mean ± SD	Min	Max
BT (mm)	A (n = 74)	1.51 ± 0.75	0.43	4.4
	B (n = 16)	0 ± 0	0	0
	C (n = 10)	-0.85 ± 0.92	-3.09	-0.54
	P	0.001*		
Angle 1 (°)	A (n = 74)	141.16 ± 13.14	105.08	168.21
	B (n = 16)	139.56 ± 10.81	111.24	155.64
	C (n = 10)	138.19 ± 12.96	114.46	151.08
	P	0.740		
Angle 2 (°)	A (n = 74)	153.42 ± 12.56	130.71	177.51
	B (n = 16)	150.83 ± 16.22	120.57	174.4
	C (n = 10)	157.73 ± 17.21	131.46	177.32
	P	0.459		
	A (n = 74)	294.58 ± 22.23	236.24	339.69

One-way ANOVA. Values are presented as mean ± standard deviation (SD). Values of *P* < 0.05 were considered to indicate statistical significance. * *P* < 0.05.

Table 6 Comparison of bone thickness (BT), angle 1 and angle 2 measurements by position of teeth.

		Position		
		Mean ± SD	Min	Max
BT (mm)	V (n = 56)	1.03 ± 0.96	-1.08	3.53
	M (n = 23)	1.36 ± 1.12	-0.56	4.4
	H (n = 16)	0.56 ± 1.5	-3.09	2.37
	D (n = 5)	1.10 ± 0.24	0.83	1.47
	P	0.167		
Angle 1 (°)	V (n = 56)	141.71 ± 12.73	106.06	168.21
	M (n = 23)	139.53 ± 13.52	111.24	167.71
	H (n = 16)	138.66 ± 12.61	105.08	164.45
	D (n = 5)	139.45 ± 11.15	122.71	150.95
	P	0.805		
Angle 2 (°)	V (n = 56)	156.0 ± 13.53	130.71	177.51
	M (n = 23)	151.23 ± 13.81	120.57	172.66
	H (n = 16)	150.0 ± 13.79	126.8	171.95
	D (n = 5)	145.96 ± 9.49	135.74	156.26
	P	0.165		
	V (n = 56)	297.7 ± 22.58	236.77	332.81

One-way ANOVA. Values are presented as mean ± standard deviation (SD). Values of *P* < 0.05 were considered to indicate statistical significance. * *P* < 0.05.

D = distoangular; H = horizontal; M = mesioangular; V = vertical.

studies focused on evaluating the lingual undercut levels on premolar and molar teeth regions of an edentulous alveolus, but no research has examined the third molar region in this regard. Momin et al³² were the first to separately report the distances between the inner border of the lingual cortical bone and the outer surface of the third molar root (space) and between the width between the inner and outer borders of the lingual cortical bone (lingual cortical width). They thought to determine the width and morphology of the mandible in the impacted third molar

region and to identify the location of the mandibular canal prior to planning impacted third molar operations. They measured this distance from cross-sectional images in which the cortical bone was thinnest at the lingual side in the third molar region, as in our study. They found the mean distances of the space and lingual cortical width were 0.31 mm and 0.68 mm, respectively, yielding a total of 0.99 mm, which is very close to our findings (1.03 mm). Momin et al³² classified the morphology of the mandible at the third molar region as: type D (round), 49%; type E (lingual extended), 18%; and type F (lingual concave), 32%. We preferred Chan et al's classification⁶ in our study as it was more appropriate for our research.

Emes et al⁵ were the only researchers who focused on the possible lingual displacement of mandibular third molars to the submandibular region by evaluating the lingual cortical bone thickness from the tooth roots to the lingual soft tissues. They grouped the relationship between the roots and the lingual soft tissues into three types: relation type A, in which there was an amount of bone between the root and the soft tissues; relation type B, in which there was no bone between the root and the soft tissues; and relation type C, in which the root protruded into the soft tissues. They evaluated 12.5% of the teeth as type B and 12.5% as type C when the apices were considered in the measurement, and they evaluated 15.6% of the teeth as type B and 15.6% as type C when the apical halves of the roots were considered in the measurement. In our study, 16% of the teeth were classified as type B and 10% were classified type C under the Emes classification. Emes et al⁵ noted that contact of the roots with lingual tissues occurred in a total of 34.3% cases; this figure was 26% in our study. Emes et al⁵ detected an average distance of 1.03 mm between the apices of the lower third molars and one of 0.65 mm between the apical half of the root and the lingual soft tissues. They treated the root apex point and half the root point as reference points to measure the distance. We measured the distance from the roots of the lower third molars to the lingual soft tissues in the coronal CBCT section in which the slice of that root was closest to the soft tissue (BT) and found a distance of 1.03 mm.

Emes et al⁵ noted that their study was limited with regard to lingual anatomy and morphology. Although they claimed that the presence of the lingual undercut was an anatomical property that also could affect the distance between the third molar roots and the lingual soft tissues, depending on the position of the tooth, they did not evaluate lingual undercuts in their study. As we evaluated the effect of anatomical angulation of the lingual undercut to the impacted mandibular third molar roots, there were no noted statistically significant differences in Ang 1 or Ang 2 according to the Emes classification⁵ among types A, B, and C (Table 5). Therefore, according to our findings, the positioning of mandibular third molar roots in the floor of mouth was not related to the variations in lingual undercut.

Chan et al⁶ studied the prevalence and the degree of lingual concavity in the edentulous first molar region from CBCT scans of the mandibles and reported that a lingual undercut was a common finding and can be difficult to manage. They focused on a lingual undercut affecting the

intended angulation in the implant positioning in the alveolus during the drilling procedure by measuring lingual undercut angles. They classified three types of lingual undercut morphology: convex (C), parallel (P), and undercut (U). We found 100% of patients to be type U under this classification.

There was no statistically significant sex difference between the BTs of the groups. However, Ang 1 and Ang 2 angles in female patients were statistically significantly higher than those in male patients. On both technical and logical grounds, we believe that smaller angles are more dangerous, theoretically. However, the literature does not support any obvious tendency toward dislocation of the third molars in men.^{1,3,4,9-19}

There was also no statistically significant right or left side difference between BT, Ang 1 and Ang 2 of the groups. When the cases involved left-sided dislocations are discussed, right-handed clinicians or dental units designed for right-handed clinicians may cause visualization issues and may lead a practitioner to apply improper force and/or an inappropriate force vector, which might displace the root or fragment into the soft tissues. However, extant case reports do not favor either side, the present findings suggest only a theoretical risk of lingual root displacement during extraction.^{1,3,4,9-19}

A review of the literature revealed no study regarding lingual undercut angulation in the region of the third molar extraction. The reason for the selection of the angles chosen by the authors for this present study is that they believe the reference points generating the measured angles on coronal sections of CBCT images are easily markable by any clinician in their own practice. Patients with lower angulation values may be considered to need much more attention theoretically and should be given extra care on extraction, as lower angulation values might allow an improper surgical application of force vector on unadvantageous lingual morphology.

As panoramic radiographs could be an alternate to CBCT for many procedures, anatomical variations of lingual undercut could only be noticed and evaluated by CBCT. Pre-operative CBCT images could be taken before impacted third molar surgeries, and the narrow angulation of the lingual balcony region and the relationship between roots and lingual soft tissues could be noted to avoid undesirable dislocation complications by giving extra caution on extraction. We think less angulation values of Ang 1 and Ang 2 would allow an improper surgical application of force vector on nonadvantageous lingual morphology. Ang 1 and Ang 2 angles in female patients were higher than those in male patients. Clinical experience shows that the improper surgical application of a force vector is of greater importance than lingual morphology and the distance of the roots to the lingual soft tissues. As lingual displacement of impacted lower third molar tooth or root is depending on factors such as clinical experience, incorrect technique, curved roots and thin lingual cortex; angulation values of lingual balcony shows only the theoretical risk of lingual root displacement during extraction. According to our findings, there is not any relationship in the floor of mouth between the position of mandibular third molar roots and variations in lingual undercut.

Conflicts of interest

No potential conflict of interest is disclosed.

References

- Primo BT, Stringhini DJ, Klüppel LE, Da Costa DJ, Rebellato LBR, de Moraes RS. Delayed removal of maxillary third molar displaced into the infratemporal fossa. *Rev Esp Cir Oral Maxillofac* 2014;36:78–81.
- Osborn TP, Frederickson G, Small IA, Torgerson TS. A prospective study of complications related to mandibular third molar surgery. *J Oral Maxillofac Surg* 1985;43:767–9.
- Jolly SS, Rattan V, Rai SK. Intraoral management of displaced root into submandibular space under local anaesthesia—a case report and review of literature. *Saudi Dent J* 2014;26:181–4.
- Huang IY, Chen CM, Chang SW, Yang CF, Chen CH, Chen CM. Surgical management of accidentally displaced mandibular third molar into the pterygomandibular space: a case report. *Kaohsiung J Med Sci* 2007;23:370–4.
- Emes Y, Oncu B, Aybar B, et al. Measurement of the lingual position of the lower third molar roots using cone-beam computed tomography. *J Oral Maxillofac Surg* 2015;73:13–7.
- Chan HL, Brooks SL, Fu JH, Yeh CY, Rudek I, Wang HL. Cross-sectional analysis of the mandibular lingual concavity using cone beam computed tomography. *Clin Oral Implants Res* 2011;22:201–6.
- Howe GL. Tooth removed from the lingual pouch. *Br Dent J* 1958;104:283–4.
- Shabakbari R, Mortazavi H, Eshghpour M. First report of accidental displacement of mandibular third molar into infratemporal space. *J Oral Maxillofacial Surg* 2011;69:1301–3.
- Medeiros N, Gaffre G. Accidental displacement of inferior third molar into the lateral pharyngeal space: case report. *J Oral Maxillofacial Surg* 2008;66:578–80.
- Yalcin S, Aktas I, Emes Y, Atalay B. Accidental displacement of a high-speed handpiece bur during mandibular third molar surgery: a case report. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105:29–31.
- Tumuluri V, Punnia-Moorthy A. Displacement of a mandibular third molar root fragment into the pterygomandibular space. *Aust Dent J* 2002;47:68–71.
- Arasa LA, Figueiredo R, Escoda CG. Iatrogenic displacement of third molar roots into the sublingual space: report of 6 cases. *J Oral Maxillofac Surg* 2012;70:107–15.
- Campbell A, Costello BJ. Retrieval of a displaced third molar using navigation and active image guidance. *J Oral Maxillofac Surg* 2010;68:480–5.
- Sverzut CE, Trivellato AE, Sverzut AT, de Matos FP, Kato RB. Removal of a maxillary third molar accidentally displaced into the infratemporal fossa via intraoral approach under local anesthesia: report of a case. *J Oral Maxillofac Surg* 2009;67:1316–20.
- Selvi F, Cakarer S, Keskin C, Ozyuvaci H. Delayed removal of a maxillary third molar accidentally displaced into the infratemporal fossa. *J Craniofac Surg* 2011;22:1391–3.
- Papadogeorgakis N, Pigadas N. Surgical removal of a lower semimpacted wisdom tooth displaced in the pterygomandibular space. *Hell Period Stomat Gnathopathoprosopike Cheir* 1990;5:125–9.
- Watanabe H, Momin MA, Kurabayashi T, Hideki H. Mandible size and morphology determined with CT on a premise of dental implant operation. *Surg Radiol Anat* 2010;32:343–9.
- Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. *Int Endod J* 2007;40:818–30.
- Nickenig HJ, Eitner S. Reliability of implant placement after virtual planning of implant positions using cone beam CT data and surgical (guide) templates. *J Craniomaxillofac Surg* 2007;35:207–11.
- Misch KA, Yi ES, Sarment DP. Accuracy of cone beam computed tomography for periodontal defect measurements. *J Periodontol* 2006;77:1261–6.
- Nakagawa Y, Kobayashi K, Ishii H, et al. Preoperative application of limited cone beam computerized tomography as an assessment tool before minor oral surgery. *Int J Oral Maxillofac Surg* 2002;31:322–6.
- Almog DM, LaMar J, LaMar FR, LaMar F. Cone beam computerized tomography-based dental imaging for implant planning and surgical guidance. Part 1 Single implant in the mandibular molar region. *J Oral Implantol* 2006;32:77–81.
- Neves FS, Souza TC, Almeida SM, Haiter-Neto F, Freitas DQ, Bóscolo FN. Correlation of panoramic radiography and cone beam CT findings in the assessment of the relationship between impacted mandibular third molars and the mandibular canal. *Dentomaxillofac Radiol* 2012;41:553–7.
- Peker I, Sarikir C, Toraman Alkurt M, Zor ZF. Panoramic radiography and cone-beam computed tomography findings in preoperative examination of impacted mandibular third molars. *BMC Oral Health* 2014;14:71–5.
- Ghaemina H, Meijer GJ, Soehardi A, Borstlap WA, Mulder J, Bergé SJ. Position of the impacted third molar in relation to the mandibular canal. Diagnostic accuracy of cone beam computed tomography compared with panoramic radiography. *Int J Oral Maxillofac Surg* 2009;38:964–71.
- Ghaemina H, Meijer GJ, Soehardi A, et al. The use of cone beam CT for the removal of wisdom teeth changes the surgical approach compared with panoramic radiography: a pilot study. *Int J Oral Maxillofac Surg* 2011;40:834–9.
- Matzen LH, Wenzel A. Efficacy of CBCT for assessment of impacted mandibular third molars: a review—based on a hierarchical model of evidence. *Dentomaxillofac Radiol* 2015;44:20140189.
- Petersen LB, Olsen KR, Matzen LH, Vaeth M, Wenzel A. Economic and health implications of routine CBCT examination before surgical removal of the mandibular third molar in the Danish population. *Dentomaxillofac Radiol* 2015;44:20140406.
- Petersen LB, Olsen KR, Christensen J, Wenzel A. Image and surgery-related costs comparing cone beam CT and panoramic imaging before removal of impacted mandibular third molars. *Dentomaxillofac Radiol* 2014;43:20140001.
- Momin MA, Koji H. Estimated mandible size and morphology using CT for dental implantation. *JICD* 2012;43:67–74.
- Braut V, Bornstein MM, Kuchler U, Buser D. Bone dimensions in the posterior mandible: a retrospective radiographic study using cone beam computed tomography. Part 2—analysis of edentulous sites. *Int J Periodontics Restorative Dent* 2014;34:639–47.
- Momin MA, Matsumoto K, Ejima K, et al. Correlation of mandibular impacted tooth and bone morphology determined by cone beam computed tomography on a premise of third molar operation. *Surg Radiol Anat* 2013;35:311–8.