Acta Clin Croat 2019; 58:693-700
doi: 10.20471/acc.2019.58.04.16

Original Scientific Paper

A DETAILED CBCT STUDY OF 'CORONOID FORAMINA' AND ACCESSORY FORAMINA OF THE MANDIBLE: A UNIQUE ANATOMIC VARIATION

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SUMMARY – The aim of the study was to evaluate accessory foramina (AF) located on the medial aspect and to present a unique finding of 'coronoid foramina' (CF) along with AF on the mandible. The cone beam computed tomography images of the mandible in 979 patients were retrospectively evaluated for the presence of CF and AF. AF was found in 39 (3.98%) patients. AF located on the medial surface below and above mandibular foramen was found in 15.38% and 84.62% of patients, respectively. CF was confirmed in 20 (2.04%) patients. Mandibular AF is important for surgical procedures in the posterior region of the mandible and for mandibular nerve anesthesia. This study including CF will be useful for further studies due to the lack of literature on the issue.

Key words: *Mandible; Mandibular nerve; Cone-beam computed tomography*

Introduction

The location and configuration of the mandibular canal are significant for surgical treatments in the mandible, such as impacted third molar extraction, dental implant practice, and sagittal split ramus osteotomy[1]. The mandibular canal begins with the mandibular foramen (MF). If MF is single, it runs anteriorly arching along the trabecular bone to the region of medial incisor alveolus. Mandibular canal is wide near the mental foramen, and begins to narrow medially[2,3]. The inferior alveolar nerve is the main sensory branch of the mandibular nerve posterior trunk. Teeth and gingiva, and additionally mucosa, skin of lower lip and chin are supplied by this nerve. It anteriorly exists in the mandibular canal[4].

The entity of the nerve is embryologically assumed to represent a presupposition to cause osteogenesis, followed by mandibular foramen and canal formation. During normal formation of the mandible, the accessory nerve is positioned on the inner side of the new formation of the mandible with Meckel's cartilage[5].

Variations of the mandible such as the mandibular accessory foramina (AF) cause some implications in clinical practice and may lead to some complications if not previously determined [6]. AFs can involve nerve fibers or blood vessels. If they involve nerve fibers, local anesthesia may fail because of the nerve branches passing through the drug. Because it may contain accessory blood vessels, this can cause difficulty to control intraosseous hemorrhage[7].

Mandibular AF is an opening apart from alveolar sockets, mandibular and mental foramina, and con-

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Received September 25, 2018, accepted January 14, 2019

stant structure in the mandible[8]. It is commonly observed in the posterior mandible and symphysis region. It is more frequently found on the medial surface of the mandible than on the lateral surface[9]. Bilateral symmetry is frequent but variations are observed in size, number and shape[10].

The term 'coronoid' derives from the Greek word for raven or crow. This is a bone projection that looks like a crow's beak. The term 'process' comes from Latin word which means 'to move forward', signifying a bone projection[11].

Knowledge the presence of such foramina is clinically important because it can lead to diagnostic and therapeutic misinterpretations. The unawareness of these anatomic variations may cause adverse effects and failure in anesthesia during surgical procedures[10].

Cone-beam computed tomography (CBCT) provides finely exhaustive scanning of the osseous structures with high contrast and burn out does not exist. Additionally, fine osseous structure may be evaluated even without lost data[12]. So, nowadays, CBCT is more effectively used to confirm the presence of AF which may not be evaluated with the conventional imaging modalities[13].

Regarding the lack of literature, especially on coronoid foramina (CF), our study was undertaken to evaluate the contents and incidence of mandibular AF and CF in a Turkish population and to lay emphasis on this unfamiliar anatomical structure.

Material and Methods

Images of 979 patients having undergone CBCT examination of the mandible for several reasons from the archives of the Health Sciences University, Gulhane Faculty of Dentistry, Department of Dentomaxillofacial Radiology were evaluated. Patient gender and age were recorded. There were 450 (45.97%) females and 529 (54.03%) males, age range 12-81, mean age 36.76 years. Fractures, pathologies such as cysts, tumors and images with artifacts were excluded; thus, 290 of 1269 images were excluded because of insufficient quality, low field of view size, fracture or pathologies in the posterior region of mandible.

Between April 2013 and December 2017, CBCT scans were obtained using a 3D Accuitomo 170 CBCT device (Morita Manufacturing Corp., Kyoto, Japan) with 90 kV and 5 mA. Exposure time of 17.5 seconds was used for all images. The CBCT machine had 140x100 mm field of view, and the voxel size was 0.08 mm. All images were analyzed with software (i-Dixel one volume viewer 2.0) for reconstruction of sagittal, axial, coronal and three-dimensional images and each image was retrospectively evaluated by a single oral and maxillofacial radiologist. In doubtful cases, a dentomaxillofacial radiologist (KG) with at least 10-year experience was consulted. The patient was placed in such a position that the occlusal plan would be parallel to the floor by using ear rods and a chinrest during scanning. The incidence and location of AF and CF were noted. The distance between MF and AF was measured with CBCT unit software (Figs. 1 and 2). All evaluations and measurements were performed on a 15.6-inch monitor with resolution of 1366x768.

Statistical analysis

The data obtained in this study were analyzed using IBM SPSS Statistics Version 22 package program. Descriptive statistics such as number, mean, standard deviation for the variables are shown in tables. Shapiro Wilk's test was used because of the unit numbers while investigating normal distribution of the variables. On interpretation of the results, the level of significance was set at 0.05; in case of $p<0.05$, the variables did not follow normal distribution, whereas in case of $p>0.05$ the variables did follow normal distribution. Mann Whitney U test was used because the variables did not differ from normal distribution. The χ^2 analysis was applied when relations between the groups of nominal variables were examined. Fisher exact test was used when the expected values in the 2x2 tables did not have sufficient volume and Pearson χ^2analysis was applied with RxC tables using Monte Carlo simulation (20% of the expected value is smaller than 5, so χ^2 analysis was done with the help of Monte Carlo simulation). On interpretation of the results, the level of significance was set at 0.05, i.e. $p<0.05$ values were considered significant.

Results

Accessory foramina were found in 3.98% and CF in 20 (2.04%) patients. CF was present unilaterally in 14 (70%) and bilaterally in 6 (30%) patients. The mean age of study patients was 36.76, age range 12-81 years. The mean distance between MF and AF was 14.59 mm.

Table 1. Frequency distribution of demographic and clinical data

		n	%
Gender	Male	529	54.03
	Female	450	45.97
	Total	979	100
Coronoid foramina	No	959	97.96
	Yes	20	2.04
	Total	979	100
Coronoid foramina localization	Right	4	20
	Left	10	50
	Bilateral	6	30
	Total	20	100
Accessory foramina	No	940	96.02
	Yes	39	3.98
	Total	979	100
Accessory foramina localization	Right	11	28.21
	Left	24	61.54
	Bilateral	4	10.26
	Total	39	100
	Below mandibular foramen	6	15.38
	Above mandibular foramen	33	84.62
	Total	39	100

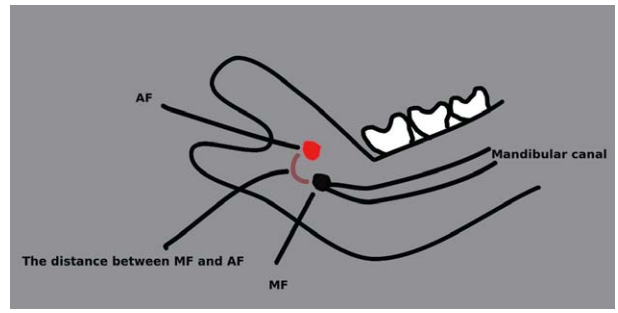

Fig. 1. A drawing of the mandible illustrating mandibular accessory foramina and mandibular foramen (based on the study by Narayana and Prashanthi[21]).

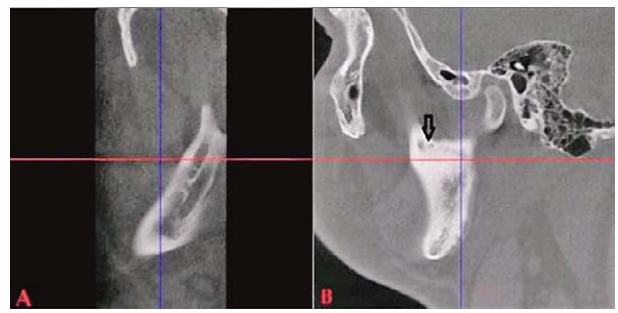

Fig. 2. Cone beam computed tomography images: (A) bifid mandibular canal; (B) coronoid foramina.

Table 2. Frequency distribution of coronoid foramina according to other variables

		Coronoid foramina					
		Not found		Found		Total	
		n	%	n	%	n	%
Gender	Male	520	54.22	9	45	529	54.03
	Female	439	45.78	11	55	450	45.97
	Total	959	100	20	100	979	100
Accessory foramina localization	No	920	95.93	20	100	940	96.02
	Yes	39	4.07	0	0	39	3.98
	Total	959	100	20	100	979	100
	Right	11	28.21	0	0	11	28.21
	Left	24	61.54	0	0	24	61.54
	Bilateral	4	10.26	0	0	4	10.26
	Total	39	100	0	0	39	100
	Below mandibular foramen	6	15.38	0	0	6	15.38
	Above mandibular foramen	33	84.62	0	0	33	84.62
	Total	39	100	0	0	39	100

Table 3. Frequency distribution of accessory foramina localization according to other variables

		Accessory foramina					
		Absent		Present		Total	
		n	%	n	%	n	%
Gender	Male	503	53.51	26	66.67	529	54.03
	Female	437	46.49	13	33.33	450	45.97
	Total	940	100	39	100	979	100
Coronoid foramina	No	920	97.87	39	100	959	97.96
	Yes	20	2.13	0	0	20	2.04
	Total	940	100	39	100	979	100
Coronoid foramina localization	Right	4	20	0	0	4	20
	Left	10	50	0	0	10	50
	Bilateral	6	30	0	0	6	30
	Total	20	100	0	0	20	100
Accessory foramina localization	Right	0	0	11	28.21	11	28.21
	Left	0	0	24	61.54	24	61.54
	Bilateral	0	0	4	10.26	4	10.26
	Total	0	0	39	100	39	100
	Below mandibular foramen	0	0	6	15.38	6	15.38
	Above mandibular foramen	0	0	33	84.62	33	84.62
	Total	0	0	39	100	39	100

Table 4. Results of χ^2-test on the relationship between accessory foramina localization and other variables

		n	%	χ^2-test	p
Gender	Male	26	66.67	0.331	0.565
	Female	13	33.33		
	Total	39	100		
Accessory foramina localization	Right	11	28.21	Fisher exact test	0.706
	Left	24	61.54		
	Bilateral	4	10.26		
	Total	39	100		
	Below mandibular foramen	6	15.38	Fisher exact test	0.37
	Above mandibular foramen	33	84.62		
	Total	39	100		

Analysis for CF revealed its absence in 97.96% and presence in 2.04% of patients. In those with CF, 50% were on the left, 30% bilateral and 20% on the right. AF was absent in 96.02% and present in 3.98% of patients. According to AF localization, 61.54% were on the left, 28.21% on the right and 10.26% bilateral. In 84.62% and 15.38% of patients with AF, it was positioned above and below MF, respectively (Table 1).

There was no statistically significant difference in the presence of CF according to age ($p>0.05$); however, patients with CR were older, but the difference was not statistically significant. Of the patients with no CF, 54.22% were male and 45.78% female. Of those with CF, 45% were male and 55% female. Of the patients without CF, 95.93% had no AF, whereas 4.07% had AF. AF was absent in all patients with CF (100%).

Table 5. Results of χ^2-test on the relationship between accessory foramina localization and other variables

		Accessory foramina (below/above mandibular foramen)							
		Below		Above		Total			
		n	%	n	%	n	%	χ^2-test	p
Gender	Male	3	50	23	69.7	26	66.67	Fisher exact test	0.38
	Female	3	50	10	30.3	13	33.33		
	Total	6	100	33	100	39	100		
Accessory foramina localization	Right	3	50	8	24.24	11	28.21	*	0.293
	Left	2	33.33	22	66.67	24	61.54		
	Bilateral	1	16.67	3	9.09	4	10.26		
	Total	6	100	33	100	39	100		

*Monte Carlo method used for analysis when the number of subjects *per* eye in χ^2 analysis was insufficient.

Table 6. Results of χ^2-test on the relationship between age groups and coronoid/accessory foramina

		Age (yrs)											
		≤20		20-39		40-59		60≥		Total			
		n	%	n	%	n	%	n	%	n	%	χ^2-test	p
Coronoid foramina	Not found	260	98.86	279	97.55	302	97.42	118	98.33	959	97.96	1.837	0.607
	Found	3	1.14	7	2.45	8	2.58	2	1.67	20	2.04		
	Total	263	100	286	100	310	100	120	100	979	100		
Accessory foramina	Not found	252	95.82	271	94.76	299	96.45	118	98.33	940	96.02	3.054	0.383
	Found	11	4.18	15	5.24	11	3.55	2	1.67	39	3.98		
	Total	263	100	286	100	310	100	120	100	979	100		

Left AF was found in 61.54%, right AF in 28.21% and bilateral AF in 10.26% of patients without CF. When MF was evaluated, 84.62% of patients without CF were found to have AF above MF and 15.38% below MF. Sex distribution revealed that 53.51% of patients without AF were male and 46.49% female. Of the patients with AF, 66.67% were male and 33.33% female. Among patients without AF, CF was absent in 97.87% and present in 2.13%. CF was absent in 100% of patients with AF. When CF was evaluated, left CF was present in 50%, bilateral CF in 30% and right CF in 20% of patients without AF (Tables 2 and 3). There was no statistically significant relationship between localization and other variables (p>0.05). Results of the χ^2-test on the relationship between localization and other variables are shown in Table 4.

There was no statistically significant relationship between AF location and other variables (p>0.05). Although not statistically significant, 50% of patients with AF positioned below MF and 69.7% of patients with AF positioned above MF were male; 50% of patients with AF positioned below MF and 30.3% of patients with AF positioned above MF were females. Detailed information is shown in Table 5.

There was no statistically significant relationship between age groups and other variables (p>0.05). Results of the χ^2-test on the relationship between age groups and CF are shown in Table 6. CF was absent in 98.3% of male and 97.56% of female patients. CF was present in 1.7% of male and 2.44% of female patients. Sex distribution showed 95.09% of males and 97.11% of females to have no AF, whereas 4.91% of males and 2.89% of females had AF. According to localization, CF was absent in 100% of the right, left and bilateral AF groups. AF was present in 100% of the right, left and bilateral CF groups. There was no CF in 100% of patients with AF below and above MF.

Discussion

Knowing variations in the mandibular canal is very important for dental implant and several surgical op-

erations[1]. Embryologic number variations of the mandibular canal may be clarified because in the early development, the inferior alveolar nerve innervates the anterior teeth, premolar and molar region independently[14]. The first description of AF was associated with irrigation and veined drainage of deciduous teeth and of the alveolar processes in formation. This canal has progressive obliteration from birth to the first year of life. Persistence of a foramen to the adult period is considered anatomic variation[15].

The phylogenetic hypothesis for CF of the mandible implies that CF has not yet been observed bilaterally in humans or in other proboscideans except for elephantines[10]. Ferretti and Debruyne[16] in their article from 2011 commented a sample of 'Elephas Maximus' as having a CF which "merged with the alveolus of the distal most erupting molar" to form a coronoid canal. This coronoid canal was first described by Tassy and Shoshani as a synapomorphy of paenungulates in 1988[17]. Further studies of human morphology are necessary to understand better this anatomic variation.

In the literature, AF incidence rates are different due to the investigation of different numbers of mandibles, methods, sample size and criteria[8]. Przysatńska and Bruska[8] report that at least one AF was observed in 96% of adult mandibles investigated. Gupta *et al.*[7] report on AF found in 48% of cases. Shalini *et al.*[18] found double AF unilaterally in 17 (8.33%) and bilaterally in 3 (1.5%) mandibles. Suazo *et al.*[19] report on 42.6% incidence of mandibular AF, whereas Choi and Han[20] recorded a lower AF incidence of 1.35%. Narayana and Prashanthi[21] report on only one large mandibular AF (0.3%) found in 335 dry mandibles. In our study, AF was observed in 3.98% of patients.

In 2005, Kilarkaje *et al.*[22] reported that the location of MF showed bilateral symmetry regardless of age. However, Freire *et al.*[15] recorded AF on the right and left sides in 17.12% and 16.22% of cases, respectively. In our study, AF was more frequently observed on the left side but there was no statistically significant relationship between localization and other variables.

Choi and Han[20] report that all double MF were located above the MF on the medial aspect of the mandible. In the study by Freire *et al.*[15], 27.93% and 43.24% of the mandibles presented at least one AF located on the medial surface in position below and above the MF, respectively. Unilaterally, mandibular AF were observed below and above the MF in 22.07% and 25.22% of the mandibles, respectively, and 5.85% and 18.02% bilaterally, respectively[15]. In our study, AF was found in 15.38% and 84.92% of patients on the medial surface in position below and above the MF, respectively.

In comparison to multi slice computed tomography (MSCT), CBCT has some major advantages. The first is that the radiation dose is relatively low[23,24]. The second reason is wide and effective use of CBCT in dental clinics, while MSCT usage is generally limited to hospitals. As a third reason, resolution in CBCT images was higher than in MSCT images[25]. So, we preferred using CBCT to evaluate AF and CF of the mandible in this study.

Dental implants have been used for more than 20 years in Turkey. The presumed rate of dental implant operations is about 350,000 *per* year. This number corresponds approximately to 4% of the total population. Although being on an increase, it is observed that the numbers of population-implant consumption in Turkey are far behind those recorded in developed countries worldwide[26]. In a pilot study from northern east Turkey, 1316 of 5000 patients had indications for tooth extraction[27]. Dentists should be guiding their patients and inform them about oral health protection such as tooth brushing[28]. Thus, it is possible to minimize the indications for tooth extraction in the community. However, in our country, the high rate of tooth extraction makes it even more important to know the variations of a relevant anatomic landmark such as the mandibular canal. Also, it has been reported that mandibular AF provides an easy way for tumor spread following radiotherapy[29,30]. If AF is present, the clinicians must be careful when planning radiotherapy[20].

Better information about variations of anatomic landmarks will help the surgeon prevent complications. For this reason, extensive and detailed preoperative radiologic assessment should be performed using proper imaging techniques. Besides, appropriate information on the anatomy will help dentists achieve success in treatment planning and prevent wrong interpretation and treatment[31].

In conclusion, bifid mandibular canal was previously found in 3.05% of patients in a Turkish population by use of CBCT[32]. We wanted to perform a more detailed investigation of the mandibular canal variations. To the best of our knowledge, there is only one case report on CF in the literature[10]. So, this will be the

first study of CF as an unfamiliar anatomic variation. Additional studies are needed to better understand and discuss the CF issue and we hope this study will be useful for future investigations.

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Sažetak

DETALJNA PROCJENA 'KORONOIDNIH FORAMENA' I POMOĆNIH FORAMENA MANDIBULE POMOĆU CBCT: JEDINSTVENA ANATOMSKA VARIJACIJA

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Cilj istraživanja bio je procijeniti pomoćne foramene (PF) smještene na medijalnom dijelu i prikazati jedinstven nalaz 'koronoidnih foramena' (KF) uz PF na mandibuli. Snimke mandibule u 979 pacijenata dobivene tehnikom CBCT (*cone beam computed tomography*) retrospektivno su procijenjene na prisutnost PF i KF. PF je nađen u 39 (3,98%) pacijenata. PF smješten na medijalnoj površini ispod i iznad mandibularnog foramena uvrđen je u 15,38% odnosno 84,62% pacijenata. KF je potvrđen u 20 (2,04%) pacijenata. Mandibularni PF je važan za kirurške zahvate u stražnjem dijelu mandibule, kao i za anesteziju mandibularnog živca. Zbog nedostatka literature o ovom pitanju, ovo istraživanje koje je obuhvatilo KF bit će korisno za buduće istraživanje u ovom području.

Ključne riječi: *Mandibula; Mandibularni živac; Cone-beam kompjutorizirana tomografija*