RESEARCH ARTICLE

Evaluation of mallear ligaments in different voxel resolutions using cone beam computed tomography

¹Cansu Gorurgoz, ¹Kaan Orhan, ²Enver Alper Sinanoglu and ³Ismail Hakan Avsever

¹Department of Dentomaxillofacial Radiology, Ankara University, Faculty of Dentistry, Ankara, Turkey; ²Department of Dentomaxillofacial Radiology, Health Sciences University, Gullhane Faculty of Dentistry, Ankara, Turkey; ³Department of Dentomaxillofacial Radiology, Kocaeli University, Faculty of Dentistry, Kocaeli, Turkey

Objectives: The aim of this study was to assess the visibility of discomalleolar ligament and anterior malleolar ligament together with anatomical morphometric measurements of petrotympanic fissure, and to determine whether the malleolar ligaments correlate with the bone compartment changes of temporomandibular joint.

Methods: Cone beam CT images of 275 patients were evaluated retrospectively. The visibility of discomalleolar and anterior malleolar ligaments were evaluated by two observers. The petrotympanic fissure was classified into four groups. Morphologic features of petrotympanic fissure and mandibular fossa were also measured in sagittal, axial and three-dimensional cone beam CT reconstructed images. Pearson's χ^2 test and Student's *t*-test were performed for statistical analysis of differences voxel sizes, age, gender, localization, temporomandibular joint and measurements ($p < 0.05$). Intra- and interobserver reliability was also performed.

Results: Type 3 petrotympanic fissure was more frequent in male, whereas females showed Type 1 and Type 2 petrotympanic fissure structures ($p < 0.05$). Anterior malleolar ligament visibility on cone beam CT images was statistically higher in bone compartment changes of temporomandibular joint. In cone beam CT images, petrotympanic fissure tunnel types 1, 2, 3 and 4 were seen in 11.5, 35.63, 51.34 and 1.53% of patients, respectively.

Conclusions: Knowledge of the anatomy may help in identifying temporomandibular joint pain and auditory symptoms due to temporomandibular disorder. Further cross-sectional studies with larger populations are needed to investigate the physiopathological relation of both disorders.

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Introduction

The temporomandibular joint (TMJ) is the smallest but the most complex joint of the human body that participates in all jaw movements, chewing, swallowing, breathing and speech functions. Previous studies revealed close relationships between TMJ and middle ear structure.¹⁻⁶ These relationships have been explained by the presence of discomalleolar ligament (DML),

sphenomandibular ligament (SML) and anterior malleolar ligament (AML).^{7,8}

DML is part of the anterior ligament of malleus. This ligamentous structure is sharing a common origin with AML, runs through a narrow bony space of the petrotympanic fissure (PF) that joins the articular disc of the TMJ and the malleus in the tympanic cavity. An adult cadaver study has shown that DML and AML are two distinct ligamentous structures.⁹ AML continues as a SML after passing through the petrotympanic fissure. Malleus connections of SML, AML and

Correspondence to: Dr Kaan Orhan, E-mail: call53@yahoo.com

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DML are different. However, the detailed structure of the temporomandibular ligaments, which are located between the PF and the tympanic cavity, neither fully understood nor evaluated.

The use of cone beam CT (CBCT) for TMJ studies has increased considerably in recent years. CBCT allows the evaluation of the bone components, joint space and pathology of the TMJ in three dimensions without superimposition. CBCT provides increased spatial resolution as compared to multislice CT (MSCT).¹⁰ Moreover, due to volume averaging and resolution limits, MSCT may overestimate the morphological evaluations. Hence, the possibilities and increasing access to CBCT imaging for surgical procedures are enabling the movement for this modality.⁷

Diagnostic imaging of lateral skull base requires high resolution due to small sized anatomic structures of interest; however, pathologic changes of these structures can have a large impact on health, including diminished hearing and balance.⁷ It is also difficult to interpret the PF because of narrow anatomical structure, and the ligaments passing through it. An understanding of the anatomy of their location is gaining importance with the rising popularity of endoscopic procedures with limited visibility.²

Considering the few number of studies evaluating these specific region via CBCT,^{11,12} the aim of this study was to assess the visibility of DML and AML together with anatomical morphometric measurements of PF using CBCT.

Methods and material

The study protocol carried out according to the principles described in the Declaration of Helsinki, including all amendments and revisions. The study was approved by the institution ethical committee (KOU-KAEK 2016/312). CBCT data of patients who recruited to outpatient clinics of two university hospitals for several reasons such as; temporomandibular disorder (TMD), pre-orthodontic treatment, impacted teeth surgery, airway basement without a history of any systemic diseases were retrospectively evaluated. Patients with evidence of bone disease (especially osteoporosis), relevant drug consumption, skeletal asymmetries or trauma, congenital disorders, a history of surgery as well as any tumour or malignancy were excluded from the study.

The patients divided into two groups, due to the presence of the osteoarthritic and bony changes in TMJ or not. Presented changes were; degeneration, flattening, erosion, cortical thinning in joint condyle, osteophyte, narrowing of the joint space, hypoplasia of the condyle. In total, 522 sides (right/left) in a total of 275 patients (171 female, 104 male) with an age range from 18 to 80 years (mean age 38.2 years) were enrolled in the study. Age groups were classified as follows: 18 to 35, 36 to 59, and 60 to 80 years.

CBCT imaging

CBCT images were taken with Planmeca Promax 3D Max CBCT (Planmeca Oy, Helsinki, Finland). As a protocol in both clinics, all CBCT scans were made according to a strict standardized scanning protocol; patients were placed in a stand-up vertical position, stabilized with head band and chin support, and monitored to ensure that they remained motionless throughout the duration of the scan. CBCT images were taken with Planmeca ProMax 3D Max (Helsinki, Finland) with following parameters; 96 Kvp, 8–12 mA, 9–15 s scan time, field of view (90×100 mm or 230×160 mm) and with two different voxel sizes (0.200 mm³, 0.400 mm³). On the axial views, the section on which the condylar process had its widest mediolateral diameter was used for the secondary reconstruction of the sagittal slices. In this axial section, a line parallel to the long axis of the condylar process was drawn and the sagittal images were reconstructed at 0.5 mm slice interval and 0.5 mm thickness. All constructions and measurements were performed using machine's own software (Romexis 3.7, Planmeca Oy, Helsinki, Finland) on a 21.3-inch flat-panel colour-active matrix TFT medical display (NEC Multi-Sync MD215MG, Munchen, Germany) with a resolution of 2048 × 2560 at 75 Hz and 0.17 mm dot pitch operated at 11.9 bits.

CBCT evaluations

All examinations and measurements were done twice by two observers. Before beginning, the radiographic evaluations in the study, 50 CBCT images other than this study, used to define and calibrate of the observers to the anatomy. Observers were blinded to the data of any other patients throughout the CBCT examinations.

First, all CBCT examinations were evaluated in terms of the visibility of DML and AML. Evaluation of DML and AML visibility will be done using 3-point scoring (Figure 1): 0- not visible, 1- possibly visible, 2- certainly visible.

The intra- and interobserver reliability for detection of ligaments were determined according to this 3-point scale with a consensus session. The final radiographic condition of each ligament obtained with consensus meeting between the two professionals. In case of any disagreement, a third observer was also included to the discussions for final classification.

Following, PF tunnel types were classified according to Sato et al study;^{11,12} with slightly modification in addition with a new type (Type 4) as; **Type 1**, wide tunnel-shaped structure;

Type 2, tunnel-shaped structure widely open in the entrance of the PF to the mandibular fossa and gradually thinning out in the tympanic cavity; **Type 3**, tunnel-shaped structure widely open in the entrance of the mandibular fossa, middle region with flat-shaped tunnel structure and narrow exit in the tympanic cavity; **Type 4**, tunnel-shaped structure widely open in the entrance of the mandibular fossa, gradually thinning, narrow exit in the tympanic cavity (Figure 2).

Figure 1 Scoring for DML and AML visibility. A: DML scoring is 2, B: DML scoring is 1, C: AML scoring is 2, D: AML scoring is 2, E: DML scoring is 2, F: DML and AML scoring 0. AML, anterior malleal ligament; DML, disco malleal ligament.

The anteroposterior diameter of mandibular fossa was performed on the central sagittal section of the condyle. The diameter of the PF at Reid's base line (the line between the infraorbital margin and the upper

margin of the external auditory meatus as radiology defined) was measured.¹¹ The measurements as follows:

- (1) The length from the center of the articular tubercle

Figure 2 Tunnel types for petrotympanic fissure. A: Type 1, B: Type 2, C: Type 3, D: Type 4. MF, mandibular fossa; PTF, petrotympanic fissure; T, temporal bone; TC, tympanic cavity.

Figure 3 Reconstruction of CBCT sections in a sample case. (A) Axial views in which the condylar process had its widest mediolateral diameter. (B) Measurement points for mandibular fossa (1), The length from the center of the articular tubercle to and the posterior part of glenoid process parallel to the sagittal plane (2), The distance from the spine of the sphenoid to the most lateral border of the mandibular fossa; (C) Central sagittal section of the condyle and (3) measurement of fossa width, which is the distance between the most inferior point on the articular eminence and the posterior part of glenoid process. (D) Measurements of petrotympanic fissure (4). The largest width of the petrotympanic fissure (5). The width of the petrotympanic fissure at the midpoint (6). The width of the petrotympanic fissure at the mandibular fossa (7), The distance from the entrance of the petrotympanic fissure to the malleus.

to and the posterior part of glenoid process parallel to the sagittal plane.

- (2) The distance from the spine of the sphenoid to the most lateral border of the mandibular fossa.
- (3) Anteroposterior diameter of mandibular fossa at parasagittal section.
- (4) The largest width of the petrotympanic fissure.
- (5) The width of the petrotympanic fissure at the midpoint.
- (6) The width of the petrotympanic fissure at the mandibular fossa.
- (7) The distance from the entrance of the petrotympanic fissure to the malleus. (Figure 3).

Statistical analysis

Statistically analyses were made among age groups, gender, side and TMD. For measurements, intra- and interexaminer validation measures conducted. To assess intraobserver reliability, the Wilcoxon matched-pairs signed rank test was used for repeat measurements. The interobserver reliability were determined by the intraclass correlation coefficient (ICC) and the coefficient of variation (CV) [$CV = (\text{standard deviation}/\text{mean}) \times 100\%$]. Values for the ICC range from 0 to 1. ICC

values greater than 0.75 show good reliability, and the low CV demonstrates the precision error as an indicator for reproducibility.¹³

Statistical analyses carried out using the IBM SPSS Statistics 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, v. 21.0. Armonk, NY: IBM Corp.) and MS-Excel 2007. Pearson's X^2 test and Student's t -test performed for statistical analysis of differences in voxel sizes, age, gender, localization, bone compartment changes of TMJ and measurements ($p < 0.05$).

Results

Intraobserver consistency

Repeated CBCT evaluation and measurements indicated no significant intraobserver difference for both observers ($p > 0.05$). Overall intraobserver consistency for Observer 1 rated at 85 and 91%, while the consistency for Observer 2 was found 89 and 92% between the evaluations and measurements, respectively. All measurements were found to be highly reproducible for both observers and no significant difference was obtained from two measurements of the observers ($p > 0.05$).

Interobserver consistency

The ICCs between Observer 1 and Observer 2, which ranged from 0.887 to 0.924. There was a high inter observer agreement, while a high ICC and low CV demonstrated that the procedure standardized between the evaluations and measurements of the observers. No statistical differences were found among observer's evaluations and measurements ($p < 0.05$). The final data calculated as the mean of all measurements.

Visibility of DML and AML

Of all patients, 55.4% patients were detected as having TMD while 44.6% patients had free of TMJ pathologies. PF tunnel types were classified as Type 1, 2, 3 and 4 with ratios of 11.5, 35.63, 51.34 and 1.53% respectively. Table 1 shows also the classification of the visibility of AML and DML. In total, 21.1% of the malleal ligaments were certainly visible on CBCT images whereas 79.9% of the ligaments were either not visible or possibly visible. No significant difference found in terms of localization (right/left) in any of these variables (Table 1). Moreover, there was also no significant difference

Table 1 Descriptive statistics AML/DML visibility

	ACRA	ACRB	ACRC	ACRD
RMLO	1565	2158	1635	1112
RMLO augmented	6579	5720	4786	5329
RCC	1561	2150	1641	1110
RCC augmented	6696	5759	4667	5317

AML, anterior malleal ligament; DML, discomalleal ligament; PF tunnel types and TMD according to localization.

Table 2 Descriptive statistics AML/DML visibility, tunnel types and TMD according to voxel sizes

	<i>Voxel sizes</i>						χ^2	
	<i>0.200 mm³</i>			<i>0.400 mm³</i>			χ^2	
	<i>n</i>	%		<i>n</i>	%		χ^2	<i>p</i>
Right AML	Not visible	65	62.5	115	71.0	180	67.7	
	Possibly visible	30	28.8	34	21.0	64	24.1	
	Certainly visible	9	8.7	13	8.0	22	8.3	
	Total	104	100.0	162	100.0	266	100.0	0.312
Right DML	Not visible	11	10.6	31	19.1	42	15.8	
	Possibly visible	71	68.3	104	64.2	175	65.8	
	Certainly visible	22	21.2	27	16.7	49	18.4	
	Total	104	100.0	162	100.0	266	100.0	0.151
Right PF Type	Type 1	14	13.5	13	8.0	27	10.2	
	Type 2	36	34.6	52	32.1	88	33.1	
	Type 3	50	48.1	95	58.6	145	54.5	
	Type 4	4	3.8	2	1.2	6	2.3	
Right TMD	Total	104	100.0	162	100.0	266	100.0	0.159
	Absent	44	42.3	81	50.0	125	47.0	
	Present	60	57.7	81	50.0	141	53.0	
	Total	104	100.0	162	100.0	266	100.0	0.221
Left AML	Not visible	62	65.3	106	65.8	168	65.6	
	Possibly visible	25	26.3	41	25.5	66	25.8	
	Certainly visible	8	8.4	14	8.7	22	8.6	
	Total	95	100.0	161	100.0	256	100.0	0.988
Left DML	Not visible	11	11.6	13	8.1	24	9.4	
	Possibly visible	58	61.1	113	70.2	171	66.8	
	Certainly visible	26	27.4	35	21.7	61	23.8	
	Total	95	100.0	161	100.0	256	100.0	0.313
Left PF Type	Type 1	16	16.8	17	10.6	33	12.9	
	Type 2	28	29.5	70	43.5	98	38.3	
	Type 3	50	52.6	73	45.3	123	48.0	
	Type 4	1	1.1	1	.6	2	.8	
Left TMD	Total	95	100.0	161	100.0	256	100.0	0.127
	Absent	39	41.1	69	42.9	108	42.2	
	Present	56	58.9	92	57.1	148	57.8	
	Total	95	100.0	161	100.0	256	100.0	0.778

AML, anteriomalleolar ligament; DML, discomalleolar ligament; PF, petrotympanic fissure; TMD, temporomandibular disorder;

Table 3 The measurements of morphologic features of PF and mandibular fossa

		Group					Independent samples test	
		<i>n</i>	<i>Mean</i>	<i>Median</i>	<i>Minimum</i>	<i>Maximum</i>	<i>SD</i>	
a	R	266	14.32	14.40	9.21	19.35	1.97	−3.048
	L	256	14.85	14.81	10.40	20.60	1.99	
	Total	522	14.58	14.59	9.21	20.60	1.99	
b	R	266	22.37	22.40	16.40	27.90	1.88	2.080
	L	256	21.92	21.80	15.59	25.05	2.91	
	Total	522	22.15	22.00	15.59	25.05	2.45	
c	R	266	14.36	14.25	7.69	20.85	2.39	1.024
	L	256	14.14	14.01	8.17	21.60	2.43	
	Total	522	14.25	14.20	7.69	21.60	2.41	
d	R	266	2.42	2.39	1.13	4.53	0.54	−0.252
	L	255	2.43	2.53	1.00	4.25	0.54	
	Total	522	2.43	2.44	1.00	4.53	0.54	
e	R	266	0.75	0.63	0.28	1.70	0.27	−1.257
	L	256	0.78	0.72	0.40	2.00	0.28	
	Total	522	0.77	0.72	0.28	2.00	0.28	
f	R	266	0.75	0.61	0.28	2.00	0.30	−2.428
	L	256	0.82	0.78	0.21	2.15	0.35	
	Total	522	0.78	0.72	0.21	2.15	0.33	
g	R	266	3.49	3.44	1.70	6.68	0.76	−1.308
	L	256	3.58	3.52	2.00	5.95	0.78	
	Total	522	3.53	3.44	1.70	6.68	0.77	

between voxel sizes for the visibility of AML and DML ($p > 0.05$) (Table 2).

Measurements of PF and mandibular fossa

Table 3 shows the measurements of morphologic features of PF and mandibular fossa. Statistical difference found for the measurements “a” and “f”. Left side measurements were higher than the right side ($p < 0.05$). There was no significant difference between right and left groups for the others ($p > 0.05$). However, for all parameters, male patients’ values were higher than females’ patients which was statistically significant ($p < 0.05$).

The evaluation of CBCT images showed PF tunnel Types 1,2,3 and 4 in 11.5%, 35.63%, 51.34 and 1.53%, respectively. On the left side, Type 3 was higher (60.4%) in males, while Type 1 (14.8%) and Type 2 (43.9%) were higher in females than males ($p < 0.05$) (Table 4). Moreover, as the age increases, the morphometric measurements related to PF decrease significantly ($p < 0.05$). In certainly visibility group of DML and AML Type 1–Type 2 were found significantly higher than Type 3–Type 4. The visibility of AML was also correlated with bone changes of TMJ ($p < 0.05$) (Table 5).

Discussion

The DML (Pinto’s ligament, mandibular-malleolar ligament) first mentioned by Rees; but was described in

detail by Pinto.⁴ The AML was similarly described for the first time by Pinto and was thought to be a muscle entering malleus.^{7,14} The morphology, embryogenic origin and clinical importance of DML and AML are still controversial. The AML, the malleus and incus develop from the dorsal end of Meckel’s cartilage. Some investigators consider DML to be a continuation of lateral pterygoid muscle, not a separate structure. However, further studies have indicated that DML is not a residue or degenerate structure, is a separate anatomic structure that links malleus to the joint disk and capsule.⁷ Sencimen et al investigated the relationship between TMJ and ear relation from anatomical and functional aspects of the DML, malleomandibular ligament and SML. They reported that extreme stretching of the condyle in conjunction with the ligaments between the ossicles of the inner ear and the TMJ could be the reason for unexplained otological problems.^{7,14}

It has been well documented that TMJ symptoms, are related with ear symptoms, often patients were admitted because of scattered or pain in the middle ear.⁸ Kurt et al⁸ showed also a possible relationship with middle ear and TMJ disorders. They stated that the developmental or genetic stages, TMJ and all of ear compartments interact in with each other’s structure as the occurring of DML or AML in between joint and ear region. Thus, ear and TMJ related pain or other symptoms of these areas might be due to attached or connected ligaments.⁸

Moreover, Kim et al⁹ concluded in their study, the relationship between TMD and aural symptoms can be

Table 4 Descriptive statistics AML/DML visibility, PF tunnel types according to gender and localization

		<i>Gender</i>							
		<i>Female</i>		<i>Male</i>		<i>Total</i>		<i>chi-square</i>	
		<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>chi-square</i>	<i>p</i>
Left AML	Not visible	103	66.5	65	64.4	168	65.6	1.13	0.567
	Possibly visible	37	23.9	29	28.7	66	25.8		
	Certainly visible	15	9.7	7	6.9	22	8.6		
	Total	155	100.0	101	100.0	256	100.0		
Left DML	Not visible	15	9.7	9	8.9	24	9.4	0.4	0.783
	Possibly visible	101	65.2	70	69.3	171	66.8		
	Certainly visible	39	25.2	22	21.8	61	23.8		
	Total	155	100.0	101	100.0	256	100.0		
Left PF tunnel types	Type 1	23	14.8	10	9.9	33	12.9	10.9	0.012*
	Type 2	68	43.9	30	29.7	98	38.3		
	Type 3	62	40.0	61	60.4	123	48.0		
	Type 4	2	1.3	0	0.0	2	0.8		
	Total	155	100.0	101	100.0	256	100.0		
Right AML	Not visible	108	64.3	72	73.5	180	67.7	3.8	0.147
	Possibly visible	47	28.0	17	17.3	64	24.1		
	Certainly visible	13	7.7	9	9.2	22	8.3		
	Total	168	100.0	98	100.0	266	100.0		
Right DML	Not visible	25	14.9	17	17.3	42	15.8	0.292	0.864
	Possibly visible	112	66.7	63	64.3	175	65.8		
	Certainly visible	31	18.5	18	18.4	49	18.4		
	Total	168	100.0	98	100.0	266	100.0		
Right PF tunnel types	Type 1	18	10.7	9	9.2	27	10.2	0.2	0.977
	Type 2	55	32.7	33	33.7	88	33.1		
	Type 3	91	54.2	54	55.1	145	54.5		
	Type 4	4	2.4	2	2.0	6	2.3		
	Total	168	100.0	98	100.0	266	100.0		

explained by the presence of DML and AML, which are special links between TMJ and middle ear. These ligaments may be injured during surgical procedures such as condylar excessive distraction, disc related operations, condylar trauma, or TMJ dysfunction involving anterior disc displacement. Especially anteromedial disc displacement may affect DML, which may induce symptoms in the middle ear structure. There are also disagreements about the effect of DML in malleal movement. Some researchers have pointed out that the malleus movement is due to the excessive stretching of the DML. However, in some studies, the effect on the malleus was not observed by stretching the DML. It is doubtful whether the DML is affecting auditory findings. When AML over stretched, mobility was found on malleus.⁹ In the current study, it was found that AML was correlated with bone compartment changes and can become clearly visible with TMJ disorder, which is in line with Kim et al's study.⁹

Several cadaver studies investigated the mobility of the malleal ligaments via stretching these ligaments. However, it should be stated that the methodology of the studies might not be suitable because the connections in the petrotympanic fissure and bone impaction

are removed to release these ligaments in cadaveric dissections.¹⁴ This condition has canalized investigators to research the histological properties of these ligaments and to find the relationship with movement of the malleus. Histologically, AML and DML consist of collagen fibers. The AML, itself does not contain elastic fibers in contrast to DML. The results of the current study regarding AML and TMD connection can be explained with lack of elastic fibers for AML. The findings of this study also showed that thickness of the ligaments might have changed due to degeneration and inflammation, thus ligaments that are certainly visible on CBCT scans, can be a sign of stretching and abnormality as in line with a previous study.¹⁵ The DML which containing elastic fibers can compensate for the tensile forces on it. The absence of such a compensation mechanism in collagen bonds may suggest that AML can undergo deformation more easily.

Petrotympanic fissure is a structure that must be considered when evaluating malleal ligaments. In this study, measurements for petrotympanic fissure and mandibular fossa are similar to previous studies.^{11,12} As the age increases, the morphometric measurements related to PF decrease significantly, which can be

Table 5 DML and AML visibility according to PF tunnel types and TMD

		<i>Not visible</i>		<i>Possibly visible</i>		<i>Certainly visible</i>		<i>Total</i>		<i>Statistical analysis</i>	
<i>DML</i>		<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>Chi-square</i>	<i>p</i>
PF tunnel Type	Type 1	5	8.3	33	55.0	22	36.7^a	60	100.0	31.4	0.0001*
	Type2	23	12.4	110	59.1	53	28.5^b	186	100.0		
	Type3	35	13.1	198	73.9	35	13.1^{a.b}	268	100.0		
	Type4	3	37.5	5	62.5	0	0.0^{a.b}	8	100.0		
	Total	66	12.6	346	66.3	110	21.1	522	100.0	1.1	0.574
TMD	Absent	28	12.0	160	68.7	45	19.3	233	100.0		
	Present	38	13.1	186	64.4	65	22.5	289	100.0		
AML		66	12.6	346	66.3	110	21.1	522	100.0		
PF tunnel Type	Type 1	38	63.3	15	25.0	7	11.7^c	60	100.0	15.1	0.021*
	Type2	111	59.7	52	28.0	23	12.4^d	186	100.0		
	Type3	195	72.8	59	22.0	14	5.2^{c.d}	268	100.0		
	Type4	4	50.0	4	50.0	0	0.0^{c.d}	8	100.0		
	Total	348	66.7	130	24.9	44	8.4	522	100.0	7.1	0.031*
TMD	Absent	150	64.4	69	29.6	14	6.0^e	233	100.0		
	Present	198	68.5	61	21.1	30	10.4^e	289	100.0		
TMD		348	66.7	130	24.9	44	8.4	522	100.0		

AML, anteriormalleolar ligament; DML, discomalleolar ligament; PF, petrotympanic fissure; TMD, temporomandibular disorder; Superior letters shows statistical significance ($p < 0.05$)

interpreted by progressive degenerative changes associated with aging. There are statistically different results in some morphometric values of the petrotympanic fissure and related structures which thought to originate from the male and female anatomy. Type 2, Type 1 and Type 4 followed the most common Type 3, respectively, in the CBCT images examined. The percentage of these tunnels differed from the Sato et al¹¹'s study. This difference can be due to the difference in the number of samples as well as population characteristics. The current study found that the certain visibility of DML and AML on Type 1-Type 2 was significantly higher than Type 3-Type 4. This may be explained by the narrow petrotympanic fissure, which limits the movements of ligaments.⁷

Although this study was the first to evaluate the visibility of AML and DML using CBCT images, there are several limitations for this study. The most important limitation of this retrospective study is the uncertainty of the clinical symptoms of patients who underwent CBCT imaging. Detailed clinical information regarding TMJ disorders was not considered for the study. Only association between the visibility of malleolar ligaments and pathology of bone elements of TMJ was investigated and considered. The poor soft tissue contrast of CBCT is another of the limitation of this study.

However, to overcome this obstacle, two independent observers with additional reviewer were used with a consensus session. Further studies must be conducted in consideration with clinical data and must investigate the potential of CBCT in spite of the inherent soft tissue contrast problem.

Conclusions

The morphometric data of this retrospective study delineate the radiographic anatomy of the malleolar ligaments and petrotympanic fissure. Detailed knowledge of this particular region may help in identifying auditory disorders and TMJ pain symptoms. Further cross-sectional studies of the region may reveal the specific physio-pathological mechanisms of both disorders.

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