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Three-dimensional morphometric study on the retromolar pad

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PURPOSE. The aim of this study was to classify the shapes of retromolar pads and assess their morphometric differences using a 3D model. **MATERIALS AND METHODS.** Two hundred fully edentulous or Kennedy Class I partially edentulous patients (400 retromolar pads) were enrolled. Scan data of the definitive mandibular casts produced through functional impressions were obtained using a 3D laser scanner. Seven parameters (transverse diameter, longitudinal diameter, transverse-contour length, longitudinal-contour length, longitudinal/transverse diameter ratio, longitudinal/transverse-contour length ratio, and angle of the retromolar pad line to the residual alveolar ridge line) were measured using image analysis software. Subsequently, the pads were classified according to the shape. Statistical analyses were performed using 95% confidence intervals. **RESULTS.** Classifying the retromolar pads into three shapes led to high intra-examiner reliability (Cronbach's alpha = 0.933). The pear shape was the most common (56.5%), followed by oval/round (27.7%) and triangular (15.8%) shapes. There were no significant differences between the left and right sides according to the shape and no significant differences in any parameter according to age. The transverse diameter and longitudinal/transverse diameter ratio differed between sexes ($P < .05$). The triangular shape had a significantly different transverse diameter, transverse-contour length, longitudinal/transverse diameter ratio, and longitudinal/transverse-contour length ratio compared with the pear and oval/round shapes ($P < .05$). **CONCLUSION.** From a clinical reliability standpoint, classifying retromolar pads into three shapes (oval/round, pear-shaped, and triangular) is effective. The differences in the sizes among the shapes were attributed to the transverse measurement values. [J Adv Prosthodont 2023;15:302-14]

KEYWORDS
Retromolar pad; Classification; Morphometry; 3D image

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INTRODUCTION

Orientation of the occlusal plane is an essential clinical procedure in the prosthodontic treatment of edentulous patients to restore speech, esthetics, and function.[1] Inadequate establishment of the occlusal plane can lead to problems. For example, if the determined occlusal plane is too high, food can accumulate in the buccal or lingual sulci; if it is too low, the tongue or cheek may be bitten.[2,3] Various extraoral and intraoral landmarks have been used to orient the occlusal plane. Typically, the anterior occlusal plane is determined by esthetics and phonetics, guided by the maxillary incisors, whereas the posterior occlusal plane is determined by the retromolar pad.[4]

The retromolar pad is a mass of elevated soft tissues distal to the mandibular third molar that contains glandular tissues.[5] The surface epithelium of the retromolar pad is divided into a keratinized anterior portion and a thin, non-keratinized posterior portion.[6] The fibers of the superior constrictor muscle, buccinator muscle, terminal ends of the temporalis muscle tendon, and pterygomandibular raphe are attached to the retromolar pad.[7] Even in edentulous patients with extensive bone resorption, bone resorption in the mandible beyond the mylohyoid ridge and buccal shelf is limited by the mylohyoid and buccinator muscles.[8,9] The retromolar pad is highly resistant to bone resorption due to the dense cortical bone below[6,10] and is considered a stable landmark.[11] Various studies[1,4,12-14] have attempted to determine the height of the retromolar pad required to orient the occlusal plane. There are multiple opinions on the appropriate height of the retromolar pad for establishing the posterior occlusal plane, but a consensus has not been reached.

When fabricating a complete mandibular denture, the denture base must cover the retromolar pad to achieve appropriate retention and provide additional support through a proper peripheral seal.[15] If the denture base does not extend to the retromolar pad, extending the denture border to the retromylohyoid area becomes difficult. Even if extension is possible, the lack of a peripheral seal markedly reduces the stability of the mandibular dentures.[16] Furthermore, a study[17] on natural teeth indicated that the lingual surface of the posterior mandibular teeth was positioned between two straight lines connecting the mesial surface of the mandibular canine and the buccal and lingual borders of the retromolar pad. Therefore, the retromolar pad may be a useful landmark for arranging posterior teeth.

The retromolar pad has been proposed as a useful anatomical landmark from a surgical perspective, as the inferior alveolar nerve can be anesthetized by injecting into the retromolar pad.[18] Additionally, the retromolar pad can be used as a landmark to select incision sites to avoid iatrogenic lingual nerve injuries.[19]

The variabilities in shape and size of the retromolar pad were mentioned as one of the possible reasons for the lack of consensus on the appropriate height of the retromolar pad for establishing the occlusal plane.[16] Additionally, as previously mentioned, a peripheral seal is an essential element for the stability of the denture when fabricating a mandibular denture. Since the retromolar pad is the limiting structure of the mandible, the variabilities in shape and size of the retromolar pad can affect a peripheral seal.[7] Therefore, the variabilities in shape and size of the retromolar pad should be evaluated. Despite the significant clinical importance of the retromolar pad in dentistry and the need to assess variabilities in its shape and size, studies on this topic remain sparse. Previous studies[7,16,20] have categorized the shape of the retromolar pad as oval, round, or triangular, or as pear-shaped, round, or triangular. However, scientific evidence for these classifications has not been previously provided.[7,16,20] Only a few parameters, such as the transverse and longitudinal diameters, have been measured, and the impression techniques for fabricating working casts and measurement methods are unclear.

Therefore, in this study, a classification of retromolar pad shapes based on scientific evidence is proposed. The differences in shape between the left and right retromolar pads and in measured parameters based on sex, age, and shape were assessed using 3D morphometry. The null hypothesis for this study was that there are no differences in the measured parameters among retromolar pads with different shapes.

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MATERIALS AND METHODS

In this study, 200 completely edentulous or Kennedy Class I partially edentulous individuals (age range 25 - 87 years, mean age 65.3 years, 98 males, 102 females) who visited Gangneung-Wonju National University Dental Hospital with a mandibular removable denture were enrolled. Patients were classified into three age groups: ≤ 40 years, 41 - 59 years, and ≥ 60 years (Table 1). Mandibular casts obtained from functional impressions were used in this study. This study was approved by the Institutional Review Board of Gangneung-Wonju National University Dental Hospital (GWNUDH IRB2017-014). The inclusion criteria were as follows: 1) mandibular casts indicating a completely edentulous arch or a Kennedy Class I partially edentulous arch, 2) no abnormal findings from the posterior mandibular residual ridge to the anterior margin of the mandibular ramus on panoramic radiographic examination, 3) functional impressions of the edentulous area, and 4) complete recording of the retromolar pad. The exclusion criteria were as follows: 1) incomplete recording of the retromolar pad, 2) deformation or absence of the retromolar pad due to past surgery, or 3) obvious deformation of the pad due to excessive pressure during impression-making.

During denture fabrication, an individual tray for the edentulous area was fabricated on a diagnostic cast for completely edentulous patients and on a dental cast after fabricating a metal framework for a removable partial denture for partially edentulous patients. To minimize deformation of the retromolar pad while fabricating the individual tray, a uniform layer of 1.5 mm baseplate wax (Anutex; Kemdent, Swindon, UK) was applied for relief. Subsequently, an individual tray was fabricated with light-cured acrylic resin (Lightplast Base plates; Dreve Dentamid GmbH, Unna, Germany) using a conventional method. During border molding, it was confirmed that there was no pressure on the retromolar pad area, and a functional impression was made using a light-body-type silicone impression material (Exadenture; GC Co., Tokyo, Japan). An improved stone (Fuji Rock EP; GC Co., Leuven, Belgium) was used to create a master cast for completely edentulous arches and an altered cast for partially edentulous arches. Fabricated edentulous casts were scanned using a 3D laser scanner (MyS; Raphabio, Seoul, Korea) to obtain image data that were converted into the final model images using image analysis software (3Shape 3D Viewer 1.3; 3Shape A/S, Copenhagen, Denmark).

From the acquired 200 model images, the outlines at the bases of the 400 retromolar pads (200 left and 200 right) were determined. Points A, P, B, and L were established on the determined outline for each retromolar pad. The transverse diameter (length of the straight line connecting points B and L), longitudinal diameter (length of the straight line connecting points A and P), transverse-contour length (length of the line starting from one of the points [B or L], following the surface contour of the retromolar pad, and ending at the other point), and the longitudinal-contour length (length of the line starting from points A or P, following the surface contour of the retromolar pad, and ending at the other point) were measured (Fig. 1). The longitudinal/transverse diameter ratio and the longitudinal/transverse-contour length ratio for each retromolar pad were calculated using the values of the previous four parameters. The residual alveolar ridge line was arbitrarily determined to be as parallel as possible to the direction of the residual ridge. The angle to the residual alveolar ridge line was measured in the sagittal plane as the angle formed by the retromolar pad line passing through points A and P and the determined residual alveolar ridge line (Fig. 2).

Table 1. Summary of the patient characteristics

Index	Sex	Age group	Edentulous state
Characteristic	98 males 102 females	≤ 40 years: 9 41 - 59 years: 57 ≥ 60 years: 134	fully: 168 partially*: 32
Total	200 patients (400 retromolar pads)		

*Bilaterally partial edentulism (Kennedy Class I).

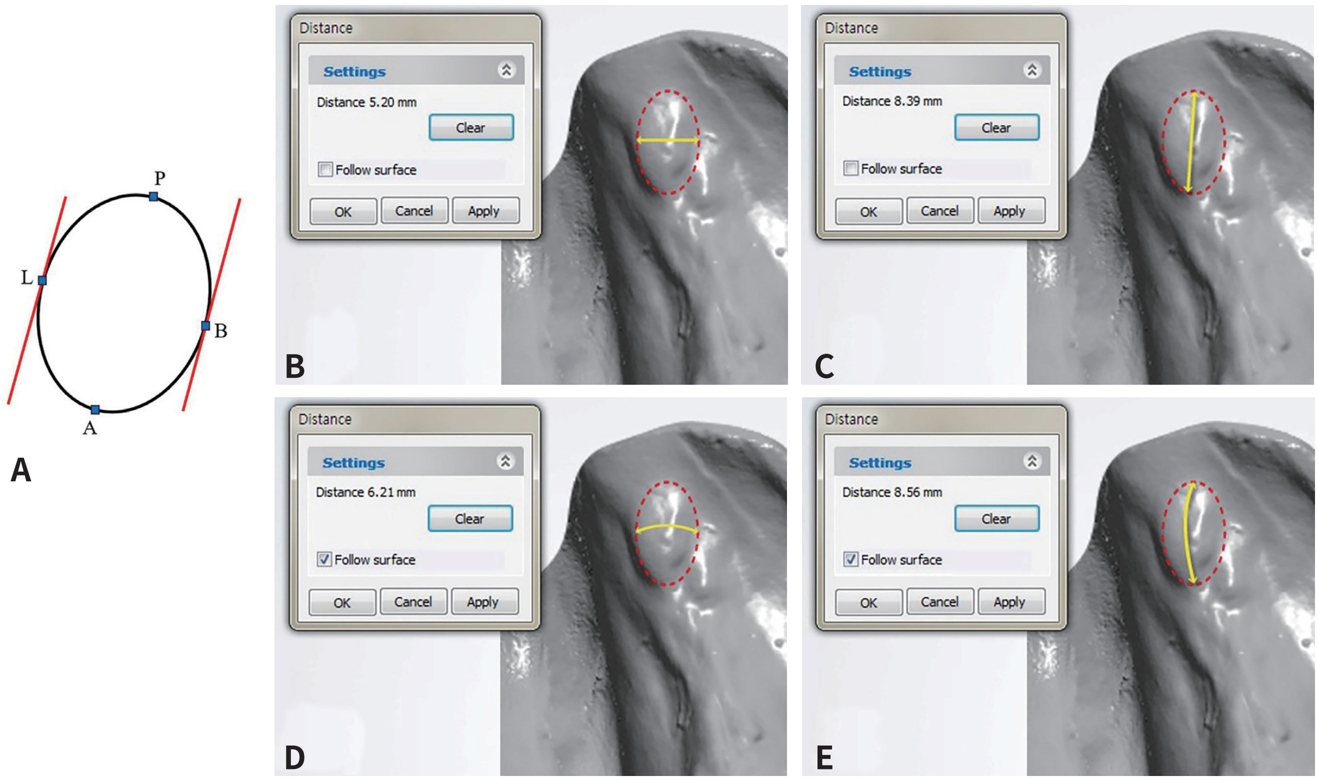
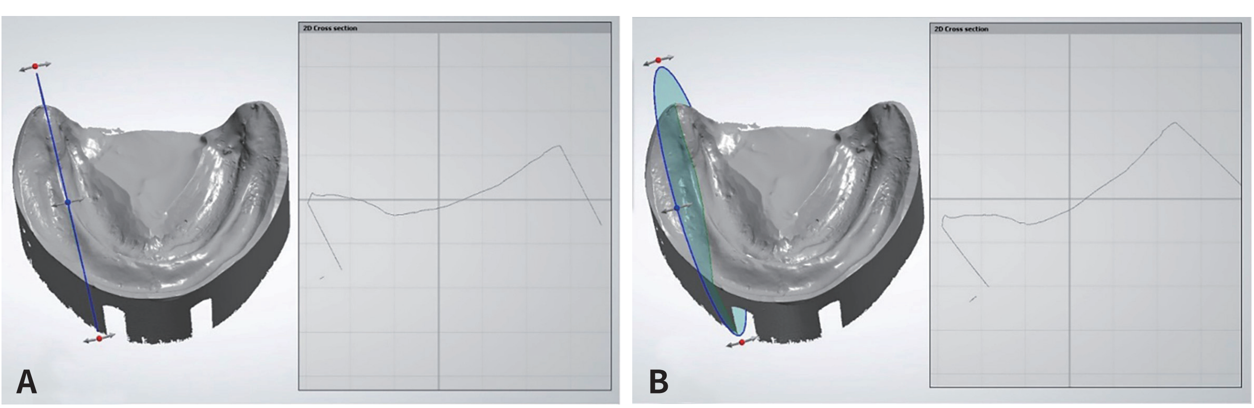


Fig. 1. Determination of measurement points A, P, B, L in the retromolar pad and measurement of the size of the retromolar pad. (A) In the schematic diagram of the outline (black ellipse) at the base of the left retromolar pad, the most anterior point in the outline was set as point A and the most posterior point was set as point P when viewed from the long axis of the retromolar pad. The point of contact with the straight line (red straight line) parallel to the straight-line AP on the buccal side of the outline of the retromolar pad was set as point B, and the point of contact on the lingual side was set as point L. (B) transverse diameter, (C) longitudinal diameter, (D) transverse-contour length, (E) longitudinal-contour length.



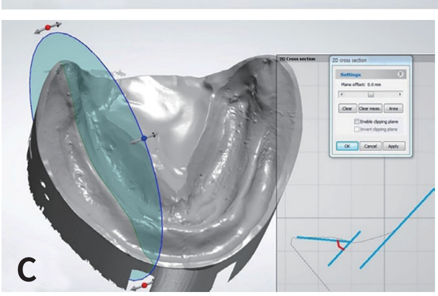


Fig. 2. Procedure for measuring the angle between edentulous residual alveolar ridge lines and retromolar pad lines. (A) 2D judgement for the residual alveolar ridge line, (B) 3D decision for the residual alveolar ridge line, (C) measurement of the angle (red arc) of the retromolar pad line to the residual alveolar ridge line.

The shapes of the 400 retromolar pads were classified based on four types: oval, pear-shaped, round, and triangular (Fig. 3).[4,6,7,16] To ensure intra-examiner reliability before classifying the shapes of the 400 retromolar pads, a single operator arbitrarily selected 60 retromolar pads and determined their shapes using one of the four types. Three rounds of assessment were performed, and Cronbach's alpha was calculated for 60 samples. The reliability was low when the four types of shapes were used, likely because of difficulties in distinguishing between oval and round shapes. Hence, oval and round shapes were combined into an "oval/round" category and three types of shapes were used (oval/round, pear-shaped, and triangular). The same three-round assessment process for the 60 retromolar pads was repeated using a modified approach, and Cronbach's alpha was calculated. Subsequently, a single operator classified all 400 retromolar pad shapes into three categories: oval/round, pear-shaped, and triangular.

Differences in shape between the left and right sides and in the transverse diameter, longitudinal diameter, transverse-contour length, longitudinal-contour length, longitudinal/transverse diameter ratio, longitudinal/transverse-contour length ratio, and angle to residual alveolar ridge line were assessed according to sex, age groups, and the three shapes.

Differences in shapes of the retromolar pad between the left and right sides were analyzed using the chi-squared test (linear-by-linear association). Differences in the seven parameters according to sex were analyzed using the independent samples t-test. Differences in the seven parameters according to age groups and the three types of shapes were analyzed using one-way analysis of variance, followed by the Scheffé multiple comparison test for post-hoc comparison. All statistical analyses were performed using a statistical software (SPSS Statistics, v25.0; IBM Corp., Armonk, NY, USA), and 95% confidence intervals were calculated ($\alpha = .05$).

RESULTS

Intra-examiner reliability was low (Cronbach's alpha = 0.559) when the retromolar pad shapes were classified into four types (oval, pear-shaped, round, and triangular). The reliability was higher (Cronbach's alpha = 0.933) when only three types (oval/round, pear-shaped, and triangular) were used.

The most common pad shape was pear-shaped

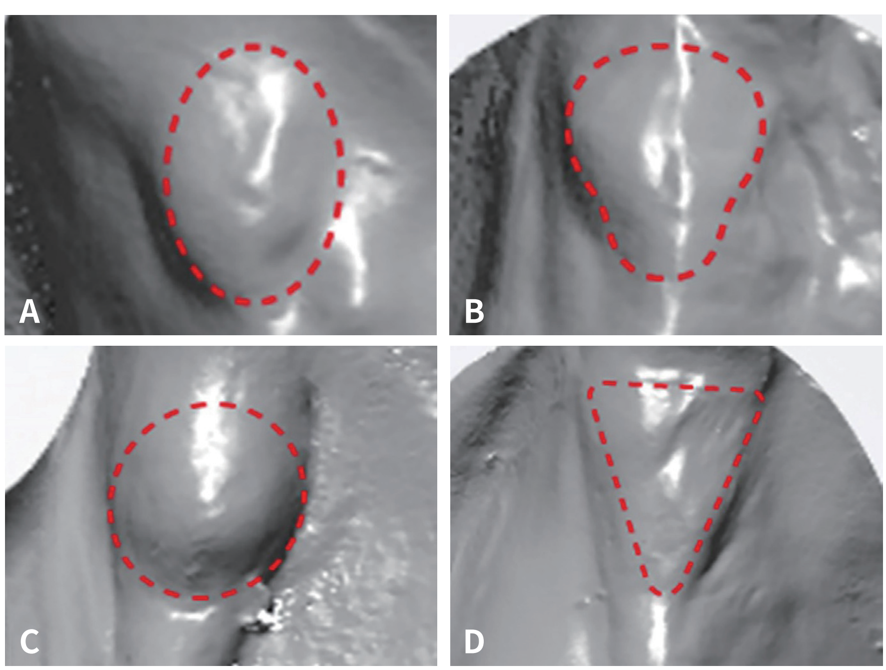


Fig. 3. Representative four images of the retromolar pad. (A) Oval, (B) Pear-shaped, (C) Round, (D) Triangular.

(56.5%), followed by oval/round (27.7%) and triangular (15.8%) on both the left and right sides, with no significant differences in shape between the left and right sides ($P > .05$) (Table 2). The pear shape was more often seen than the oval, round, and triangular shapes combined.

Males had a significantly higher transverse diameter ($P < .05$) and a significantly lower longitudinal/transverse diameter ratio than females ($P < .05$). There were no sex differences in the longitudinal diameter, transverse-contour length, longitudinal-contour length, longitudinal/transverse-contour length ratio, or angle to the residual alveolar ridge line ($P > .05$) (Table 3).

Comparisons between age groups showed no significant differences in the transverse diameter, longitudinal diameter, transverse-contour length, longitudinal-contour length, longitudinal/transverse diameter ratio, longitudinal/transverse-contour length ratio, or angle to the residual alveolar ridge line ($P > .05$) (Table 4).

There were no significant differences in the longitudinal diameter, longitudinal-contour length, and angle to the residual alveolar ridge line among shapes ($P > .05$). The transverse diameter, transverse-contour length, longitudinal/transverse diameter ratio, and longitudinal/transverse-contour length ratio differed significantly among shapes ($P < .05$) (Table 5 and Ta-

Table 2. Differences between the left and right sides according to the retromolar pad shape

Side	Shape (n)			Total (n)	*P**
	oval/round	pear	triangular		
Left	56	110	34	200	.758
	28.0%	55.0%	17.0%		
Right	55	116	29	200	
	27.5%	58.0%	14.5%		
Total	111	226	63	400	
	27.7%	56.5%	15.8%	100%	

*No statistical significance was found ($P > .05$, chi-square test/linear by linear association).

Table 3. Independent t-test results of sex difference (n = 400)

Variables	Sex[a]	Mean	SD	t	df	*P*
Transverse diameter (mm)	1	5.7595	1.00049	-3.737	398	< .0001*
	2	6.1198	0.92458			
Longitudinal diameter (mm)	1	8.3463	1.24517	-1.714	398	.087
	2	8.5647	1.30437			
Transverse-contour length (mm)	1	6.6196	1.22307	-1.666	398	.096
	2	6.8144	1.10931			
Longitudinal-contour length (mm)	1	8.4673	1.26783	-1.764	398	.079
	2	8.6963	1.32896			
Diameter ratio[b]	1	1.4709	0.22290	2.722	398	.007*
	2	1.4131	0.20013			
Contour length ratio[c]	1	1.2996	0.19270	0.499	398	.618
	2	1.2902	0.18458			
Angle[d] (°)	1	43.752	9.39596	-0.127	398	.899
	2	43.873	9.79847			

[a]1: females (n = 204), 2: males (n = 196); [b]longitudinal/transverse diameter ratio; [c]longitudinal/transverse-contour length ratio; [d]angle of retromolar pad line to residual alveolar ridge line; *statistically significant ($P < .05$).

Table 4. Means and standard deviations of the measured parameters by age group

Variables	Age (years)	n	Mean	SD[a]	SE[b]	95% CI[c] Lower limit	95% CI[c] Upper limit	Minimum	Maximum
Transverse diameter (mm)	≤ 40	18	6.1106	0.97016	0.22867	5.6281	6.5930	4.74	8.12
	41-59	114	5.9073	1.03232	0.09669	5.7157	6.0988	3.86	8.18
	≥ 60	268	5.9366	0.95950	0.05861	5.8212	6.0520	3.88	9.69
	sum	400	5.9361	0.97958	0.04898	5.8398	6.0324	3.86	9.69
Longitudinal diameter (mm)	≤ 40	18	8.2300	1.31731	0.31049	7.5749	8.8851	6.21	9.63
	41-59	114	8.4019	1.10908	0.10387	8.1961	8.6077	6.11	12.2
	≥ 60	268	8.4902	1.34251	0.08201	8.3287	8.6516	5.33	12.9
	sum	400	8.4533	1.27761	0.06388	8.3277	8.5789	5.33	12.9
Transverse-contour length (mm)	≤ 40	18	6.5883	0.90263	0.21275	6.1395	7.0372	5.08	8.32
	41-59	114	6.6180	1.19632	0.11205	6.3960	6.8400	4.28	11.9
	≥ 60	268	6.7649	1.17690	0.07189	6.6233	6.9064	4.35	12.4
	sum	400	6.7151	1.17131	0.05857	6.5999	6.8302	4.28	12.4
Longitudinal-contour length (mm)	≤ 40	18	8.2300	1.31731	0.31049	7.5749	8.8851	6.28	9.75
	41-59	114	8.4019	1.10908	0.10387	8.1961	8.6077	6.22	12.5
	≥ 60	268	8.4902	1.34251	0.08201	8.3287	8.6516	5.36	12.9
	sum	400	8.4533	1.27761	0.06388	8.3277	8.5789	5.36	12.9
Diameter ratio[d]	≤ 40	18	1.3617	0.21658	0.05105	1.2540	1.4694	1.01	1.71
	41-59	114	1.4441	0.19287	0.01806	1.4083	1.4799	1.11	1.98
	≥ 60	268	1.4477	0.22148	0.01353	1.4210	1.4743	0.99	2.14
	sum	400	1.4428	0.21371	0.01069	1.4218	1.4638	0.99	2.14
Contour length ratio[e]	≤ 40	18	1.2789	0.20591	0.04853	1.1765	1.3813	1.00	1.67
	41-59	114	1.3082	0.15668	0.01467	1.2791	1.3372	1.02	1.72
	≥ 60	268	1.2909	0.19975	0.01220	1.2669	1.3149	0.88	1.92
	sum	400	1.2953	0.18850	0.00943	1.2767	1.3138	0.88	1.92
Angle[f] (°)	≤ 40	18	42.817	10.1348	2.38880	37.777	47.857	17.8	56.3
	41-59	114	43.805	9.50528	0.89025	42.042	45.569	23.5	64.8
	≥ 60	268	43.880	9.61239	0.58717	42.724	45.036	21.2	70.3
	sum	400	43.811	9.58344	0.47917	42.869	44.753	17.8	70.3

[a]standard deviation; [b]standard error; [c]confidence interval; [d]longitudinal/transverse diameter ratio; [e]longitudinal/transverse-contour length ratio; [f]angle of retromolar pad line to residual alveolar ridge line.

ble 6). Post-hoc tests revealed that the triangular shape had a significantly higher transverse diameter and transverse-contour length than the oval/round and pear shapes ($P < .05$). The triangular shape had a significantly lower longitudinal/transverse diameter ratio and longitudinal/transverse-contour length ratio than the oval/round and pear shapes ($P < .05$). There were no significant differences in any parameter between the oval/round and pear shapes ($P > .05$) (Table 6).

DISCUSSION

Based on the results of this study, the null hypothesis (i.e., that there are no differences in the measured parameters according to the shape of the retromolar pad) was rejected. There were significant differences in the measured parameters according to each shape (oval/round, pear-shaped, and triangular). Specifically, the triangular shape had a larger transverse diameter and transverse-contour length than the oval/round and pear shapes and a significantly

Table 5. Means and standard deviations of measured parameters by retromolar pad shape

Variables	Shape	N	Mean	SD[a]	SE[b]	95% CI[c] Lower limit	95% CI[c] Upper limit	Minimum	Maximum
Transverse diameter (mm)	oval/round	111	5.6841	0.95962	0.09108	5.5036	5.8646	3.86	8.12
	pear	226	5.8431	0.81801	0.05441	5.7358	5.9503	4.06	8.25
	triangular	63	6.7137	1.16349	0.14659	6.4206	7.0067	4.63	9.69
	sum	400	5.9361	0.97958	0.04898	5.8398	6.0324	3.86	9.69
Longitudinal diameter (mm)	oval/round	111	8.3427	1.42533	0.13529	8.0746	8.6108	5.38	12.9
	pear	226	8.4541	1.21616	0.08090	8.2947	8.6135	5.33	11.9
	triangular	63	8.6454	1.21378	0.15292	8.3397	8.9511	6.17	11.1
	sum	400	8.4533	1.27761	0.06388	8.3277	8.5789	5.33	12.9
Transverse-contour length (mm)	oval/round	111	6.6084	1.30375	0.12375	6.3631	6.8536	4.28	11.9
	pear	226	6.5748	0.93315	0.06207	6.4525	6.6971	4.43	9.18
	triangular	63	7.4062	1.44086	0.18153	7.0433	7.7691	5.05	12.4
	sum	400	6.7151	1.17131	0.05857	6.5999	6.8302	4.28	12.4
Longitudinal-contour length (mm)	oval/round	111	8.4939	1.45909	0.13849	8.2194	8.7683	5.40	12.9
	pear	226	8.5731	1.23591	0.08221	8.4110	8.7351	5.36	12.1
	triangular	63	8.7537	1.24006	0.15623	8.4413	9.0660	6.24	11.3
	sum	400	8.5795	1.30157	0.06508	8.4516	8.7075	5.36	12.9
Diameter ratio[d]	oval/round	111	1.4914	0.26057	0.02473	1.4424	1.5405	0.99	2.14
	pear	226	1.4579	0.18450	0.01227	1.4337	1.4821	1.03	2.01
	triangular	63	1.3030	0.15818	0.01993	1.2632	1.3429	1.06	1.80
	sum	400	1.4428	0.21371	0.01069	1.4218	1.4638	0.99	2.14
Contour length ratio[e]	oval/round	111	1.3081	0.21720	0.02062	1.2673	1.3490	0.92	1.92
	pear	226	1.3148	0.17131	0.01140	1.2924	1.3373	0.90	1.85
	triangular	63	1.2025	0.16744	0.02110	1.1604	1.2447	0.88	1.72
	sum	400	1.2953	0.18850	0.00943	1.2767	1.3138	0.88	1.92
Angle[f] (°)	oval/round	111	43.268	10.4819	0.99490	41.296	45.239	17.8	70.1
	pear	226	43.889	9.06588	0.60305	42.701	45.078	23.0	69.3
	triangular	63	44.487	9.84031	1.23976	42.009	46.966	22.5	70.3
	sum	400	43.811	9.58344	0.47917	42.869	44.753	17.8	70.3

[a]standard deviation; [b]standard error; [c]confidence interval; [d]longitudinal/transverse diameter ratio; [e]longitudinal/transverse-contour length ratio; [f]angle of retromolar pad line to residual alveolar ridge line.

smaller longitudinal/transverse diameter ratio and longitudinal/transverse-contour length ratio. Due to the morphometric characteristics, transverse measurements were performed at the distal end of the pad for the triangular shape but at the middle portion for the oval/round and pear shapes. These findings suggest that the distal end of the triangular shape is transversely wider than the middle portions of the oval/round and pear shapes. However, there were no significant differences among the shapes in terms of the longitudinal diameter and longitudinal-contour length. Therefore, it seems that identifying and marking the posterior border of the retromolar pad are not as difficult as expected, as the longitudinal diameter and longitudinal-contour length are similar among shapes. In actual clinical situations, cases are frequently encountered in which the anterior starting point of the retromolar pad is clear, but the posterior limit of the retromolar pad is unclear on the mandibular cast obtained during mandibular denture fabrication. Considering the result of this study that the longitudinal diameter has a value of approximate-

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Table 6. Multiple comparison (post-hoc test) of the differences in parameters between retromolar pad shapes

Variables	Between groups (Shapes)		Mean difference	SE[a]	*P*	95% CI[b]	
						Minimum	Maximum
Transverse diameter	oval/round	pear	-0.15891	0.10659	.330	-0.4208	0.1030
		triangular	-1.02951*	0.14507	< .0001	-1.3859	-0.6731
	pear	oval/round	0.15891	0.10659	.330	-0.1030	0.4208
		triangular	-0.87060*	0.13103	< .0001	-1.1925	-0.5487
	triangular	oval/round	1.02951*	0.14507	< .0001	0.6731	1.3859
		pear	0.87060*	0.13103	< .0001	0.5487	1.1925
Longitudinal diameter	oval/round	pear	-0.11141	0.14803	.754	-0.4751	0.2523
		triangular	-0.30269	0.20147	.324	-0.7977	0.1923
	pear	oval/round	0.11141	0.14803	.754	-0.2523	0.4751
		triangular	-0.19128	0.18196	.576	-0.6384	0.2558
	triangular	oval/round	0.30269	0.20147	.324	-0.1923	0.7977
		pear	0.19128	0.18196	.576	-0.2558	0.6384
Transverse-contour length	oval/round	pear	0.03360	0.13158	.968	-0.2897	0.3569
		triangular	-0.79781*	0.17907	< .0001	-1.2378	-0.3578
	pear	oval/round	-0.03360	0.13158	.968	-0.3569	0.2897
		triangular	-0.83141*	0.16173	< .0001	-1.2288	-0.4340
	triangular	oval/round	0.79781*	0.17907	< .0001	0.3578	1.2378
		pear	0.83141*	0.16173	< .0001	0.4340	1.2288
Longitudinal-contour length	oval/round	pear	-0.07918	0.15093	.871	-0.4500	0.2917
		triangular	-0.25978	0.20541	.450	-0.7645	0.2449
	pear	oval/round	0.07918	0.15093	.871	-0.2917	0.4500
		triangular	-0.18060	0.18553	.623	-0.6364	0.2752
	triangular	oval/round	0.25978	0.20541	.450	-0.2449	0.7645
		pear	0.18060	0.18553	.623	-0.2752	0.6364
Diameter ratio[c]	oval/round	pear	0.03357	0.02376	.369	-0.0248	0.0919
		triangular	0.18843*	0.03233	< .0001	0.1090	0.2679
	pear	oval/round	-0.03357	0.02376	.369	-0.0919	0.0248
		triangular	0.15486*	0.02920	< .0001	0.0831	0.2266
	triangular	oval/round	-0.18843*	0.03233	< .0001	-0.2679	-0.1090
		pear	-0.15486*	0.02920	< .0001	-0.2266	-0.0831
Contour length ratio[d]	oval/round	pear	-0.00671	0.02140	.952	-0.0593	0.0459
		triangular	0.10557*	0.02912	.002	0.0340	0.1771
	pear	oval/round	0.00671	0.02140	.952	-0.0459	0.0593
		triangular	0.11228*	0.02630	< .0001	0.0477	0.1769
	triangular	oval/round	-0.10557*	0.02912	.002	-0.1771	-0.0340
		pear	-0.11228*	0.02630	< .0001	-0.1769	-0.0477
Angle[e]	oval/round	pear	-0.62181	1.11260	.855	-3.3555	2.1119
		triangular	-1.21973	1.51420	.723	-4.9401	2.5007
	pear	oval/round	0.62181	1.11260	.855	-2.1119	3.3555
		triangular	-0.59792	1.36761	.909	-3.9582	2.7623
	triangular	oval/round	1.21973	1.51420	.723	-2.5007	4.9401
		pear	0.59792	1.36761	.909	-2.7623	3.9582

[a]standard error; [b]confidence interval; [c]longitudinal/transverse diameter ratio; [d]longitudinal/transverse-contour length ratio; [e]angle of retromolar pad line to residual alveolar ridge line. *Statistically significant difference ($P < .05$, Sheffé test).

ly 8.5 mm regardless of the shape of the retromolar pad (Table 5 and Table 6), it is deemed appropriate to identify a point approximately 8.5 mm posterior along the long axis of the retromolar pad from its anterior starting point as the posterior limit, especially when the retromolar pad posterior limit is unclear. Furthermore, despite of the potential variation in the slope of the residual ridge line based on the severity of posterior alveolar bone resorption, no significant difference was observed in the angle to the residual alveolar ridge line among shapes. Ultimately, the differences among shapes are attributed to the transverse components of the parameters: namely, the transverse diameter and transverse-contour length. These differences among shapes suggest size discrepancies among pads, which indicate variations in the denture-bearing area[7] and may influence denture stability.[21] However, there are limitations in evaluating a 3D structure using only 2D measurements.

Intra-examiner reliability was tested and established using three rounds of assessments of 60 samples prior to classifying the shapes of 400 retromolar pads. The distinctive morphology of the mesial portion of the pear-shaped retromolar pad facilitated its differentiation from other shapes. It can be difficult to differentiate oval and round shapes. Round shapes are easily distinguishable, as their transverse and longitudinal diameters become equal (i.e., the longitudinal/transverse diameter ratio approaches 1). However, distinguishing between oval and round shapes becomes increasing difficult as the longitudinal diameter of a round shape increases. Therefore, high intra-examiner reliability was secured (Cronbach's alpha = 0.933) by combining oval and round shapes in one category without distinguishing between them. However, when attempting to classify diverse shapes, it can be controversial whether the classification system should be further simplified, owing to the necessity of high repeatability.

López *et al*.[16] classified retromolar pads as oval, round, or triangular and reported that the oval shape was the most common (> 50%), followed by round and triangular shapes. Other studies[7,20] classified shapes as pear-shaped, round, or triangular, with the pear shape accounting for over half of the cases, followed by triangular and round shapes. In this study, shapes were classified as oval/round, pear-shaped, or triangular, with the pear shape being the most common, followed by the oval/round and triangular shapes. Assuming that there were no differences in the research methods, there were differences in the retromolar pad shape classifying methods among the studies. Furthermore, while a similar order of frequency was observed in some studies,[7,20] the frequency of each type varied among studies. It is unclear whether these variations are due to differences in sample sizes or racial characteristics. Additionally, as it is challenging to determine the shape of a retromolar pad solely based on an objective indicator such as size, the examiner's subjective bias in determining the boundaries of the retromolar pad may have contributed to these discrepancies.

In this study, only 18 patients had different retromolar pad shapes between the left and right sides; therefore, there was no significant difference in the retromolar pad shape between the two sides, which is consistent with previous findings.[7,16] Females had smaller transverse diameters and larger longitudinal/transverse diameter ratios than males, with no significant differences in other parameters between sexes. Some reports[22,23] have indicated that females have smaller dental arches than males. Based on this observation, it could be assumed that females have a smaller buccolingual width of the posterior residual ridge. It was thought that this assumption about a smaller buccolingual width contributed to the results of this study, which showed shorter transverse diameters in females. Furthermore, there were no significant differences in parameters among age groups. These results suggest that the size of the retromolar pad remains constant regardless of age.

In addition to the transverse and longitudinal diameters measured in previous studies,[7,16,20] the transverse-contour length, longitudinal-contour length, longitudinal/transverse diameter ratio, longitudinal/transverse-contour length ratio, and angle to residual alveolar ridge line in a 3D model were measured to analyze the 3D form of retromolar pads. Previous studies[7,16,20] defined the outline of the retromolar pad directly on the mandibular cast and measured the size of the pad from the mandibular cast. Such a direct method of measurement is not suitable for

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several parameters, which might explain why previous studies only measured the transverse and longitudinal diameters when classifying and comparing the shapes of retromolar pads. It was expected that the contour length would complement the diameter, which is a straight line, to express the 3D structure of the retromolar pad. However, the results obtained based on the contour length were similar to those obtained based on the diameter. Residual ridge resorption occurs quickly for approximately 10 weeks following dental extraction and more slowly but continuously thereafter.[24] Therefore, the angle to the residual alveolar ridge line, which is the angle formed by the retromolar pad and residual ridge in the sagittal plane, was expected to differ depending on at least age within sexes, age, and shape of the pad. However, our results showed no significant differences with respect to age. This may be because this was a cross-sectional study.

Functional impressions were used to fabricate mandibular casts to measure retromolar pads. While the anterior part of the retromolar pad consists of firm keratinized gingiva, the posterior part is composed of a relatively mobile non-keratinized mucosa.[6] Considering this, sufficient relief was achieved on the inner surface of the individual trays corresponding to the retromolar pad after fabricating the individual trays and border molding, and then impressions were made. To ensure that the denture base around the retromolar pad was in harmony with the movement of the surrounding muscles, both active muscular control by the patient and passive muscular control by the operator were used while making functional impressions. When making functional impressions, pressure is inevitably applied to the retromolar pad both by muscular control and by the impression material and impression tray. Therefore, the shape of the retromolar pad in this study can be considered a clinical shape accompanying a series of procedures for prosthodontic rehabilitation rather than an intact anatomical shape.[25] Considering that the retromolar pad on mandibular casts fabricated through functional impression making is used for determining the occlusal plane during denture fabrication, it can be considered appropriate that this study conducted measurements on the clinical shape of the retromolar pad rather than its anatomical shape.

The fibers of the buccinator muscle are attached to the buccal side of the bone tissue inferior to the retromolar pad and those of the mylohyoid muscle are attached to the lingual side inferior to the retromolar pad.[8,9] As such, the bone tissue inferior to the retromolar pad can resist bone resorption,[10] and the retromolar pad can be a relatively stable landmark even in patients with severely resorbed mandibular residual ridges.[26] However, it is uncertain whether the original shape and size of the retromolar pad, which is composed of soft tissue, remain constant throughout a person's lifetime, or if changes are possible. The retromolar pad contains both muscle fibers and glandular and loose connective tissues; therefore, changes may be possible.[9] Because of the presence of the mandibular third molar, the anterior retromolar pad can be affected, as the retromolar papilla adjacent to the distal aspect of the third molar blends with the anterior retromolar pad after extracting the third molar.[27] Therefore, changes in the shape and size of the retromolar pad may be associated with the period following third-molar extraction. Changes in the retromolar pad are suspected to be influenced by the presence and eruption patterns of the third molar and healing processes after extracting the third molar. A focus of this study was the potential for acquired changes in the shape and size of the retromolar pad and patients' history of third-molar extraction. However, there was high uncertainty regarding the accuracy of history taking, as most patients were older adults who had to recall information based on their memory. Therefore, while the results of history investigations could be important, they were inevitably excluded from this study.

This study has some limitations. First, the measurements were performed using a 3D model for high reproducibility. Although measurements using a 3D model are more reproducible than measurements directly on a dental cast and the differences in measurements between a dental cast and a 3D model are reportedly clinically acceptable,[28] possible discrepancies from the actual values on a dental cast should be noted when interpreting the measurements of this study. Second, this study is subject to the inherent limitations of its cross-sectional design. Additional longitudinal studies should be conducted to assess the stability of the shape and size of the retromolar pad after extracting the mandibular third molar and to examine changes in the spatial relationship between the residual ridge and the retromolar pad. Third, as there are racial differences in the arch form and dimensions,[29,30] the possibility of racial differences in the shape and size of the retromolar pad could not be excluded. Hence, additional anthropological studies comparing the shape and size of retromolar pads among various races are required.

CONCLUSION

Intra-examiner reliability was higher when the shapes of the retromolar pads were classified into three types (oval/round, pear-shaped, and triangular) than into four types (oval, pear-shaped, round, and triangular). The most common retromolar pad shape was pear, followed by oval/round and triangular shapes. When comparing the triangular shape with the pear and oval/round shapes, there were differences in the transverse components among the measured parameters. Such size differences based on the shape of the retromolar pads may be related to differences in the denture-bearing area. Within the limitations of this study, if the posterior limit of the retromolar pad is unclear on the mandibular cast obtained during the fabrication of the mandibular denture, it is considered possible to identify a point approximately 8.5 mm posterior from its anterior starting point as the posterior limit.

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