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VARIATION IN RADIOLOGYANATOMY MORPHOMETRY OF THE ANKLE IN PATIENTS WITH ANKLE FRACTURE TREATMENT AT REGIO DENPASAR HOSPITAL, 2019-2023

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ABSTRACT

An ankle fracture is a condition where the continuity of the bone in the ankle is partially or completely disrupted Radiological imaging can be used to determine changes in the morphometric variations of the ankle due to ankle fractures. These radiological-anatomical morphometric variations in patients can be assessed through various measurements. This study aims to understand the radiological-anatomical morphometric variations of ankle fractures in patients treated at Regio Denpasar Hospital from 2019 to 2023. The research was conducted using an observational cross-sectional study approach. The results indicate that based on the type of displacement, the average values of radiological-anatomical morphometry of the ankle in ankle fracture patients at Regio Denpasar Hospital from 2019 to 2023 consist of talocrural angle (91.6°), lateral malleolar length (18.2 mm), medial malleolar length (10.6 mm), tibiofibular overlap (6.4 mm), medial clear space (5.1 mm), Johnson angle (96.1°), anterior distal tibial angle (88.9°), and tibiofibular clear space (2.9 mm). For undisplaced fractures, the values are talocrural angle (78.6°), lateral malleolar length (23.3 mm), medial malleolar length (9.1 mm), tibiofibular overlap (5.9 mm), medial clear space (2.4 mm), johnson angle (87.5°), anterior distal tibial angle (82.1°), and tibiofibular clear space (3.1 mm). There is a significant difference between displaced and undisplaced fracture types in the variables talocrural angle, lateral malleolar length, medial malleolar length, medial clear space, and anterior distal tibial angle. However, no significant difference was found between the displaced and undisplaced fracture types for the variables tibiofibular overlap and tibiofibular clear space.

Keywords : Ankle Fracture, Morphometry, Radiologyanatomy

INTRODUCTION

The musculoskeletal system experiences a multitude of complaints, prevalent across nearly the entire world. This issue is intricately linked with daily activities. Disruptions in this system can cause significant problems for sufferers, leading to tingling sensations, pain, numbness, swelling, stiffness, burning sensations, and trembling.[1] According to the Human Safety and Work statistics (2018), there were 500,000 cases related to the musculoskeletal system in the UK throughout 2017.[2] Meanwhile, in Indonesia, a study conducted by the Department of Health in 12 districts revealed that musculoskeletal system cases constituted 16%, cardiovascular system cases 8%, nervous system cases 5%, respiratory system cases 3%, and ENT (Ear, Nose, Throat) cases 1.5%.[1]

Most musculoskeletal cases are caused by mild to severe trauma to the bones, resulting from both non-traffic and traffic accidents. Cases within the musculoskeletal system can encompass diseases related to bones, joints, and tendons. Examples of these diseases include infections and bone fractures. A fracture, often known as a broken bone, refers to a condition where there is a discontinuation in bone continuity, either in part or entirely.[3] According to Riskesdas (2018), the body part most affected by fractures in the lower extremities, accounting for 67%, with ankle fractures being a part of it. An ankle, resembling a ring with two parts, each connected by ligaments and bones, works together to maintain stability. If a fracture occurs in one part of this ring, the condition can still maintain balance. However, a fracture in two parts leads to reduced ankle stability.[4] Ankle fractures can result from two types of factors: direct and indirect. Direct factors include impact and injury from specific accidents that can cause bone trauma. Indirect factors encompass bone weakness due to certain diseases.[4]

Abnormalities in patients with ankle fractures can be assessed further through radiological imaging. Various modalities can be used, such as CT scans, X-rays, arthrography, and MRI. However, the simplest modality for assessment is through X-rays. Despite its less detailed images compared to other modalities, X-rays are sufficient to explain a patient's ankle anatomy in two dimensions.[5]

The sequence of fracture incidents varies significantly, generally following this order: the talus rotates laterally, the lateral posterior malleolus is pushed, the AITFL (Anterior Inferior Tibiofibular Ligament) is stressed and ruptured, followed by the PITFL (Posterior Inferior Tibiofibular Ligament) rupture, and concludes with disturbances in the deltoid ligament.[6] This process leads to changes, resulting in various morphometric variations in the ankle bone region during fractures. Combined with different types of fracture treatment procedures like cast usage, pin placements, and many more, it presents diverse radiological pictures for each patient.

These radiological variations in patient anatomy can be observed through various measurements, including talocrural angle, lateral malleolar length, medial malleolar length, tibiofibular overlap, medial clear space, Johnson angle, anterior distal tibial angle, and tibiofibular clear space.[7]

Based on the background presented above, the aim of this study is to analyze and document the variations in ankle morphology in patients with fractures, as observed through radiological imaging, particularly focusing on specific measurements such as the talocrural angle and tibiofibular overlap, within the population of patients treated in hospitals in the Denpasar region.

LITERATURE REVIEW

Anatomy of Ankle

The ankle is a rather complex part of the body when examined anatomically. It's defined as a ring with two parts, each connected by ligaments and bones working together to maintain stability. The ankle is divided into two sections: lateral and medial.[4] The lateral ligament consists of the anterior talofibular (ATFL), calcaneofibular (CFL), and posterior talofibular (PTFL) ligaments, connecting to the lateral malleolus and the ankle. A syndesmosis is a ligament composed of the anterior and posterior inferior tibiofibular ligaments (AITFL and PITFL) and the interosseous ligament, positioned between the tibia and fibula.[4]

The medial part of the ankle includes the medial malleolus and the medial collateral ligament, also known as the deltoid ligament. The deltoid ligament is significantly stronger than the lateral ligament. The deltoid further divides into superficial and deep deltoid. The deep deltoid includes components like the anterior and posterior talotibial ligaments (ATTL and PTTL). The anterior part extends distally and laterally to insert into the anterior lateral margin of the malleolus, with increased fiber length distally. The posterior part is the strongest, originating from the medial posterior malleolus, moving posterior-medially and then to the plantar and articular surfaces. However, it's important to note that the deltoid ligament tightens when weight-bearing or in the plantigrade position because the fibers within this ligament play a crucial role in the ankle.[4]

The mechanism of ankle fractures generally begins with pressure on the lateral structures, and as the force continues, the medial structures are eventually involved.[8] In stage I, the talus rotates laterally, pushing the posterior lateral malleolus and stressing the AITFL. As the lateral rotation of the talus progresses, the lateral structures experience further stress leading to stage II, where the AITFL ruptures. In stage III, there is a rupture of the PITFL or a posterior tibia malleolus fracture observed in addition to the AITFL rupture, along with a spiral fibula fracture. In stage IV, involvement of the medial ankle structures is seen alongside the lateral (fibula or AITFL) and posterior (PITFL or posterior malleolus) structures. In this stage, fractures through the medial malleolus or disruptions in the deltoid ligament become prominent.[6]

Fracture Ankle

Fractures are among the disorders affecting the musculoskeletal system, impacting muscles, tendons, joints, and bones.[9] Purnomo encapsulates the definition of a fracture as the general loss of bone continuity, whether partial or complete, resulting in cracking, brittleness, and loss of alignment. Fractures can also be described as the disruption of the bone's continuity due to trauma and physical force.[10]

The body's lower extremities are the most vulnerable to fractures, accounting for 67%, followed by upper extremities at 32%, head injuries at 11.9%, spinal injuries at 6.5%, chest injuries at 2.6%, and abdominal injuries at 2.2%. Fracture-related injuries can occur anywhere and anytime. In 2018, household environments contributed to the highest percentage of injuries at 44.7%, compared to roadways at 31.4%, workplaces at 9.1%, and schools at 6.5%.[11] Fractures can occur due to several factors including, indirect trauma, direct trauma, and trauma due to muscle pulling.[12]

Ankle fractures can result from various types of trauma to the bone, ligaments, or muscles. Such trauma can cause external rotation forces, both deep and superficial.[13] External rotation, or lateral rotation, is the movement of limbs away from the body's midline.[8] This action causes the deltoid ligament to rupture or move in one direction while tendons suddenly pull in the opposite direction from the medial malleolus. The deltoid serves as an effective medial support stabilizing the talus for movement. Therefore, the rupture of the deltoid ligament compromises ankle stability.[13]

Fractures can also damage blood vessels, leading to bleeding. This bleeding results in reduced blood volume in the body, causing a decrease in COP (Cardiac Output), which can lead to tissue perfusion changes. As a result of tissue perfusion changes, hematoma exudes plasma and proliferates into local body accumulation forming local edema.[13]

In suspected cases of ankle fractures, three radiography views of the ankle joint are required to evaluate fractures, subluxations, and bone dislocations.[14] Hence, several types of radiographic views, both general and specific, are required to determine the diagnosis related to the fracture including, anteroposterior (ap) view, mortise view, lateral view, oblique view, stress view, external rotation stress view.[15] Fractures come in various types determined by several indicators, such as based on bone fragment displacement, there are undisplaced fractures and displaced fractures. an undisplaced fracture occurs when there's a crack or break in the bone, but the bone fragment maintains its position and alignment. a displaced fracture involves bone dislocation where the bone breaks into two or more parts that shift, causing the ends to misalign.[15]

Ankle Morphometric Variations

Several previous studies, such as the one conducted by Marsil (indicate differences in radiological examination values of the ankle joint in both normal conditions and during trauma. The assessed areas can reveal pathological conditions that vary among individual patients.[7]

Talocrural Angle

The Talocrural Angle is the degree formed by a line perpendicular to the distal tibial articular surface and a line connecting the ends of the malleoli. This degree is used to measure fibular shortening in ankle fractures. The normal value ranges between 75˚ to 78˚.[16] When examining the talocrural angle, it's essential to assess the difference in this angle between both feet, as it significantly determines the fracture prognosis in patients. A prognosis is considered good if the difference in talocrural angle between both feet is not more than 2˚.[17] The Talocrural Angle can be seen in Figure 1.

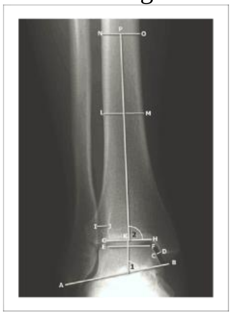

Figure 1: Radiograph of Talocrural Angle, Line connecting malleoli (AB), Medial Clear Space (CD), Line connecting talus (EF), Distal Tibial Articular Surface (GH), Tibial axis (PK), Tibiofibular Clear Space (IJ).[16]

Lateral Malleolar Length

The length of the lateral malleolus is measured from the top of the talus to the end of the malleolus. The maximum and minimum values for lateral malleolar length are 28 mm and 20 mm, with an average of 23.7 mm.[18] The lateral malleolar length can be observed in Figure 2.

Figure 2: Radiograph of Lateral Malleolar Length (LLM), Medial Malleolus (A), Anterior Distal Tibial Angle (ADTA), Lateral Distal Tibial Angle (LDTA).[19]

Medial Malleolar Length

The length of the medial malleolus is measured from the end of the tibia to the malleolus. The normal value ranges from 8 to 10 mm.[16] Medial malleolar length can be seen in Figure 3.

Figure 3: Radiograph of Medial Malleolar Length.[20]

Tibiofibular Overlap

Tibiofibular overlap is the overlapping area between the medial part of the distal fibula and the anterior part of the distal tibia. It's considered normal if the horizontal distance is >6 mm.[20] Tibiofibular overlap can be observed in Figure 4.

Figure 4: Radiograph of Tibiofibular Overlap.[16]

Medial Clear Space

The medial clear space is the widest distance between the lateral border of the medial malleolus and the medial part of the talus, measured parallel to the superior surface of the talus articular. It's normal if it's less than 4 mm.[20] Medial clear space can be seen in Figure 5.

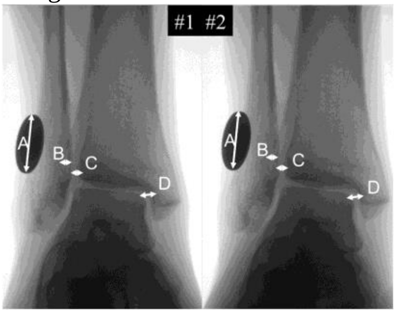

Figure 5: Radiograph of Medial Clear Space (D), Tibiofibular Overlap (B), Tibiofibular Clear Space (C).[20]

Johnson Angle

The Johnson angle is measured as the angle between the tibial axis and the tibial plane. It's used to assess varus or valgus deviation. The normal range is 75-92˚.[21] Johnson's angle can be seen in Figure 6.

Figure 6: Radiograph of Johnson Angle.[21]

Anterior Distal Tibial Angle

The anterior distal tibial angle is the angle between the axis of the tibia and the line connecting the anterior and posterior surfaces of the tibia. The measurement is used to assess the tilt of the tibial component during ankle fractures. The normal value is 82.53˚±2.70˚.[22] Anterior distal tibial angle can be seen in Figure 7.

Figure 7: Anterior Distal Tibial Angle.[22]

Tibiofibular Clear Space

The tibiofibular clear space indicates syndesmosis stability and syndesmotic diastasis. The maximum normal value for tibiofibular clear space is 6 mm. Values above 6 mm indicate lateral stretching, indicating syndesmosis diastasis in ankle fracture patients.[17] Tibiofibular clear space can be seen in Figure 8.

Figure 8: Anterior Distal Tibial Angle.[17]

Patient Morphometric Variations in Ankle Fracture Treatment

In ankle fracture treatment, the initial goal is the improvement of the fracture and the alleviation of pain in patients. However, recent research emphasizes the focus on the stability of three components: the medial malleolus and medial ligament, the lateral malleolus and lateral ligament, and the tibiofibular syndesmosis. Other important parameters for evaluation include tibiofibular clear space, overlap, talocrural angle, and the length of both malleoli.[17]

In fractured conditions, the Talocrural Angle obtained from radiographic results, represented by a line dividing the tibial axis and a line through the ends of the medial and lateral malleoli, may show an increased angle of more than 15˚ and a difference in angle between both feet of more than.[17] The length of the malleolus in fractures isn't extensively discussed, but its assessment is crucial as it helps evaluate the talocrural angle. If a patient exhibits a change in the position of the medial malleolus, especially in malleolus fractures, it not only alters the talocrural angle but also indicates an unfavorable outcome in fracture recovery. Fibular shortening that's acceptable is up to 2 mm.[23]

Tibiofibular overlap is used to identify injuries to the syndesmosis. This overlap should always be present in all ankle radiographs. The absence of tibiofibular overlap or a very small assessment (<6 mm) may indicate a syndesmosis injury. In addition to tibiofibular overlap, another parameter used to determine syndesmosis involvement in ankle fractures is the medial clear space. This assessment helps identify whether the deltoid ligament, as the strongest ligament, experiences imbalance. Previous studies indicate that a medial clear space larger than 5 mm serves as an indicator of deltoid injury.[19] Johnson angle is used to assess varus or valgus deviation. In patients with fractures during the recovery period, the Johnson angle might show a deviation of 5-10˚.[21]

Another evaluation is the anterior distal tibial angle, which is used to observe the influence of the tibial component on the talus position during fractures. A positive outcome is indicated if the obtained angle ranges between 83˚ and 90˚.[22] The last crucial assessment during the fracture recovery process is the tibiofibular clear space. This measurement indicates syndesmosis stability and diastasis. The maximum normal value is 6 mm. A measurement exceeding 6 mm indicates lateral stretching, indicating syndesmosis diastasis in ankle fracture patients.[17]

MATERIALS AND METHODS

The design of this research is an observational analysis with a cross-sectional study approach. This design was chosen because the researchers did not intervene with the research subjects, and data collection was carried out by obtaining the medical records of patients with fractures at the Denpasar Regional Hospital from 2019 to 2023. This research will be conducted at the Orthopedic Department of the Denpasar Regional Hospital, Bali. The study will involve the medical records and X-ray results of patients from January to December 2023. The instruments used in this research include patient medical record reports, patient X-ray results, rulers, calipers, and the ImageJ application for patients undergoing ankle fracture treatment at the Denpasar Regional Hospital from January 2019 to March 2023.

The collected data will be analyzed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS). The data analysis procedures used in this research are descriptive analysis, normality test, homogeneity test, and hypothesis
testing. All collected data will be grouped according to variables: categorical and numerical. Categorical variables will be presented in graphs or tables, including categories (n) and the percentage of each category (%). Numerical variables will be presented in graphs or tables to determine measures of central tendency (mean, median, mode) and measures of dispersion (standard deviation, variance, coefficient of variance, interquartile range, range, and minimum-maximum).

The normality test for this research uses the Kolmogorov-Smirnov test because the sample size is >50. Data are considered normal if the significance value (p) >0.05. The homogeneity test is used to assess whether the data groups come from the same population. In this research, the homogeneity test uses Levene's test of homogeneity of variance. Hypothesis testing in this research uses comparative hypothesis testing of numerical variables to find comparisons between two groups. T-test is used if the data are normally distributed, and the Mann-Whitney U test is used if the data are not normally distributed. If the data are normal but not homogeneous, the measurement will be repeated.

RESULTS

Patients undergoing ankle fracture treatment at the Denpasar Regional Hospitals—Prof. dr. I.G.N.G Ngoerah

Central General Hospital (RSUP) and Wangaya Regional General Hospital (RSUD) from 2019 to 2023—had an accessible population of 138 patients, comprising 87 from RSUP Prof. dr. I.G.N.G Ngoerah and 50 from RSUD Wangaya. However, 29 patients from RSUP Prof. dr. I.G.N.G Ngoerah and 16 from RSUD Wangaya had incomplete medical records and/or ankle X-ray images. Therefore, the sample from these two Denpasar regional hospitals is 92 patients.

Based on Table 1 presents the characteristics of the research sample, including gender, age, and fracture type, it is observed that the research sample ankle fracture patients from RSUP Prof. dr. I.G.N.G Ngoerah and RSUD Wangaya from 2019 to 2023 comprise an equal balance of male and female genders (n = 46; 50%). The study involves 35 male patients and 23 female patients from RSUP Prof. dr. I.G.N.G Ngoerah, and 23 male patients and 11 female patients from RSUD Wangaya.

Table 1. Characteristics of research subjects based on gender, age, and type of ankle fracture, year 2019-2023

Variable		Total N (%)	2019	2020	2021	2022	2023
			N (%) Year				
Sex	Men	46 (50)	1 (1.1)	0 (0)	8 (8,7)	31 (33,7)	6 (6,5)
	Women	46 (50)	1 (1,1)	1 (1,1)	6 (6,5)	26 (28,3)	12 (13)
Age	Children (0-14 tahun)	3 (3,3)	0 (0)	0 (0)	0 (0)	1 (1,2)	2 (2,1)
	Adolescents (15-24 tahun)	20 (21,7)	1 (1,1)	0 (0)	4 (4,3)	13 (14,2)	2 (2,1)
	Young adults (25-44 tahun)	24 (26,1)	0 (0)	1 (1,1)	3 (3,2)	14 (15,2)	6 (6,6)
	Middle-aged adults (45-60 tahun)	29 (31,5)	0 (0)	0 (0)	5 (5,4)	17 (18,5)	7 (7,6)
	Elderly adults (>60 tahun)	16 (17,4)	1 (1,1)	0 (0)	2 (2,1)	12 (13,1)	1 (1,1)
Type	Displaced	52 (56,5)	1 (1)	1 (1)	12 (11,5)	33 (31,7)	5 (4,8)
	Undisplaced	40 (43,5)	1 (1,2)	0 (0)	2 (2,5)	24 (30)	13 (16,3)
Total Sample		92 (100)	2 (2,2)	1 (1,1)	14 (15,2)	57 (62)	18 (19,5)

In terms of age characteristics, the majority of the research sample comes from the middle-aged adult group, totaling 29 individuals (31.5%). Based on fracture type characteristics, the most prevalent ankle fracture type is displaced, totaling 52 cases (56.5%).

Based on Table 2 the research findings indicate that the variables in ankle radiological anatomy morphometry variation with the displaced fracture type talocrural angle (91.6 ± 4.4), medial malleolar length (10.6 ± 3.6), tibiofibular overlap (6.4 ± 3.7), medial clear space (5.1 ± 0.7), johnson angle (96.1 ± 3.2), and anterior distal tibial angle (88.9 ± 10.1) have larger average values compared to the undisplaced type. However, for the variables lateral malleolar length (18.2 ± 3.9) and tibiofibular clear space (2.9 ± 1.4), the average values are higher in the undisplaced fracture type compared to the displaced type.

Table 2. Subject characteristics based on radiological anatomy ankle morphometric variations

Variable		Mean ± Std. Deviasi	Median	Min	Maks
Talocrural Angle	Displaced	91,6º ± 4,4º	90,7	87,0	106,9
	Undisplaced	78,6º ± 4,9º	79,4	65,6	86,9
Lateral Malleolar Length	Displaced	18,2 mm ± 3,9 mm	18,3	8,8	28,8
	Undisplaced	23,3 mm ± 2,3 mm	22,7	20,2	27,5
Medial Malleolar Length	Displaced	10,6 mm ± 3,6 mm	10,1	4,5	20,1

	Undisplaced	9,1 mm ± 2,7 mm	7,7	5,6	15,3
Tibiofibular Overlap	Displaced	6,4 mm ± 3,7 mm	6,3	0,0	13,8
	Undisplaced	5,9 mm ± 2,6 mm	5,6	1,7	12,3
Medial Clear Space	Displaced	5,1 mm ± 0,7 mm	4,9	4,0	7,8
	Undisplaced	2,4 mm ± 0,8 mm	2,2	1,2	4,1
Johnson Angle	Displaced	96,1º ± 3,2º	96,2	92,0	103,6
	Undisplaced	87,5º ± 4,1º	88,2	74,5	92,6
Anterior Distal Tibial Angle	Displaced	88,9º ± 10,1º	87,2	69,1	139,5
	Undisplaced	82,1º ± 5,1º	80,7	72,1	99,3
Tibiofibular Clear Space	Displaced	2,9 mm ± 1,4 mm	3,2	0,0	6,21
	Undisplaced	3,1 mm ± 1,3 mm	2,5	1,7	5,8

Based on Figure 9, in the displaced type group at RSUP Prof. Dr. I.G.N.G Ngoerah, the average measurement results for the variables are as follows: talocrural angle (91.55º), lateral malleolar length (18.7 mm), medial malleolar length (11 mm), tibiofibular overlap (6.5 mm), medial clear space (5.1 mm), johnson angle (96.2º), anterior distal tibial angle (89.5º), tibiofibular clear space (3 mm). Meanwhile, the measurements at RSUD Wangaya provided average results for the variables: talocrural angle (91.9º), lateral malleolar length (15.1 mm), medial malleolar length (7.8 mm), tibiofibular overlap (5.4 mm), medial clear space (4.9 mm), johnson angle (95.1º), anterior distal tibial angle (85.6º), tibiofibular clear space (2.7 mm). There's a substantial difference in the average measurements of lateral malleolar length, medial malleolar length, and anterior distal tibial angle, exceeding 3 mm and 3 degrees between the two hospitals in this displaced type group.

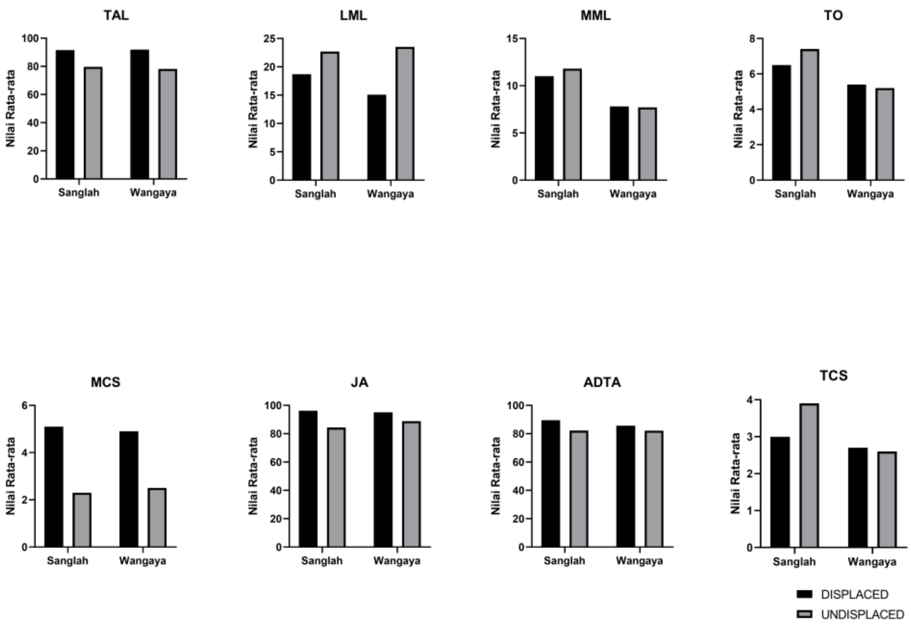

Figure 9. Bar graph of radiological anatomy ankle morphometry characteristics

In the undisplaced type group at RSUP Prof. dr. I.G.N.G Ngoerah, the average measurements for the variables are talocrural angle (79.6º), lateral malleolar length (22.7 mm), medial malleolar length (11.8 mm), tibiofibular overlap (7.4 mm), medial clear space (2.3 mm), johnson angle (84.4º), anterior distal tibial angle (82.2º), tibiofibular clear space (3.9 mm). However, at RSUD Wangaya, the average measurements for the variables are talocrural angle (78.1º), lateral malleolar length (23.5 mm), medial malleolar length (7.7 mm), tibiofibular overlap (5.2 mm), medial clear space (2.5 mm), johnson angle (88.9º), anterior distal tibial angle (82.1º), tibiofibular clear space (2.6 mm).

Table 3. Analysis of normality and homogeneity of radiological anatomy ankle morphometry based on fracture type

Variable		Kolmogorov-Smirnov	*Levene's test*
Talocrural Angle	*Displaced*	0,000	0,280*
	Undisplaced	0,200*	
Lateral Malleolar Length	*Displaced*	0,004	0,072*
	Undisplaced	0,193*	
Medial Malleolar Length	*Displaced*	0,200*	0,057*
	Undisplaced	0,000	
Tibiofibular Overlap	*Displaced*	0,200*	0,068*
	Undisplaced	0,200*	
Medial Clear Space	*Displaced*	0,200*	0,311*
	Undisplaced	0,143*	
Johnson Angle	*Displaced*	0,010	0,226*
	Undisplaced	0,093*	
Anterior Distal Tibial Angle	*Displaced*	0,003	0,057*
	Undisplaced	0,001	
Tibiofibular Clear Space	*Displaced*	0,200	0,825*
	Undisplaced	0,000	

Significance (P - *Value*)

The analysis of mean differences begins with normality and homogeneity tests. The normality test assesses whether the data are normally distributed or not, using the Kolmogorov-Smirnov test because the sample size is >50. The homogeneity test aims to evaluate whether the data groups come from the same population, using Levene's test. For the Kolmogorov-Smirnov test, if the result yields $p>0.05$, the data are considered normally distributed; if $p<0.05$, the data are not normally distributed. As per Table 3, ankle fracture type displaced with ankle morphometry variables medial malleolar length, tibiofibular overlap, medial clear space, and tibiofibular clear space exhibit normal distribution, while other ankle morphometry variables talocrural angle, lateral malleolar length, johnson angle, and anterior distal tibial angle do not exhibit normal distribution.

For ankle fracture type undisplaced, variables such as talocrural angle, lateral malleolar length, tibiofibular overlap, medial clear space, and Johnson angle are stated to have a normal distribution, while medial malleolar length, anterior distal tibial angle, and tibiofibular clear space are not normally distributed. The homogeneity test using Levene's test yields $p>0.05$, indicating that the data come from the same population or that the data for each ankle morphometry variable are homogeneous.

Table 4. Analysis of mean differences in radiological anatomy ankle morphometry based on fracture type using independent t-test

Variable		Mean ± Std. deviate	*Mean difference* (95% CI)	*P - value*
Tibiofibular Overlap	*Displaced*	6,37 ± 3,6	0.47	0,497
	Undisplaced	5,9 ± 2,6	(-0,89-1,82)	
Medial Clear Space	*Displaced*	5,1 ± 0,7	2.61	0,001*
	Undisplaced	2,4 ± 0,8	(2,29-2,94)	

The analysis of mean difference for normally distributed variables uses the Independent T-test. Based on Table 4, the variable tibiofibular overlap, has a higher mean in the displaced group compared to the undisplaced group; however, based on the analysis, the null hypothesis (Ho) is accepted, signifying no statistically significant difference between tibiofibular overlap in the displaced and undisplaced groups. Medial clear space has a higher mean in the displaced group compared to the undisplaced group, and the analysis of mean difference states that the null hypothesis is rejected, indicating a statistically significant difference between medial clear space in the displaced and undisplaced.

Table 5. Analysis of mean differences in radiological anatomy ankle morphometry based on fracture type using Mann-Whitney test

Variable		***Mean Rank***	**Z**	***P-value***
Talocrural Angle	*Displaced*	66,50	-8,191	0,001*
	Undisplaced	20,50		
Lateral Malleolar Length	*Displaced*	30,33	-6,624	0,001*
	Undisplaced	67,53		
Medial Malleolar Length	*Displaced*	51,86	-2,194	0,028*
	Undisplaced	39,54		
Johnson Angle	*Displaced*	66,30	-8,109	0,001*
	Undisplaced	20,76		
Anterior Distal Tibial Angle	*Displaced*	49,32	-4,824	0,001*
	Undisplaced	42,84		
Tibiofibular Clear Space	*Displaced*	47,56	-0,433	0,665
	Undisplaced	45,13		

Among the variables that underwent the normality test using Kolmogorov-Smirnov, some were found not to have a normal distribution talocrural angle, lateral malleolar length, medial malleolar length, johnson angle, anterior distal tibial angle, and tibiofibular clear space. These non-normally distributed data were further analyzed for mean difference using the Mann-Whitney test. As per Table 5, the talocrural angle in the displaced group is higher than in the undisplaced group, and the analysis of the mean difference rejects the null hypothesis, signifying a statistically significant difference between the talocrural angle in the displaced and undisplaced groups. The lateral malleolar length has a lower mean in the displaced group compared to the undisplaced group, and the analysis of the mean difference concludes that the null hypothesis is rejected, signifying a statistically significant difference between lateral malleolar length in the displaced and undisplaced groups.

The medial malleolar length has a higher mean in the displaced group compared to the undisplaced group, and the analysis of the mean difference with a rejected null hypothesis indicates a statistically significant difference between medial malleolar length in the displaced and undisplaced groups. Johnson angle has a higher mean in the displaced group compared to the undisplaced group, and the analysis of mean difference, rejecting the null hypothesis, shows a statistically significant difference between Johnson angle in the displaced and undisplaced groups.

Anterior distal tibial angle has a higher mean in the displaced group compared to the undisplaced group. Based on the analysis of the mean difference, the null hypothesis is rejected, indicating a statistically significant difference between anterior distal tibial angle in the displaced and undisplaced groups. Tibiofibular clear space has a higher mean in the displaced group compared to the undisplaced group. The analysis of mean difference accepts the null hypothesis, signifying no statistically significant difference between tibiofibular clear space in the displaced and undisplaced groups.

DISCUSSION

Based on the research findings, there is a 50% occurrence of ankle fractures in females (46 patients) and 50% in males (46 patients). This result contrasts with several previous studies. For instance, Hansen et al. found that males (54%) experienced more ankle fractures than females (46%).[24] Mizusaki et al. (2021) similarly reported that ankle fracture cases were dominated by males (61.34%) compared to females (38.66%).[25] The age group in this study indicates that ankle fractures are predominantly experienced by middle-aged adults, around 45-60 years old. This aligns with other studies reporting that most ankle fractures occur at around 55 years of age.[26] In this study, displaced fractures predominated, contrary to previous research by Robertson et al., who found that undisplaced fractures (52) were more common than displaced fractures (44).[27]

Talocrural Angle

In terms of undisplaced fractures, Rolfe et al. (2016) found an average talocrural angle ranging between 75º - 86º, consistent with the 78.6º found in this study.[28] For displaced fractures in this study, the average talocrural angle was 91.6º. This result is consistent with earlier research indicating an average talocrural angle for displaced fractures between 79º - 92º.[29]

Lateral Malleolar Length

For undisplaced fractures in this study, the average lateral malleolar length was 23.3 mm, aligned with previous research suggesting an average range of 20 – 28 mm.[7] However, for displaced fractures, the average length was 18.2 mm, in line with Black et al.'s (2021) finding that the average lateral malleolar length for displaced fractures is < 20.5 mm.[30]

Medial Malleolar Length

In undisplaced fractures, Xie et al. (2021) reported an average medial malleolar length of 8 - 9 mm, consistent with this study's average of 9.1 mm.[23] For displaced fractures, the average medial malleolar length in this study was 10.6 mm, similar to previous studies reporting averages in the range of 10 – 12 mm.[31]

Tibiofibular Overlap

Huang et al. found an average tibiofibular overlap ranging from 3.1 mm – 8.7 mm.[32] Which aligns with this study's result of 5.9 mm. In this study, displaced fractures had an average tibiofibular overlap of 6.4 mm, also supported by Mulligan's study with results > 6 mm.[33]

Medial Clear Space

For undisplaced fractures in this study, the average medial clear space was 2.4 mm, consistent with previous research indicating an average medial clear space for undisplaced fractures of < 4 mm.[34] In displaced fractures, Gibson et al. found averages in the range of 4 mm – 7 mm, similar to this study's average of 5.1 mm.[35]

Johnson Angle

In undisplaced fractures, the average Johnson angle was 87.5º in this study, aligning with previous research showing an average range of 85º - 92º.[36] However, for displaced fractures in this study, the average Johnson angle was 96.1º, contrary to Krackhardt et al.'s findings of averages ranging between 88º - 90º for displaced fractures.[21]

Anterior Distal Tibial Angle

Undisplaced fractures had an average anterior distal tibial angle of 82.1º in this study, consistent with Kellam et al.'s findings within the range of 76º - 92º.[37] Displaced fractures, however, had an average of 88.9º, also in line with Buckley & Sands' findings of > 82º.[38]

Tibiofibular Clear Space

For undisplaced fractures in this study, the average tibiofibular clear space was 3.1 mm. This result was supported by Pogliacomi et al.'s) research, which found a range of 3 mm – 10 mm for tibiofibular clear space.[39] Meanwhile, displaced fractures in this study had an average of 2.9 mm, consistent with Jakušonoka et al.'s report of an average < 3 mm for tibiofibular clear space.[40]

Based on the bivariate analysis of this study's data, significant differences were found between displaced and undisplaced types in variables such as talocrural angle, lateral malleolar length, medial malleolar length, medial clear space, Johnson angle, and anterior distal tibial angle. However, no significant differences were observed in tibiofibular overlap and tibiofibular clear space between the displaced and undisplaced types.

These significant differences align with Singh et al.'s research, indicating differences in radiological measurements between displaced and undisplaced fractures, notably a > 5º difference in talocrural angle and up to an 8 mm difference in anterior distal tibial angle.[15] Similarly, the significant difference in lateral malleolar length between displaced and undisplaced types is supported by Black et al.'s findings, suggesting a 3.1 times larger measurement for undisplaced fractures due to lateral malleolus shortening in displaced fractures.[30]

The discrepancy in medial malleolar length is explained by Patil et al.'s research, attributing significant differences between displaced and undisplaced types to tibial traction mechanisms leading to larger measurements in displaced fractures.[41] Johnson angle differences might stem from significant increases in measurements in displaced fractures, allowing easy recognition of deviations.[21]

Tibiofibular clear space and overlap showed no significant differences, as reported by Singh et al,indicating similar measurements (< 5 mm) for both displaced and undisplaced fractures. This minimal impact on ankle changes due to fractures led to non-significant differences in measurements between the two types.[39]

CONCLUSIONS

Based on the conducted research, the following conclusions were drawn, based on the displaced type, the average values of ankle radiological morphometric variables among ankle fracture patients in the Denpasar regional hospital during the 2019-2023 period are as follows: talocrural angle (91.6º), lateral malleolar length (18.2 mm), medial malleolar length (10.6 mm), tibiofibular overlap (6.4 mm), medial clear space (5.1 mm), Johnson angle (96.1º), anterior distal tibial angle (88.9º), and tibiofibular clear space (2.9 mm).

Based on the undisplaced type, the average values of ankle radiological morphometric variables among ankle fracture patients in the Denpasar regional hospital during the 2019-2023 period are as follows: talocrural angle (78.6º), lateral malleolar length (23.3 mm), medial malleolar length (9.1 mm), tibiofibular overlap (5.9 mm), medial clear space (2.4 mm), Johnson angle (87.5º), anterior distal tibial angle (82.1º), and tibiofibular clear space (3.1 mm).

Significant differences were observed between displaced and undisplaced fracture types in the variables talocrural angle, lateral malleolar length, medial malleolar length, medial clear space, and anterior distal tibial angle. No significant differences were found between displaced and undisplaced fracture types in the variables tibiofibular overlap and tibiofibular clear space.

Based on the conducted research, the author suggests enhancing the use of radiological morphometric variations in diagnosing and providing care for ankle fracture patients. The researcher also hopes that these research findings can serve as a reference for further studies and emphasize the need for more in-depth research on the relationship between ankle radiological morphometric variations and the selection of ankle fracture patient treatment procedures.

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