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ORIGINAL ARTICLE

PRE-PLANNING ANKLE ARTHRODESIS USING 3D RECONSTRUCTED TOMOGRAPHIES

DESENVOLVIMENTO DA ARTRODESE DO TORNOZELO BASEADA NA TOMOGRAFIA COM RECONSTRUÇÃO 3D

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ABSTRACT

Objective: To implement one analysis method of the ankle bone contour that could make a more precise ankle arthrodesis. Methods: Twenty tomographies were submitted to 3D reconstruction. Seven points of anatomic interest for ankle arthrodesis with the three screws technique were marked with a triplannar marker. The median of the position of markers was estimated, and the union of the seven median points allow the construction of one median ankle for that population. Using this median ankle, sizes and angles for the screws position were determined. Results: Two median ankles were reconstructed, left and right. The position of the screw passage were determined considering the anatomical parameters. In the right ankle the lateral to medial screw should enter 4.56 cm and 0.79 above and posterior to lateral malleolus, with one inclination of 17.34° in relation to tibial longitudinal axis; and 0° in relation to tibial axial plane. The position for the other two screws is also described. Conclusion: Our article is the first to presents one precise guide for ankle arthrodesis based on a populational assessment. ***Level of evidence II, Diagnostic Studies.***

Keywords: Foot. Ankle. Arthrodesis. Pre-Planning. 3D-Reconstruction. Joint Diseases.

RESUMO

Objetivo: Implementar método de análise do contorno e alinhamento ósseos no tornozelo de uma população normal, possibilitando uma artrodese tibiotársica mais precisa. Métodos: Tomografias de vinte tornozelos foram submetidas à reconstrução 3D. Nesses exames, 7 pontos anatômicos de interesse para a técnica de fixação com 3 parafusos foram identificados e marcados com indicadores da posição triplanar. As médias das localizações de cada ponto foram calculadas. A união dessas médias permitiu a reconstrução de um tornozelo padrão daquela população. Nesses tornozelos médios estudou-se os comprimentos e ângulos para a passagem dos parafusos. Resultados: Dois tornozelos, direito e esquerdo, foram reconstruídos. A posição para a passagem dos parafusos em relação a parâmetros anatômicos foi determinada. Para o tornozelo direito, a passagem do parafuso de lateral para medial deve ocorrer com o ponto de entrada 4,56 cm acima e 0,79 cm posterior à ponta do maléolo lateral, com inclinação de 17,34° em relação ao eixo longitudinal e 0° em relação ao eixo axial da tíbia. As posições dos outros dois parafusos também estão descritas. Conclusão: Esse é o primeiro trabalho que apresenta um guia preciso para realização da artrodese do tornozelo, baseado em um estudo populacional. ***Nível de evidência II, Estudos Diagnósticos.***

Descritores: *Artropatias. Pé. Tornozelo. Artrodese. Pré-Planejamento. Reconstrução 3D.*

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INTRODUCTION

Ankle arthrodesis (AA) is a procedure for salvation in advanced ankle arthrosis. Despite the new techniques such as ankle arthroplasty, it is the only possible procedure in the case of young patients or bone defects. In addition, many studies have shown similar complication scans and quality of life between procedures.[1-3]

Many studies have compared different forms of fixation.[4,5] Screw fixation is the most traditional method, usually made with two crossed screws, one with medial entry and the other with entry.[3,6,7] A third screw was generally added to the anteroposterior axis due to the high incidence of non-consolidations, usually with posterolateral entry into the tibia towards the neck of the talus, known as "home-run" screw (Figures 1 and 2).[7-10]

All authors declare no potential conflict of interest related to this article.

This study was developed at Universidade Federal do Ceará, Department of Surgery.
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Figure 1. Fixing technique with 3 screws.

Figure 2. Fixing technique with 3 screws.

The screw is positioned to confront the strong deformation force of the Achilles tendon.[11-13] The stability of arthrodesis made only with the screws seems to be sufficient.[5,11] But plates are often used to neutralize rotation forces along the screws.[9,14,15] Additional stability increased consolidation rates;[8] however, plates cannot be used in some cases as in arthroscopic arthrodesis.

Most parameters used to determine surgery with good alignment and good position of screws use postoperative radiographs with load. As this type of examination is not likely to be performed intra-operatively, the surgeon may have difficulty in positioning and passing the screws.[16]

Thus, the best form of guiding the surgeon are the anatomical references. Although several studies show the functional results of the fixation technique with three screws[5,6,17,18], we did not find studies on the anatomical population variation of the ankle and reference points that could be used by the surgeon for screw fixation and bone positioning.

Our study showed a cheap and simple method of study with a group of individuals without anatomical anomalies to create a practical guide for positioning and fixation in ankle arthrodesis, using 3D reconstruction of scans.

METHODS

This is a retrospective study with access to the archive of tomographic images of the General Hospital of Fortaleza approved by the Ethics Committee of the Institution under the opinion number: 2.889.433, wherein the signing of an informed consent form was not necessary. We selected 20 tomographies of 13 patients, 8 men and 5 women, aged between 18 and 70 years (10 left and 10 right ankles) to study the ideal positioning between the ankle bones and the best points of passage of the screws in the ankle arthrodesis.

We used the tripod fixation technique with two crossed screws, one entry and one of medial entry In addition to entry screw known as "home run screw," as described by Schuberth et al.[19], the tests were performed on a platform that kept the foot at 90°, positioned relative to the tibia. The images were obtained from the medical archive after approval by the ethics committee of the General Hospital of Fortaleza. Only ankles without bone misalignment or deformities were included according to evaluation of a radiologist and an orthopedist for each ankle.

The device used was the multislice tomography (Toshiba Medical System Corporation) with cuts of 1 mm. Using the Horos program (GNU Lesser Genera Public License®), the 104 tomographies were reconstructed three-dimensionally adjusting the density parameters for the best possible bone contour definition. Initially, we scored a standard zero point on all images and from these points we scored 8 points (Figure 3):

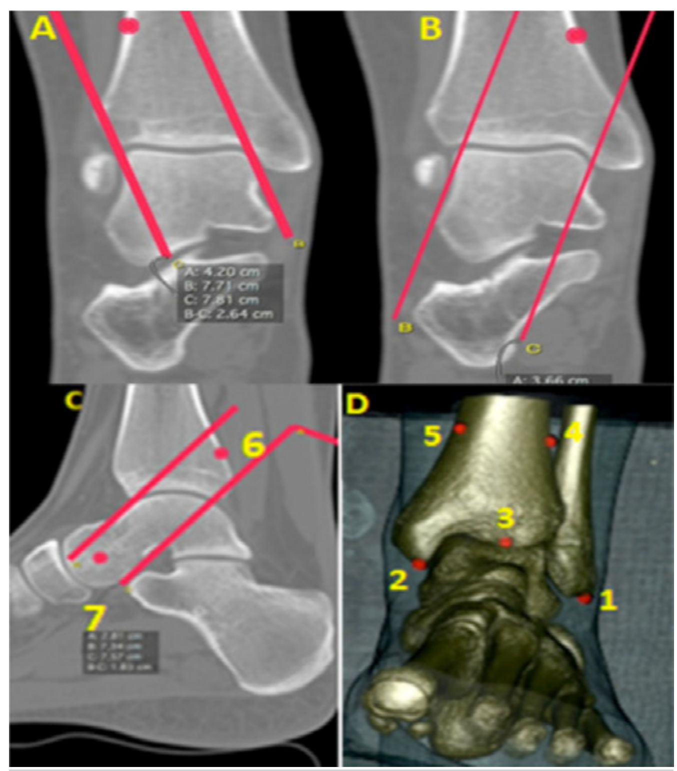

Figure 3. Marking of the entry points of the screws and anatomical reference points. A: determination of the lateral entry point in the middle distance of two parallel lines within the limits of the talus in the anteroposterior incidence and justa anterior point of the fibula in the profile; B: medial entry point, half distance of two parallel lines within the limits of the talus at the most central point of the tibia in the profile; C: posterior entry point determined by two parallel lines within the limits of the talus in the profile and the center point of the talus head determined as the center of a circumference between the upper point of the talus head and the lower point; D: 3D reconstruction image.

1. lateral malleolus (more distal point of fibula)
2. medial malleolus (most distal point of tibia)
3. most anterior point of tibial pestle
4. Entry point of the medial screw
5. Entry point of the medial screw
6. Entry point of the posterior screw
7. Upper talus point
8. lower point of the talus (we defined the center of the circumference made between these last two points as the center of the talus)

The program generated the reference in the X, Y, and Z planes for each point from the given zero point. We estimated the mean compiling the data and confidence interval (CI) by simple inferential analysis for each plane of each point. Each midpoint was marked in the AutoCAD graphic design program®, generating the average ankle of the study population (Figure 4). The relationship between the points was analyzed and a guide for the passage of the screws and intraoperative positioning of the ankle was generated.

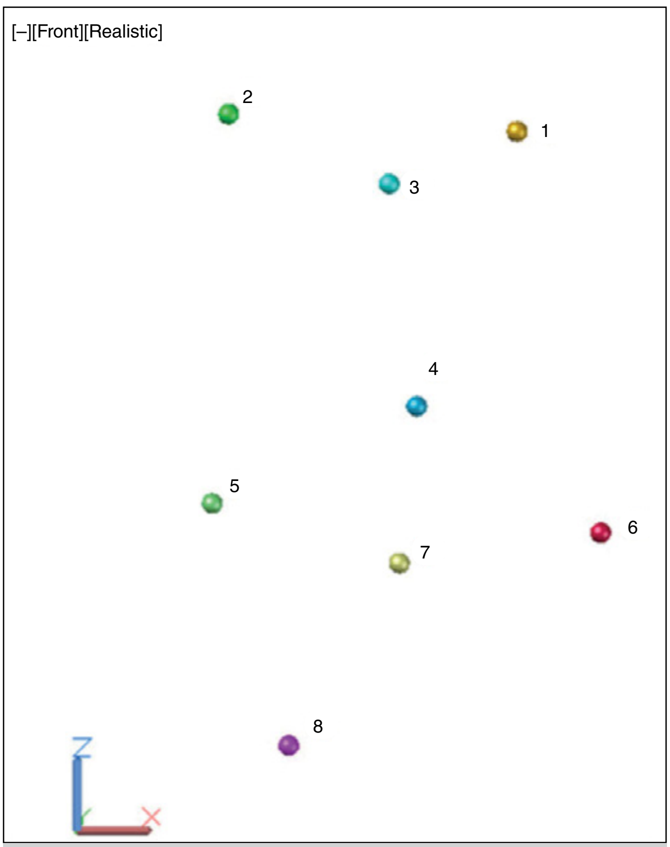

Figure 4. The estimated means for each point plotted in drawing program, the distances and angles between these points can be used to guide the passage of the screws.

RESULTS

We could not unify the data for the left and right ankles due to the topographic evaluation of the points. Thus, a guide was created for each laterality. Table 1 shows the means obtained for the positioning of each point with the confidence interval. Table 2 shows the result of the relationship between the points plotted in the drawing (Figure 3), generating the guide to perform the surgery, with expected length of the screws, distance between the points of entry of the screws and the reference points and the angles of attack of the screws. Figures 5, 6 and 7 exemplify the use of the Table 2 guide.

Table 1. The means obtained for the positioning of each point with the confidence interval.

Plane X Right Ankle	**Mean**	**CI**
Lateral Entry Point	34.78 mm	(29.97 – 39.58)
Medial Entry Point	61.46 mm	(56.25 – 66.66)
Posterior Entry Point	45.57 mm	(39.15 – 52.00)
Anterior Tibia Point	46.03 mm	(41.47 – 50.60)
Medial Malleolus Point	70.26 mm	(65.45 – 75.07)
Lateral Malleolus Point	26.80 mm	(17.15 – 36.45)
Talus Upper Point	47.98 mm	(42.98 – 53.01)
Talus Upper Point	56.309	56.309
Plane Y Right Ankle	**Mean**	**CI**
Lateral Entry Point	13.25 mm	(8.01 – 18.49)
Medial Entry Point	8.82 mm	(4.90 – 12.75)
Posterior Entry Point	19.39 mm	(1.51 – 37.28)
Anterior Tibia Point	-0.06 mm	(-3.48 – 3.35)
Medial Malleolus Point	4.46 mm	(-1.32 – 10.61)
Lateral Malleolus Point	25.81 mm	(20.42 – 31.20)
Talus Upper Point	-15.76 mm	(-18.87 – -12.64)
Talus Upper Point	-3.85 mm	3.85
Plane Z Right Ankle	**Mean**	**CI**
Lateral Entry Point	1143.86 mm	(1141.29 – 1146.42)
Medial Entry Point	1146.83 mm	(1145.42 – 1148.23)
Posterior Entry Point	1128.67 mm	(1108.43 – 1148.90)
Anterior Tibia Point	1117.26 mm	(1114.59 – 1119.92)
Medial Malleolus Point	1109.98 mm	(1106.71 – 1113.24)
Lateral Malleolus Point	1098.22 mm	(1095.95 – 1100.49)
Talus Upper Point	1102.61 mm	(1100.52 – 1104.69)
Talus Upper Point	1083.8 mm	1083.8 mm
Plane Z Right Ankle	**Mean**	**CI**
Lateral Entry Point	77.96 mm	(69.76– 86.17)
Medial Entry Point	50.79 mm	(41.39 – 60.19)
Posterior Entry Point	65.88 mm	(57.68 – 74.07)
Anterior Tibia Point	68.47 mm	(63.10 – 73.84)
Medial Malleolus Point	49.14 mm	(28.81 – 69.47)
Lateral Malleolus Point	85.88 mm	(77.11 – 94.64)
Talus Upper Point	66.85 mm	(59.85 – 73.85)
Talus Upper Point	56.309 mm	56.309 mm
Plano Y Left Ankle	**Mean**	**CI**
Lateral Entry Point	14.58 mm	(7.46 – 21.71)
Medial Entry Point	5.77 mm	(2.53 – 9.00)
Posterior Entry Point	27.19 mm	(22.15 – 32.22)
Anterior Tibia Point	2.44 mm	(-1.09 – 5.98)
Medial Malleolus Point	1.77 mm	(-0.9 – 4.47)
Lateral Malleolus Point	29.22 mm	(19.71 – 38.73)
Talus Upper Point	-12.26 mm	(-17.15 – -7.37)
Talus Upper Point	3.85	3.85
Plano Z Left Ankle	**Mean**	**CI**
Lateral Entry Point	1141.95 mm	(1134.99 – 1148.91)
Medial Entry Point	1143.59 mm	(1139.39 – 1147.80)
Posterior Entry Point	1136.99 mm	(1135.05 – 1138.92)
Anterior Tibia Point	1115.93 mm	(1111.35 – 1120.51)
Medial Malleolus Point	1106.72 mm	(1104.19 – 1109.24)
Lateral Malleolus Point	1103.96 mm	(1084.03 – 1123.90)
Talus Upper Point	1101.08 mm	(1099.50 – 1102.66)
Talus Upper Point	1083.8	1083.8

Table 2. Surgical guide obtained by the analysis of the correlation between the midpoints of the right ankle.

Right Ankles		
Entry Point Lateral	Superior to Medial Malleolus	4.56 cm
	Posterior to Medial Malleolus	0.79 cm
Entry Point Medial	Superior to Medial Malleolus	3.68 cm
	Posterior to Medial Malleolus	0.88 cm
Posterior Entry Point	Superior to Medial Malleolus	3.045 cm
	Posterior to Medial Malleolus	1.87 cm
Entry angle in relation to the longitudinal axis of the Tibia	17.34 degrees (for lateral and medial screws)	
Entry angle in relation to tibia axial axis	zero for lateral and medial screws	
Entry angle in relation to the longitudinal axis of the Tibia	39.05 degrees (for the posterior screw)	
Entry angle in relation to tibia axial axis	59.26 degrees (for the posterior screw)	
Length of lateral screw	4.62 cm	
Length of medial screw	4.34 cm	
Length of posterior screw	4.57 cm	
Entry Point Lateral	Superior to Medial Malleolus	3.79 cm
	Posterior to Medial Malleolus	0.79 cm
Entry Point Medial	Superior to Medial Malleolus	3.68 cm
	Posterior to Medial Malleolus	0.15 cm
Posterior Entry Point	Superior to Medial Malleolus	3.303 cm
	Posterior to Medial Malleolus	2 cm
Entry angle in relation to the longitudinal axis of the Tibia	17.34 degrees (for lateral and medial screws)	
Entry angle in relation to tibia axial axis	zero for lateral and medial screws	
Entry angle in relation to the longitudinal axis of the Tibia	38.35 degrees (for the poserior screw)	
Entry angle in relation to tibia axial axis	57.29 degrees (for the poserior screw)	
Length of lateral screw	4.33 cm	
Length of medial screw	4.48 cm	
Length of posterior screw	6.2 cm	

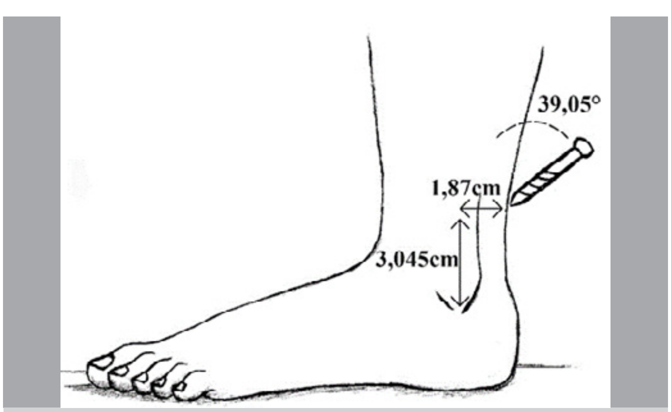

Figure 5. Application of coordinates from Table 2.

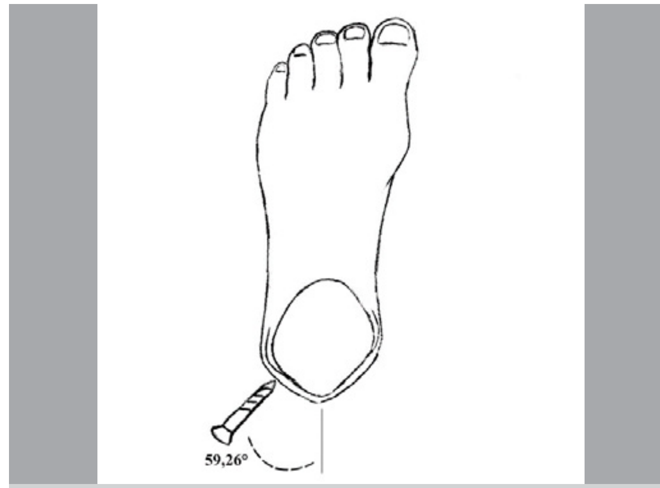

Figure 6. Application of coordinates from Table 2.

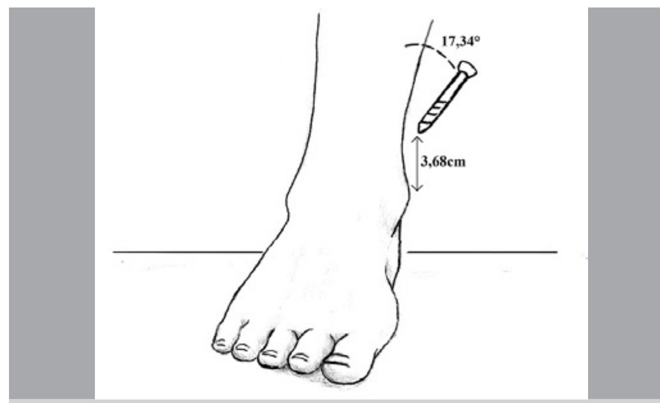

Figure 7. Application of coordinates from Table 2.

DISCUSSION

Although ankle arthrodesis is a widely performed procedure, especially because it is the only possible procedure in many cases, we could not find a description of each step based on an anatomical study.

High non-consolidation rates reported in all types of fixation make this an important issue.[7,8,15] Many studies focus on the biomechanical stability of different fixation methods[11]; however, they do not mention how to find the best entry point and the entry angle for the screw, which increases the need for experience and skill of the surgeon, increasing the chance of error.

The best positioning and the quantity of screws are still controversial. The two screws of the crossed coronal plane can compress at the arthrodesis site, failing, however, to stabilize the strong traction in the sagittal plane of the Achilles tendon or the dorsiflexor force made by the forefoot in the soil, which generated the need to add a third screw in the sagittal plane.[11.20]

Despite the evidences showing that the screw of the sagittal plane should be passed from anterior to posterior[13], we have chosen to study the method as a posterolateral "home-run" screw to the center of the talus head because it seems to be the most used method by surgeons.[10]

The confidence interval was very wide in most of the points analyzed, often greater than 10 cm, which is above the tolerable considering that the ankle is a small joint. Thus, our study can work as an initial orientation for surgeons. Initial statistical analysis showed that we will need 357 ct scans to develop an accurate guide to be used with all the population. This study has been developed by our group. Despite the small sample, the two groups generated, right and left, showed similar results (angles of entry of the lateral and medial screws were 17.34°for the right and 18° to the left, for example). This suggests that the applied method is simple and reproducible. Moreover, it uses widely available computer tests and programs, generating the possibility of evaluating larger populations.

AUTHORS' CONTRIBUTION: Each author contributed individually and significantly to the development of this article: RSA: project design, development of the ct analysis technique, data compilation, writing of the article. MPBC: data compilation and tabulation, marking of points of interest in tomography. JRL: selection of appropriate tomographic cuts, adjustment of images for analysis. MPBC: data compilation and tabulation, marking of points of interest in tomography. MJDT: coordination of the project, statistical analysis and review of the article. JADL: project coordination, statistical analysis and review of the article.

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