Mathematical approximation of fibular malleolus curvature

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INTRODUCTION

The distal part of the fibula, lateral malleolus, forms the outer ankle joint, which is thickened and flattened in the transverse direction. Articular surface for talus is found on the inner, medial, surface of the lateral malleolus. That surface is in slight valgus in relation to the vertical axis of the fibula.

A number of researchers established that even the slightest incongruence of articular surfaces leads to significant changes in the physiological intraarticular biomechanical relationship of the structures involved. Unequally distributed strain occurs on articular surfaces leading to degenerative processes in articular cartilage causing arthritis. This rule also applies to the ankle joint, being the most strained joint of the human body. The fibula takes approximately one fifth of all the forces straining the leg.6

In most instances plain radiographs determine operative or conservative treatment. In cases where primary displacement or possible secondary displacement is anticipated operative intervention is carried out. The goals of operative treatment using the plate include anatomical reduction with stable fixation and early range of motion.5

Several papers have described the articular surfaces of the ankle joint and the fibula itself, but there are no studies describing the outer surface and the degree of curvature of the fibular malleolus.8-15 The morphology of the ankle joint as well as its stability and natural mobility have to be kept in mind when designing stabilization plates.8

Considering that in the operative treatment of a lateral malleolar fracture a plate is placed on the outer lateral malleolar surface, topographical anatomical data could facilitate the development of an anatomic plate that can be used for the osteosynthesis of the fibular malleolar fracture. This study therefore aims to mathematically approximate the sagittal curvature of the outer surface of the lateral malleolus based on standard anteroposterior radiographs.

MATERIALS AND METHODS

Following local ethical approval (University of Zagreb School of Medicine Ethical Committee) 30 adult consecutive male patients presented in our emergency department due to ankle sprains, where they underwent a standard anteroposterior x-ray of the ankle in the neutral position were recruited for the study.12 The distance between the focus and the film was 100 cm. There is a certain factor of magnification on such images, but this study ignored that magnification as it has no impact on the shape and curvature of the fibula.8,9,12 The study included patients whose clinical examination and x-ray analysis established no fracture of the ankle joint,7 were between 20 and 35 years of age and had BMI lower than 25 kg/m2. Patients with

KEYWORDS

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ABSTRACT

While there are several manuscripts describing the articular surfaces of the ankle joint and the fibula itself, there is no study describing the outer surface and the degree of curvature of the fibular malleolus. This paper aims to approximate the sagittal curvature of the outer surface of the lateral malleolus mathematically. Such data would facilitate the design of the anatomic plate that can be used for the osteosynthesis of the fibular malleolar fracture.

30 males who were examined in the emergency department due to ankle sprains, where they underwent a standard anteroposterior x-ray of the ankle in the neutral position were recruited. The radiographs which revealed no bony injury were digitized and statistically processed. A mathematical function for each separate fibula was obtained through the processing of the digitized x-rays. When all the functions were applied to one graph, common traits of all fibulas were noted. The mean value of all functions was obtained and it corresponds to the polynomial function of degree 6.

Mathematical approximation of the curvature is a simple and reliable method that can be applied to other ellipsoid human bone structures besides the ankle, thus being a valuable method in anthropometric, radiological and virtual geometric calculations.

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corresponding to the polynomial function of degree 6.

Results

Each fibula is presented by a separate curve defined by coefficients \(a_0, a_1, a_2, a_3, a_4, \ldots, a_9\) (Figure 2; Table 1), corresponding to the polynomial function of degree 6.

\[ y = a_0 + a_1 x + a_2 x^2 + \ldots + a_9 x^9 \]

Polynomial function of degree 6

Considering that all fibulas were analyzed in the same manner i.e. all were fitted by a polynomial function of degree 6, it was possible to obtain a mean value for all fibulas. We had 30 fibulas with 60-70 edge points per fibula and that enabled us to derive to a typical form of the fibula. Each curve represents a fibula (shown in dotted lines). By superpositioning all fibulas on one graph, the similarities between them become even more pronounced. In this manner, a mean value describing a typical form of the fibula was obtained (continuous line), (Figure 3). The graph shows all fibulas have similar traits. The curvature rises steeply (maximum being 0.75 to 1.5 cm) after which a less pronounced. In this manner, a mean value describing a typical form of the fibula was obtained (continuous line), (Figure 3). The graph shows all fibulas have similar traits. The curvature rises steeply (maximum being 0.75 to 1.5 cm) after which a less pronounced. In this manner, a mean value describing a typical form of the fibula was obtained (continuous line), (Figure 3). The graph shows all fibulas have similar traits. The curvature rises steeply (maximum being 0.75 to 1.5 cm) after which a less pronounced. In this manner, a mean value describing a typical form of the fibula was obtained (continuous line), (Figure 3). The graph shows all fibulas have similar traits. The curvature rises steeply (maximum being 0.75 to 1.5 cm) after which a less steep fall occurs. The overall length of the outer surface of fibular malleolus is approximately 3 cm. The continuous black curve represents the mean value of all fibulas which, is the polynomial function of degree 6.

Discussion

Malleolar fractures are among the most common lower limb injuries.\(^{23,24}\) The majority of these require operative treatment. Anatomic reduction and stable fixation accompanied by soft tissue preservation can lead to an optimum outcome.\(^ {5}\)

In cases where both the distal tibia and fibula are fractured, except the tibial fixation by an external fixation device or intramedullary osteosynthesis, a growing number of authors supports the osteosynthesis of the fibula with a plate which facilitates reconstruction of the lateral column providing additional support to the ankle joint.\(^ {25,26}\)

The curvature of the bone to which a plate is being placed to, is the key factor determining the contact surface and the amount of stress the plate applies to the bone.\(^ {22}\)

In this study, using a mathematical modeling process we evaluated the surface topography of the fibula. Such information would provide important information for the appropriate design of anatomical contoured plating systems.

Limitations of the study include the relatively small sample of patients recruited, all patients being males (same sex) and only...
The method requires standard X-ray imaging, bone geometry when deciding on the appropriate implant or method enables the analysis of the ankle morphology and contact area between the plate and the bone. The plate that matches specific fibula could be selected based on the individual. Current osteosynthetic plates are not adapted to the curvature of the distal part of the fibular shaft. Which represents in this case the end of the fibular malleolus i.e. the lateral malleolus curvature, mode of bone plate application and bone plate design on bone structure besides the ankle such as oclecranon of the ulna, proximal part of the humerus, mandibular condyle. According to preliminary results presented in this paper, this methodology can provide valuable method in anthropometric, radiological and virtual geometric calculations.

Conflict of interest

All authors declare no conflict of interest and no funding was used to carry out the project.

References


Fig. 3. All fibulas superpositioned on one graph. Mean value of all fibulas is represented with continuous line.