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Automatizing Bone Surface Mapping in 3D Reconstructed Tomographies

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Abstract

Introduction: In orthopedic surgery, having the bone in it's exactly position is the most important factor for success. In comminuted fractures there is no bone edge to fit, surgeon's ability becomes fundamental and human error is common. The way to diminish the human factor is to provide anatomically contoured implants so they can be guides for the surgeon. To make these implants it is necessary to compare the 3D bone contour in the population and find the most fitable implant.

Materials and Methods: Twenty ankle tomographies were selected and 3D reconstructed for this research. We design and tested a software for semi-automatized bone superficial scanning. The software marked points on bone surface and constructed a spreadsheet with the 3D cartographic reference for each point.

Results: The software was able to set the points in bone surface and the reconstruction of the original bone from the spreadsheet was successful. We were not able to reconstruct an average ankle from the averages of the points.

Conclusion: Despite the transformation of the 3D bone surface in its numeric presentation was successful, we were still not able to compare individuals. We believe that volumetric paring could be a solution.

Keywords: 3D Perception; 3D Reconstruction; Active perception; 3D Data processing; 3D Visualization

Introduction

Precision is a definitive facture for orthopedic surgery success, many studies have shown that reduction is the most important factor for fracture consolidation for example [1,3]. Reduction can be accomplished be connecting bone edges perfectly docked or by reestablishing bone's original length, angulation and rotation [1]. In comminuted fractures is difficult to find the adjustment between the pieces, and in these cases surgeon`s ability is crucial [4,6]. Since the begging of bone fracture surgery, the principle is to reduce and them make the fixation [1,6,7,11], in comminuted fractures the surgeon ability becomes the most important factor for bone healing. To mitigate the possibility of human error anatomically designed plates were made to guide the surgeon so the plate becomes one of the parameters for reduction [6,8,10].

In many cases like in ankle fractures the existing plates lacks the possibility of rotational control, bad rotation alignment is one of the most causes of bad reduced fractures in orthopedic practice [9,10,12]. Bone tuberosities and micro contour irregularities can be used to guide rotational control. Little is known about this micro contour variance in population [12,13]. In the willing to study populational variance of micro bone superficial anatomy and look for pattern repetitions that could make commercially viable new plates and guides for bone alignment rotational control in orthopedic surgery, we started this protocol for the development of a software for an automatized bone contour scanning using 3D reconstructed tomographies. This paper describes our initiative for the software construction.

Materials

Ankle tomographies images were obtained from the medical archive after approval by the ethics committee of the General Hospital of Fortaleza. Inclusion criteria were ankles considerate without bone deformities after the analysis of both one radiologist and an orthopedic surgeon. Exclusion criteria were ankle images with bad definition (more than 1 mm space between the cuts).

The device used was the multislice tomography (Toshiba Medical System Corporation). 20 patients were included for the initial study, only left ankles were included.

Methods

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee CEP-HGF of september 13, 2018. Project identification code 2.889.433. CAAE: 97777118.1.0000.5040

First the researcher marked the zero point at the tip of the fibula (Figure 1). Them a sequence of points were automatically marked within a space of 1mm between each other, in all the fibula circumference and in all the slides for 4 cm above the tip of the fibula. For every point the program generated a X, Y and Z reference in relation to the zero point (Figure 1). Also, automatically the X, Y and Z references were incorporated in an Excel® (Microsoft) spreadsheet.

The numeric 3D references for the points of the entire ankle for

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every one of the 20 patients were compared, for example the simple average between point 2 values in all 20 patients, then the simple average between point 3 in all 20 patients.

Results

The software was able to determine the differences between gray shades (Figure 1). But not able to distinguish the fibula to the tibia, and so both data were added to the spreadsheet. For every ankle between 170,000.00 to 340,000.00 points were generated.

To test system accuracy, from the cartographic spreadsheet of every ankle the 3D ankle was reconstructed (Figure 2). The general aspect of the image generated was similar to the original ankle. From the averages for each point one average ankle was generated (Figure 2).

Discussion

The knowledge of bone surface configuration comes from the begging of medical studies, tendon and ligament insertion makes ledges at bones and those ledges are constants in every human. Large bone ledges are related to important tendons and ligaments but in the other hand little is known about the micro differences in these ledges between individuals (i.e. anterior tibial tuberosity can be 4 mm/18mm in one individual and 3mm/11mm in other individual). Also, the literature lack on information about the variations on the small ledges [14]. To control the rotation on the reduction the relationship between bones ledges is the parameter used.

The first question this protocol addressed is which bone ledges are more present and if they have a prevalence of occurrence that could justify the manufacturing of products as plates. The challenge is how to compare 3D structures as bones for populational studies [15]. Few medical articles showed solutions for that matter, although this kind of study is fundamental for orthopedic implant designs, we believe that lack of publishing is due to the fact that these softwares are protected by patents and compound industrial secrets, having this technology open for all the academic public is important for more populational specific designs, commonly the product design is made by great companies to be sold all over the world but regional specific anatomical variances cannot be addressed in that way, regional industries in different countries could make more race specific orthopedic implants.

We decided to transform 3D contour in a numeric spreadsheet, using the 3D reference of points all over the circumference of the bone. Comparing spreadsheet is statistically easy, we hypothesized that the set of all averages of all points would become an average ankle of that population in which the implants could be design upon. Another possibility could be to have the most frequent points, the new implants design should be the connection of the points.

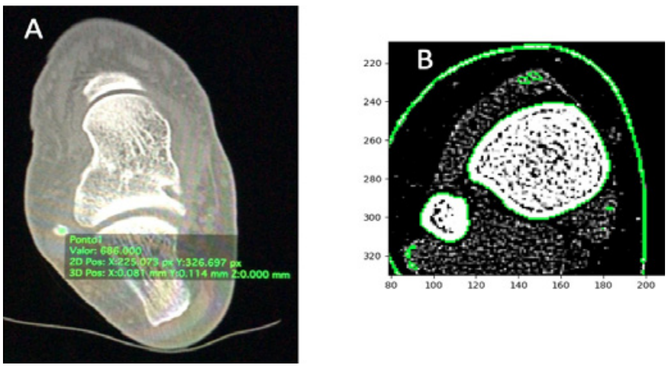

Figure 1: **A:** Setting the zero point. **B:** Setting the points all over the circumference, we decided to let the program include the skin contour to rise the sensitivity, the selection of the fibula values could be done at the spreadsheet.

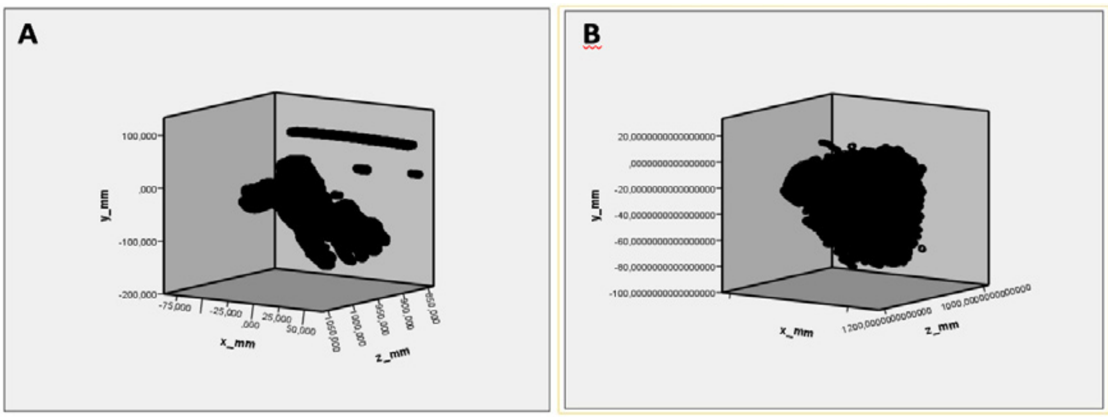

Figure 2: **A:** The aspect of the reconstructed ankle and foot from patient 1. **B:** Aspect of the reconstruction of the ankle from the average points of all 20 ankles.

Despite our initial believe it was not difficult to have the software to distinguish gray scale and recognize the bone edge. The system not only analyzed the fibula, it also recognized the tibia contour and skin, which made large spreadsheets making their processing slow. It came to our attention was the difference in the number of points of different ankles, we understood that it could be due to fact that different exams could vary in the amount of ankle in the screening field because, for example, of the patient's position at the exam table.

The first test which consisted in transforming the spreadsheet in its original ankle seems to work. When we made the average for every point between the 20 patients it didn't resulted in an ankle. We concluded that we have made a methodologic error not paring by the volume. Different ankles have different sizes, when we marked points every 1mm, the point 99 could represent the anterior aspect of the fibula in one individual and the lateral aspect of the fibula in other, so basically, all points are not the same in different individuals.

We are now developing a new software in which all ankles are pared by volume, and then marked with the points. In this new strategy we will first find the anatomic ledges that can be used for plates designs. After that, creating three or more implant sizes for populational adaptation. If we fail again the next strategy will be to avoid the numeric part of the populational analyses. For that, first volumetric pairing and them adding all images together. The most frequent ledges could be identified by the density of the tracing.

Conclusion

Volumetric differences seem to be fundamental in bone surface comparing between individuals. More studies must be done to accomplish the best software that could answer if is there bone edges so frequent that could justify the manufacturing of rotational adjusting fracture plates.

Conflicts of Interest: The authors declare no conflicts of Interest.

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