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Evaluation of disturbances of the measurement methods in selected morphometric parameters based on the radiographs

Abstract. The paper will be presented to test the accuracy of measurements in collaboration with doctors and orthopedic surgeons in conducted morphometric parameters of the human ankle joint based on digital radiographic images. These measurements were carried out by the author, with the use of intra- and inter-operators on radiological images performed in standardized projections. The research has revealed the influence of parameters selection of image processing and choice of the operator on increase of measurements variability.

Streszczenie. W artykule przedstawiono badania oceny dokładności pomiarów wybranych przy współpracy z lekarzami ortopedami parametrów morfometrycznych stawu skokowego człowieka w oparciu o cyfrowe obrazy radiologiczne. Pomiary realizowane były przez autora oraz z wykorzystaniem zewnętrznych operatorów na obrazach radiologicznych wykonanych w standaryzowanych projekcjach. W badaniach zaobserwowano kilkukrotny wzrost zmienności wyników pomiarów wynikający z wpływu zmiany parametrów przetwarzania, czy zmiany operatora. (Ocena zakłóceń metod pomiarowych wybranych parametrów morfometrycznych w oparciu o obrazy radiologiczne)

Keywords: measurement, morphometric parameters, ankle, disturbances.
Słowa kluczowe: pomiary, parametry morfometryczne, staw skokowy, zakłócenia.

Introduction

X-ray is most often carried out in imaging examination of the skeletal system, in particular the joint connections. One of the most common skeletal malformations in children are the disadvantages of the ankle joint. This could be an equine deformation (setting foot plantar) or varus deformity (setting foot in reverse).

The ankle joint is responsible for flexing the foot while standing on toes and straightening while based on the heel [1]. It fulfills basic function in the human locomotion, it is therefore important for its correct structure and arrangement.

The treatment of such deformations should be done as soon as possible after diagnosis. A number of plaster casts, foot stretching exercises and special shoes is mostly used. In extreme cases surgical treatment is applied [2].

To assess the progress of treatment several parameters are described. They may be among other four parameters measured on radiographs in the lateral projections:

- TaAL (Fig.1a segment FE);
- SRTa (Fig.1a);
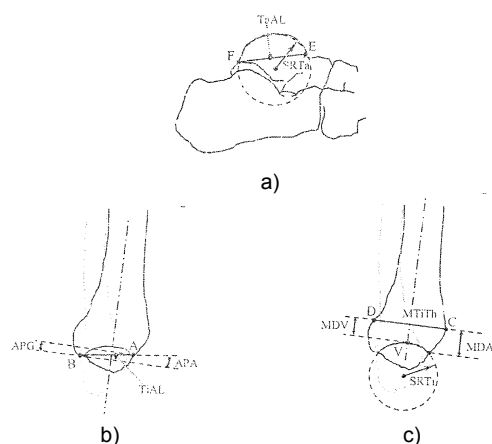- TiAL (Fig.1c segment AB);
- SRTi (Fig.1a).

a)

b)   c)

Fig.1. Diagrams presenting the morphological measurements execution of selected parameters for the ankle joint [3]

Types of radiographs performed for the ankle joint

Due to the fact that the computed tomography (CT) or magnetic resonance imaging (MRI) techniques are less accessible as well as often more expensive than digital radiography, they are used as supplementary methods depending on the needs [4].

Radiographs of ankle joint can be performed in a few projections: antero-posterior, postero-anterior and lateral, which are selected depending on the patient's age and on the applied recommendations.

In the conducted researches, there were used radiographs performed in the lateral projection of a few years old children (Fig. 2a) and teenagers (Fig. 2b) with the club foot [5].
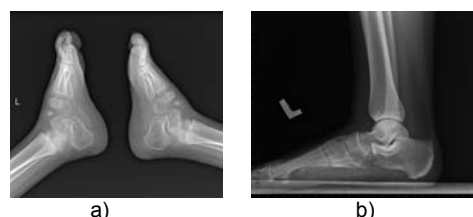

a)   b)

Fig.2. Images of the ankle joint bones in the lateral projection of younger (a) and older (b) children

Elaborated measuring tools

The auxiliary program for the studies was developed to carry out the image processing, extracting and measuring of selected morphometric parameters for the ankle joint (Fig. 3) and the other objects of skeletal structures of the foot.
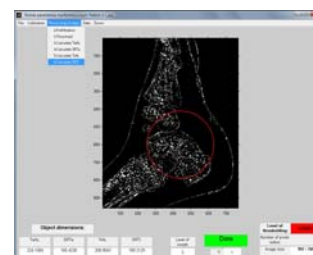

Fig.3. Presentation of the program

Objects that are not studied or different elements could be extracted in an automatic way, both isolated and placed in the skeletal structures of the foot [6].

Evaluation of disturbances of the developed measurement methods

Every measurement could be burdened by errors of different origin. The developed measurement methods of

selected morphometric parameters perform indirect measurements on radiographic images which reflect projections of the examined bone structures.

Because of the necessity of morphometric parameters measurement with the use of operator developed methods the measurement could be burdened by many disturbances. Their level and nature depend on such factors as:
- knowledge of morphometry in the measured parameters;
- training in implementation of measurements in specific parameters and etc. [7].

The influence the operator could be limited by the selection of pre-processing parameters or the level of edge detection [8] and its profiling.

Besides the operator factor the age of the patients significantly influenced the level of measurement error. The skeletal system of the foot of children over the age of 10-11 is already fully formed (Fig. 4a) therefore the above-mentioned parameters could be quite clearly defined.

Whereas in children 6-7 years old, and especially younger, not all bone anastomoses are formed. This makes it difficult to define those parameters on such radiograph (Fig. 4b).
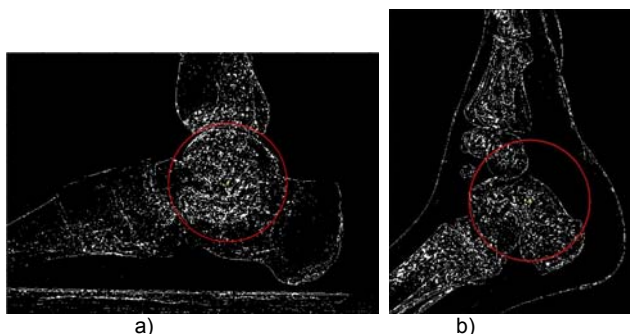

a)   b)

Fig.4. Measurements on the radiographs of older (a) and younger (b) children's feet

The measured values are presented in pixels of the analyzed image because it was not yet possible to perform tested radiographs with the measurement model.

Analysis of the obtained results
The basic statistical parameters of measurement results were compared using available radiographs of patients from older and younger groups. For the younger group significantly greater differences in measurement results were observed. The standard deviation was sometimes more than twice as high, especially for the parameters SRTi and SRTa [6]. The skeletal system of foot not yet fully formed at this age influenced the obtained results. This causes greater discipline for performing radiographs in the standardized repeatable projections.

The radiographs of the older children's group of patients were selected for further analysis. The series of 30 measurements were performed for the selected several processing parameters:
- size of the structural element (morf);
- the level of thresholding edge detection (lev);
(which parameters were presented in [7]).

The changes in processing parameters of radiological images influenced the measured values and their statistical parameters in a fundamental way. Then concern especially SRTi parameter for which the S.D. increased up to 3, 4 times. Already at morf=5 and lev=0.015 the changes in images limited the operators' visual evaluation of ankle joint construction.

The measurements were also performed by another operator, who was very little acquainted with the construction of the skeletal system and taking measurements in the examined parameters. Table 1 presents the selected results. There was even a several times increase of the measurements variability, which significantly limits the choice of the operator.

Table 1. Mean and standard deviation of the 4 morphological measurements of the ankle performed by intra- and inter-operators.

		Patient 1 – right leg			
		TaAl	SRTa	TiAl	SRTi
intra-operator	Mean	174,21	149,59	182,37	138,48
	S.D.	3,83	12,47	2,05	7,96
inter-operator	Mean	174,58	175,80	182,91	150,91
	S.D.	4,70	31,25	5,17	20,06

Conclusions
The elaborated methods are planned to be applied to assess the ankle joint, especially treated surgically, to evaluate its functionality after several years of observation, or comparative studies of effects of surgical treatment carried out in several methods.

You can say that in the implementation of measurements of morphometric parameters on the radiographs many factors could distort measurements, e.g.:
- parameters selection of image processing;
- level of edge detection;
- standardization of radiographs performance;
- training of operator.

Especially the first two factors have to be individually selected for radiographs of patients of different age groups. It requires broadening of research at statistically significant number of patients in each group.

Preparation is conducted to enable the implementation of radiographs of the ankle with a measurement model. This would eliminate the influence of image magnification on the radiograph of the skeleton by X-ray beam divergence. However, this requires obtaining the status of a research project with the approval of the bioethical commission.

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