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Contribution to the Current Trends in Digital Foot Surgery Planning

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Abstract

There are various tools for application of digital technologies in the planning of orthopedic surgery. However, in practice there is always a need for new solutions, with tendence to achieve a balance between functionality and ease of use. We decided to complement the existing practice with our solution that will enable the surgeon, a set of the tools needed to implement the surgery over the foot bone structures. The program also enables 3D reconstruction , and work in the 3D interface with all necessary tools for manipulation, simulation, measurements and other actions in order to define optimal parameters for the implementation of the intervention. These parameters are ultimately stored in the final report, which gives the operator a clear guidelines on each of the procedure step. As a result of the implementation of such a plan it is also possible to obtain a virtual model which can be physically produced, thus providing the ability to practice procedures over the real model.

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Keywords: digitizing; digital measuring device; 3D reconstruction; virtual model; digital surgery planning; path generation

1. Introduction

Orthopedic practice has not been bypassed by revolution in the application of digital technologies. The need for faster, more accurate, simpler and cheaper methods, which aim to improve the practice and allow all participants in the clinical process less stressful and better implemented method, and a better outcome of the procedure, becomes imperative. With a given problem, engineers and programers have got a number of tasks with the aim of finding out better solutions for the given problems on daily basis.

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Advances in imaging technology and computer science have improved orthopedic practice in numerous ways[1]. The application of digital methods in orthopedics has enabled better planning of surgery both in terms of corrective and in the reconstruction of bone after trauma[2,3]. Before the advent of CT and MRI technology planning orthopedic surgery was predominantly based on the use of traditional radiographs. The analysis of the given material was carried out mainly on the 2D image taken from multiple views. Some authors created a methodology that has enabled us to, with use of such material, knowledge of the parameters under which they were recorded, and established correspondences between the images,a 3D wireframe model, which provides a simplified geometric basis for further analysis, was created[4]. However,due to complexity of the geometry of the bones,a higher quality and accuracy of the reconstruction is required, because based on this data it largely depends the outcome of the planning, and the surgical procedure. This issue has been significantly resolved with the progress CT diagnostic devices, which provide images in high resolution, yet with far less radiation dose. 3D reconstructions derived from such materials provide far better description of the surface of the bone and other structures essential for the implementation of the planning [5].

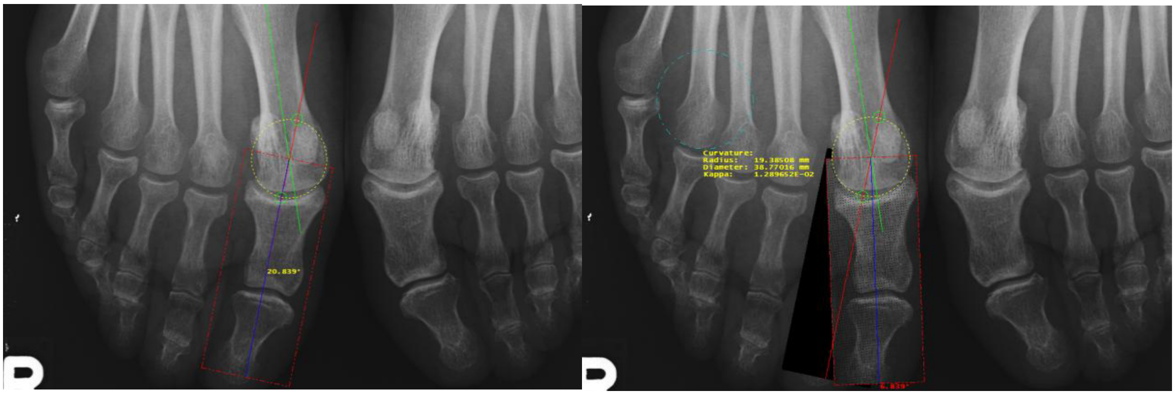

Fig. 1. Preoperative measurements conductedover x-ray images.

The logical continuation of the surgical planning is the implementation of its results in practice [6]. Here are primarily imposed on the use of navigation systems, the application of robotic technologies to physical implementation, or to assisting in surgical procedures in practice, and the development of physical models of deformed or traumatized bone of interest with the aim of practicing of surgery. Today, in practice we can find numerous applications that are intended to enable clinicians for planning of interventions based on available material obtained during the various diagnostic tests. For applications that are used in orthopedics, common approach includes implementation of surgery planning based on the results of radiological examinations. This includes 3D reconstruction from CT or MRI DICOM images, and / or the use of calibrated conventional radiographs through 2D or 3D software packages. Such programs allow measurement and manipulation aimed at defining the optimal approach to intervention in terms of defining the individual steps and related parameters. Problems with broader deployment of digital planning of surgical procedures in orthopedic practice include several aspects. They are manifested in the fact that it is still a young discipline, and there is a lack of quality retrospective analysis of the experience with these systems. Also these digital systems are often developed separately based on the experiences and needs of individual clinics, and due to this fact there is a discrepancy in the definition of the methodology accessing a particular practical problem.

In addition, although such programs are usually passed extensive preclinical testing, a large number of solutions lacks intuitive dimension, and it often happens that surgeons give up the application of these tools because work with them takes too much time, or such applications have too engineering character. Besides, these applications often do not cover most of the needs, so several tools need to be combined. One of the major problems that users encounter in the work is the inability to adapt these programs to the specifics of their practices. Manufacturers are in most cases very secretive and surgeon has no choice but to expect that in one of the future editions, solutions for at least part of their needs will be implemented. Finally, there is the issue of the price of such applications. Here, we assume large quotes that represent a great item even for wealthy clinics, so the question of viability of implementing such a system is always subject to debate.

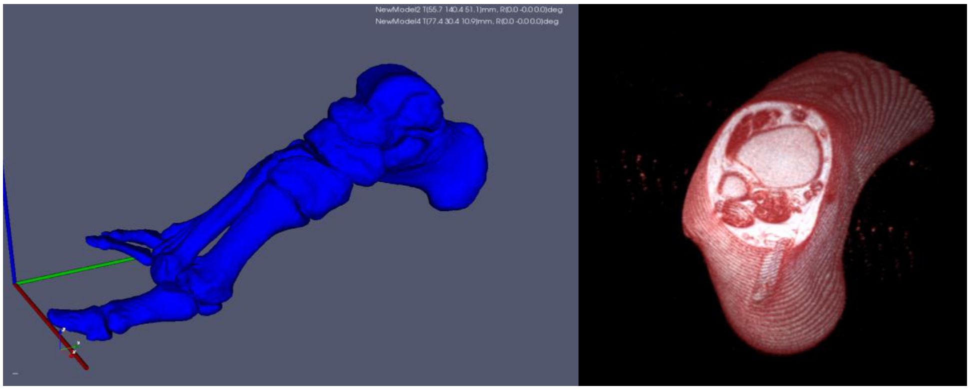

Fig. 2. 3D reconstructions obtained from a series of CT and MRI DICOM images.

Such questions prompted idea on the need for development of specific and affordable software tools and modules that would define a solution that would help planning the surgery on the bones of the foot in terms of the implementation of all necessary measurements on a given material within the virtual interface, defining the anatomical orientation points, defining the cutting planes for osteotomy in a defined coordinate system, conduct simulation, and define the all necessary surgical equipment and materials. In addition the system as output should provide a generation of the physical model of foot bones in real size for implementation of practical exercise needed for the given procedure. Also this solution should allow for very simple operation, provide as accurately as possible output parameters, and models production should be quick and easy. All elements of the application will be resolved by modular approach, so future upgrades would not require a change the whole program, but only the individual parts.

2. Current concepts

The application of digital methods in today's practice includes the implementation of a number of systems with different purposes. We find such solutions that help in educating, sharing and storing data using a regular computer, tablet or mobile phone. Digital images are replacing the classic radio-graphs, and inspection and manipulation of them is done in the digital graphic interface.

In orthopedics digital methods have found broad application in the sections related to the diagnosis (measuring the shape, size and volume of the body part of interest), surgery planning, determining right sizes of implants, intraoperative navigation with or without the application of virtual reality technology and the use of robotic systems for the implementation of the procedure [7]. Today is very common for the digital technology to be used in the design of individual implants. Also, using the results obtained during diagnostic radiological examinations, today there is increase in trends of making custom implants from a bio-compatible material or titanium with special RP (Rapid Prototyping) process[8]. Also, these technologies allow for the possibility of physical adjustments of patients own bone for filling defects, forming a corrective wedges and more [4]. Wider application of these methods is also found in the manufacturing of orthoses, prostheses, etc. [9,10,11,12].

3. Our contribution

Commenting on the large number of present applications with exceptional technical solutions, we find the need for additional improvements which will facilitate the expansion of the application of these methods in practice, and generally increase interest in their implementation at clinics. This is a particular problem in areas where the health system has poorly funded or where it is difficult to expect that the use of such systems could soon pay off. It is necessary to point out that the initiation of work with this application means that staff have passed at least a rough training, which also requires additional financial support.

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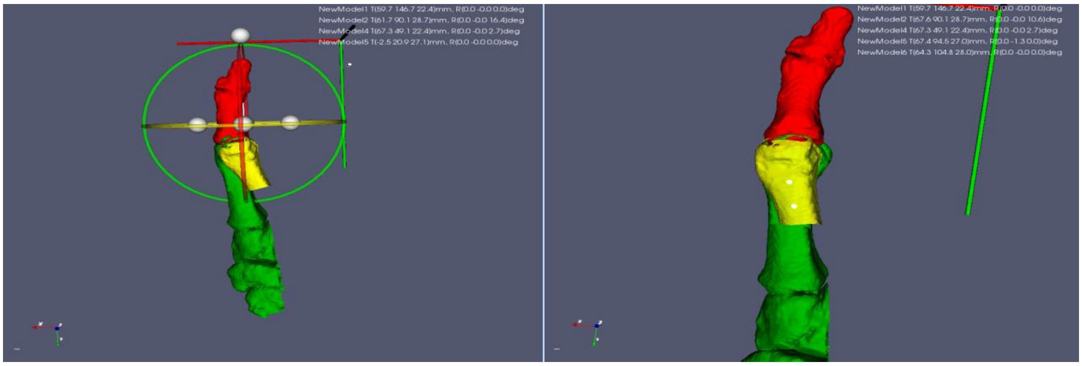

Fig. 3. Tools for mesh editing.

Along with a broad range of solutions currently present, we go out with our own concept, for which we expect it would at least partially cover the needs of the particularity of orthopedic practice in the area of the foot, and would give a general contribution to this field.

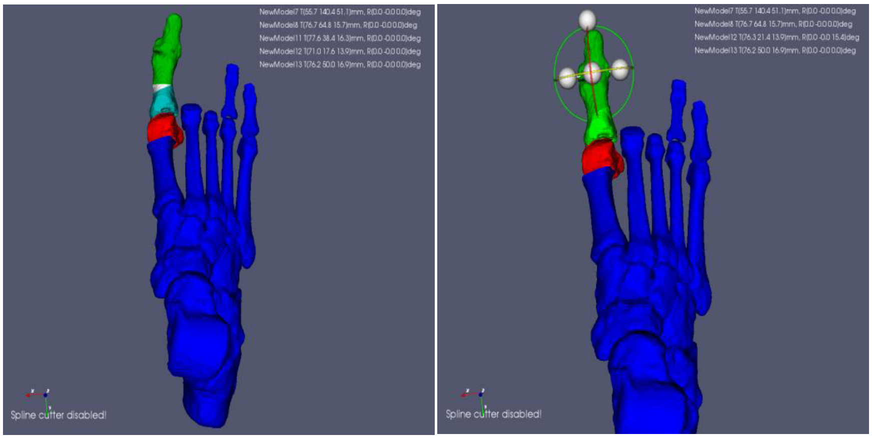

Fig. 4. Virtual planning of surgery in the area of the big toe and the first metatarsal bone.

Our system relies on the functions of the software package CogniVision, (www.cognitus.com). The program has a module for 3D reconstruction from a set of DICOM images from CT and MRI obtained during radiologic imaging, which are used to achieve volume reconstruction or as output generates triangle meshes that describe the boundaries of isolated tissues. The basic set of tools carry out a measurement in terms of distance, circumference, angles, volume, curvature and the like. With specific tools we can do manipulations such as volume excision, surfaces cutting by various tools (planes, curved surfaces, arbitrarily defined areas), mirroring, rotation and translation of certain parts, model deformation to the desired shape etc. Another set of tools allows for simulation in terms of introducing the models of screws or plates, defining the position and orientation of the bones undergo osteotomy, and position of elements needed for fixation.

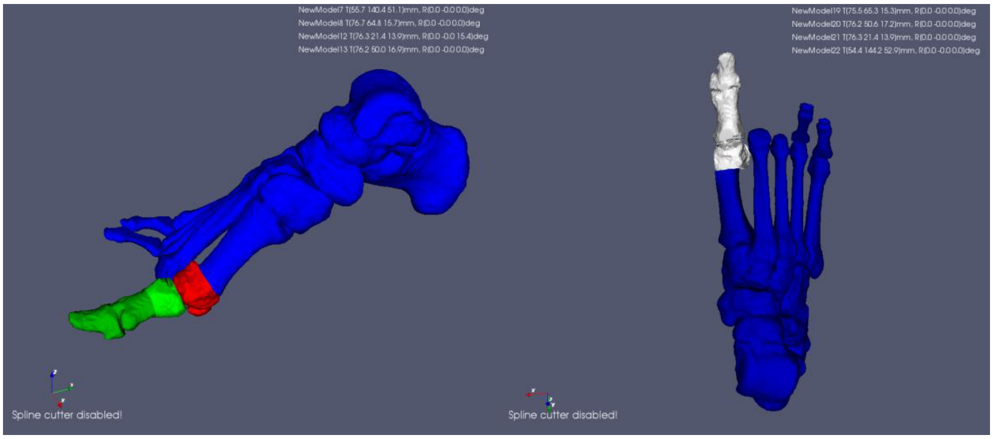

Fig. 5.The results of the surgery planning.

Thefinal set of tools enables the realization of all the preconditions that will enable creation of physical model. The program allows to define a physical model for production using RP or CNC (Computer Numerical Control) machine. In so far implemented activities, we decided that the model is to be manufactured using numerically controlled machine whenever possible, because of the lower costs, shorter manufacturing time and greater flexibility in the choice of materials to be used. For the implementation of project planning in the foot, special interface is defined in which, through a specifically defined workflow, it is carried out planning activities to deliver the desired results. Results achieved so far are encouraging and provide the basis for further work and future application.

Conclusion

In this short review mentioned several current examples of the use of digital technologies in orthopedics as well as innovations that will find wider application in the future. Also mentioned is the start of the work on software intended for planning foot surgical procedures and making physical testing models.

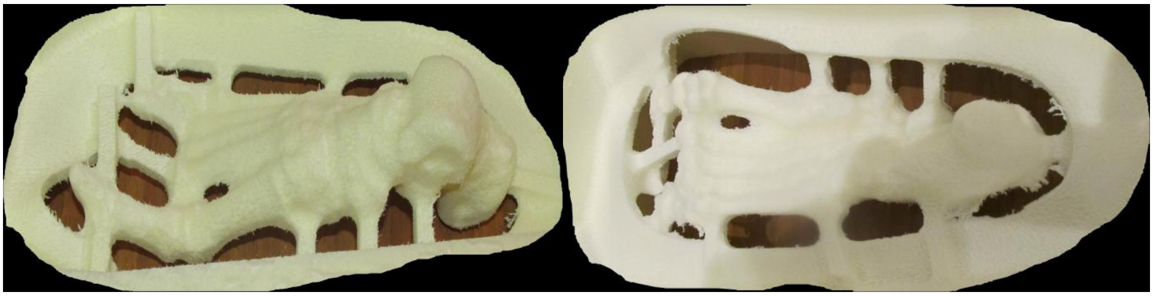

Fig. 6.A physical model of foot bones made of polystyrene, using CNC milling machine.

It is evident that orthopaedics as a branch of the medical profession is an area in which it is expected that the use of digital systems will spread rapidly. It is also expected that with time, these methods will become a regular part of practice because, they provide a better procedure planning, less invasive procedure, shorter surgery time (and thus lower risks), and better operating results [13]. Considering these facts, we started to develop our own system for the planning of foot surgery, which would improve existing practice, and contribute to the current trends.

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