

## THE MODELING OF SOME TYPES OF IMPLANTS AND PROSTHESES USED FOR OSTEOINTEGRATION

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Keywords	Abstract
Dental Implant Virtual Bone Complex 3D Shapes Virtual Prototyping Virtual Human Skeleton	In order to understand the problems, which occur during the implanting and the prosthetics process, it was highly important to be acquainted with the anatomy of the human skeleton, the way these components are working together to achieve a normal functionality. In this respect CAD parametric software has been used as it allows to define models with a high degree of difficulty. First, the main bone components were defined by using CT images. These images were then transferred to AutoCAD where the outer and inner contours of the bone were approximate to polygonal lines composed by many segments. These contours were transferred to SolidWorks where, step by step, and section by section, the virtual model of the chewing system has been defined. Using the direct measurement method the virtual metallic components used during implant process were generated. The virtual models were then exported to a software for kinematical and FEA simulation. Using similar initial parameters for each case studied (as total force and torque) there were obtained dynamic maps of stress, strain and displacement. Furthermore the results have been analyzed and compared, leading subsequently to the main extracted conclusions.

### 1. Introduction

To understand the problems, which appear in human body, it is very important to know the anatomy and morphology of the human bones and the way in which the components are working together to realize a normal functionality. Starting from understanding the geometry of different components and their behavior in the human body and using CAD parametric software we were able to define models with a high degree of difficulty.

For some components, as vertebrae, mandible or skull bones, it can be used a preliminary model obtained by parallel sections. Starting from this, the model can be defined using the main 3D curves for final virtual solid model.

This subject permits the cooperation between many researchers activating in different fields, which have the capacity to develop informational methods and technologies to solve difficult problems given by the complexity of the scientifically target. On the same model can be analyzed the pathological, surgical or post-surgical situations or can be tested different

types of implants or prosthesis (Baciu, 1986). Using computer-aided design (CAD) we can developed a virtual model of dynamic and static behavior of different components of skeleton and human body. For example, the cervical human spine that includes the main muscle groups have been simulated by springs with dynamic parameters, nonlinear and variable. So, we were able to study the main types of movements (displacements) lateral bending (left-right) and flexion-extension movements in order to simulate the impact behavior for auto front neck. (Buciu et al., 2012-1; Buciu et al., 2012-2; Buciu et al., 2013-2).

### 2. Some Anatomical Aspects of Human Skeleton

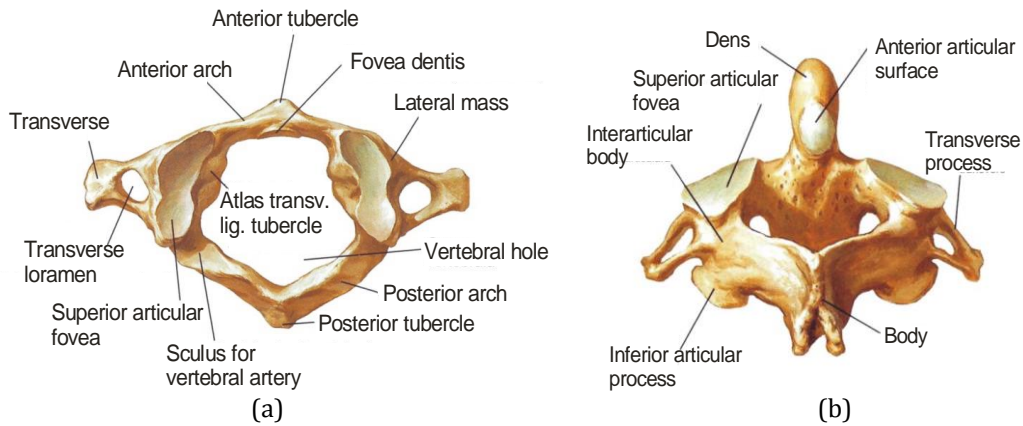
Some bones of a human adult (teaching materials of the University of Medicine and Pharmacy of Craiova) have been studied for analysis of the geometric forms. We measure and established all important geometrical shapes of these parts (Figure 1).

We also use some geometrical and morphological aspects presented in different books of human anatomy (Figure 2).

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**Figure 1.** The real bones studied to determine the primitive shapes.

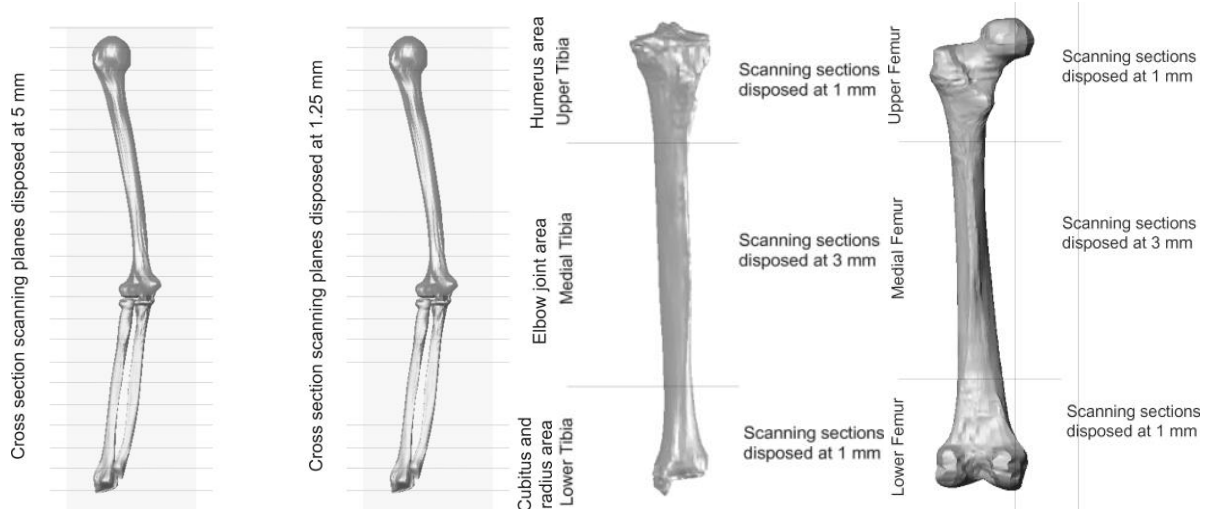


**Figure 2.** The vertebrae of the upper cervical spine (a) Atlas (C1), (b) Axis (C2) (Abedrabbo; Ciunel et al., 2013)

### 3. Medical Methods for Imaging the Main Bones.

For determining the geometrical shape of different type of bones we used for the experiment CT installed at Emergency County Hospital Craiova. Tomography machine allows the user to obtain images in DicomWorks format, specialized software for CT or MRI images and their management (Popa et al., 2010).

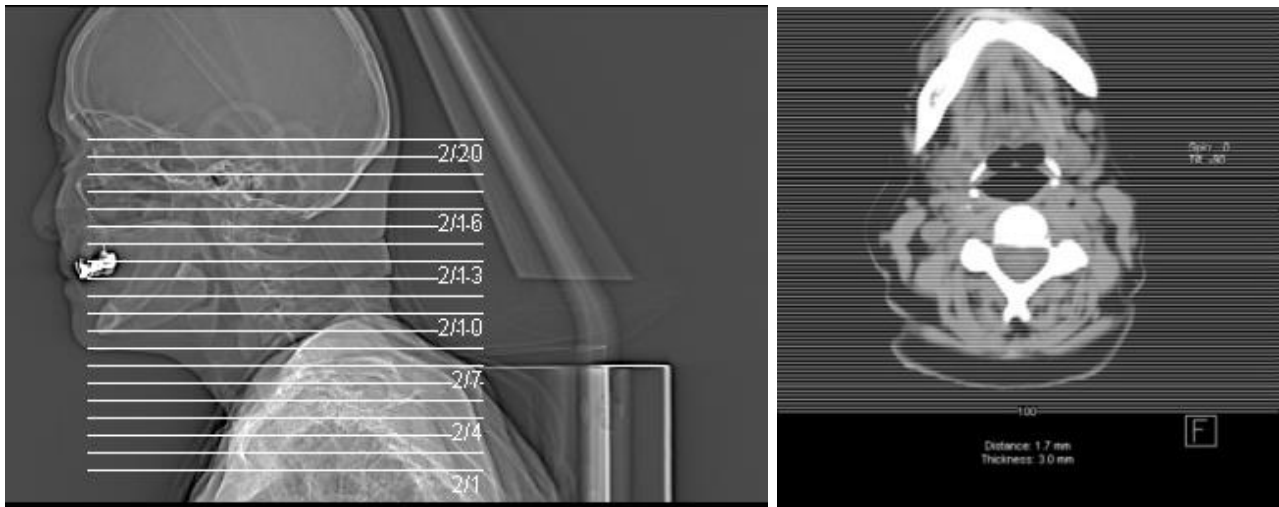
So, in order to obtain the tomographical images of the three bone components (humerus, cubitus and radius) were used two scanning schemes. First, it was completed a complete scanning operation for 5 mm distances having the results 147 images. After that, had been obtaining cross section images at the distance of 1.25 mm for the ends of the bones and the elbow joint area. For the femur and tibia bone were used two scanning schemes at 1 and 3 mm (Figure 3)



**Figure 3.** The CT scan schemes used for elbow and knee

For the human cervical spine were analyzed 284 computer tomography images obtained in different planes. There are three schemes used for scanning: scanning with cross-sectional planes parallel with

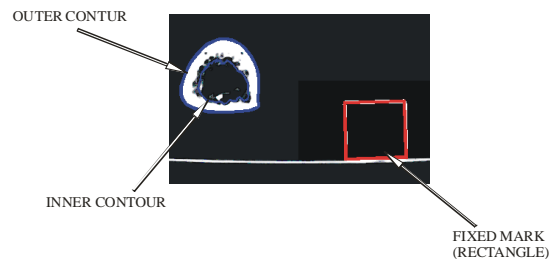
distance of 10 mm, a scanning plane parallel to the front with the distance of 1.7 mm, a scanning plane parallel to the sagittal distance with 1.1 mm (Figure 4).



**Figure 4.** The CT scan schemes used for skull and cervical spine (Ciunel et al., 2013)

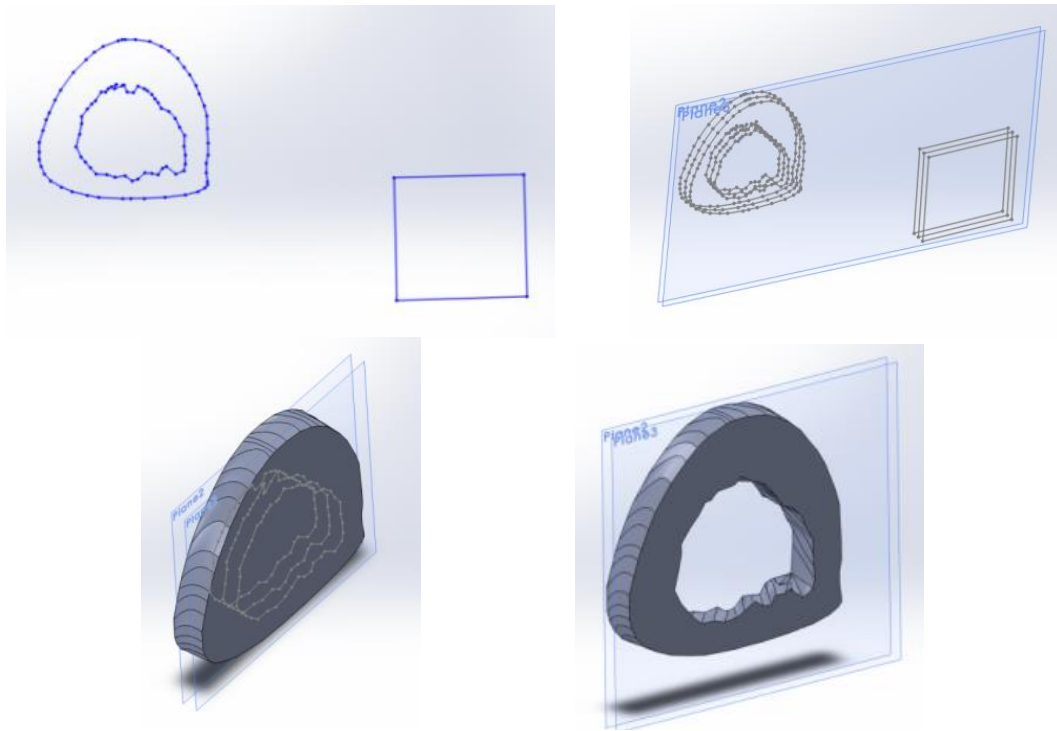
#### 4. Technics Used to Obtain Virtual Models of the Human Bones

Images compatible with most Windows-based files were loaded one-by-one in AutoCAD. The computer aided design software allows defining two-dimensional non-parametric models. First, the images were loaded into the program to determine the geometric scale made by computer tomography. Because each CT image contains a fixed benchmark (a plastic rod with square section with sides of 20 mm) comparing the square on the images with real section was determined the scale of these images and these were loaded into AutoCAD, so images appear to the natural scale 1:1. For the beginning, over loaded image in AutoCAD and properly scaled to the natural size, were drawn inner and outer contours of the bone and a square with sides of 20 mm corresponding to bar section used as a fixed reference (Figure 5).



**Figure 5.** The 2D elements drawn in AutoCAD over the imported CT image.

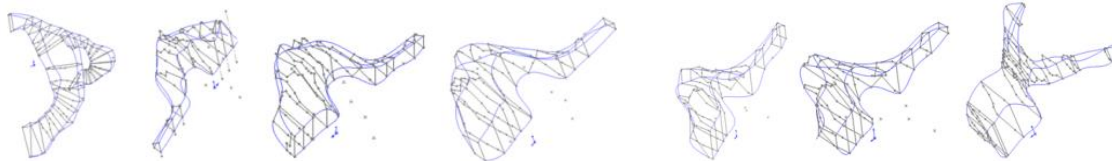
These contours were transferred successively into a three-dimensional parametric design program as SolidWorks, used in mechanical engineering. In this program, were initially defined several parallel planes at a distance of 1 mm or 3 mm, according to the scheme used for CT operation. This operation of defining the contours and transfer to SolidWorks was repeated for each CT scan. To obtain a parametric solid were "unified" the outer contours in a loft type form. For example, to generate the inner channel of the virtual bone were used the 3 inner sections and a feature like CUT-LOFT type.



**Figure 6.** The 2D elements drawn imported in SolidWorks.

Using the CT sections of the vertebrae, for defining the cervical spine model, were generate, in the first stage,

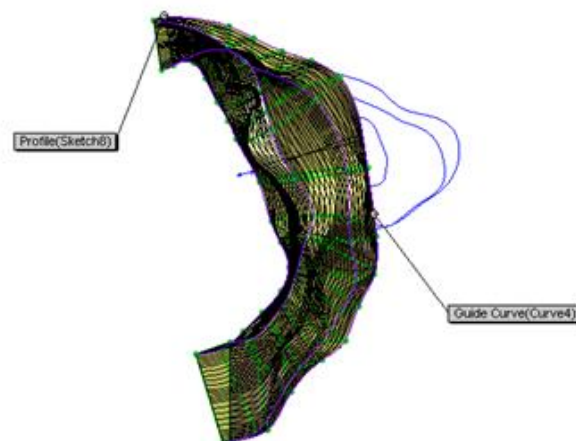
the primitive curves for each vertebra as in the Figure 7.



**Figure 7.** The primary curves which defined the base shapes of the C1-C7 vertebrae (Ciunel et al., 2013)

SolidWorks allows for getting a solid model by merging cross sections in parallel or oblique planes. To "solidify" these sections was used, as called Loft shape, which is based on these sections and a guiding

curve defined automatically by the program. For example, Figure 8 presents the Loft defining scheme for C1 vertebra.



**Figure 8.** The defining Loft shape for C1 vertebra (Ciunel et al., 2013).

## 5. Virtual Models of the Human Bones

Using similar operations in the virtual parametric software were defined femur, tibia, fibula, humerus,

cubitus, radius, C1-C7 vertebrae, cervical spine and human head-neck system (Figure 9).



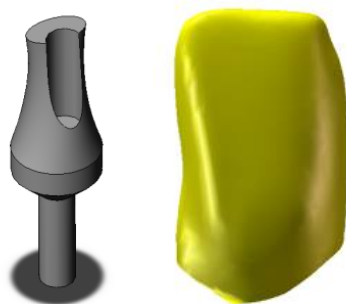
**Figure 9.** The virtual human bones defined in SolidWorks.

In some of our researches, parallel to the 3D bone reconstruction of the bone will be designed and will be obtained the model of the dental implant. For this model was be used the adequate geometric shapes which can induce a good initial stability and for a better osseointegration (Buser et al., 2007). This initial model can improve the initial fixation failure percentage estimated around 2%. In this step, from start, the implant was not considered as a composite model with two major components: the main metallic shape and the cover material which can determine a good osseointegration (Figure 10) (Popa et al., 2013).



**Figure 10.** The 3D model of a dental implant, TehnoMed Impex Co model

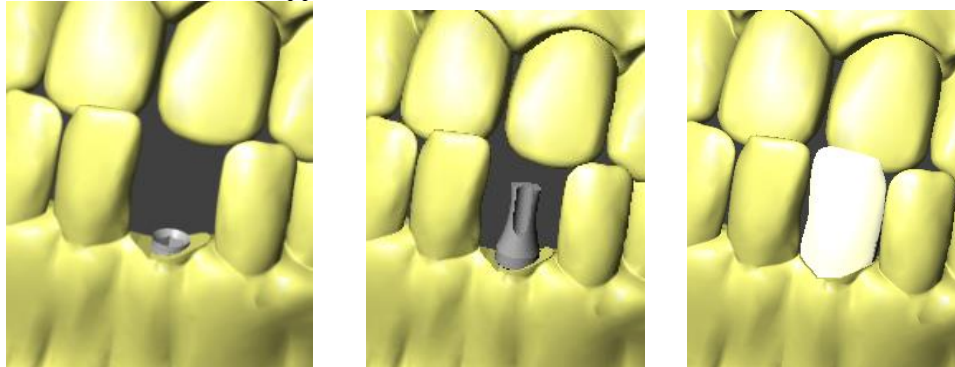
Also, there were defined the other components: the support and the ceramic crown (Figure 11).



crown (ceramic tooth).

The all 3D models were assembled using anatomical knowledge. In this research step, were defined also, the studied positions for dental implants. Based on this positions will be defined and organized the main simulation studies (Figure 12).

**Figure 11.** The 3D models of the support and the

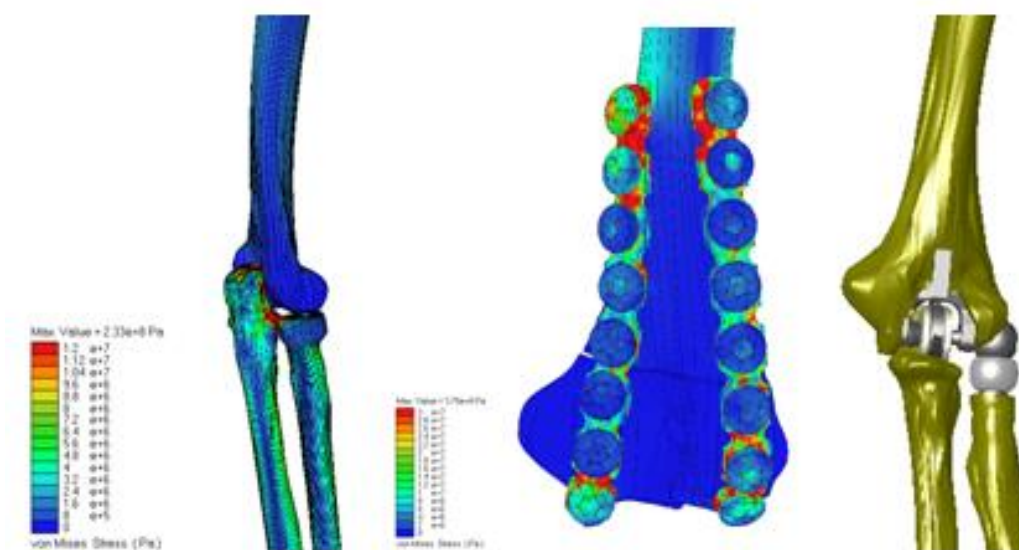


**Figure 12.** The steps of the 3D complete model.

## 6. Different Simulation Using Virtual Models of the Human Bone Systems

Using the model of the human elbow joint were developed different simulations as flexion-extension,

pronation-supination kinematic simulations and was analyzed, using finite element method, the behavior of different implants or elbow prosthesis. In Figure 13 were presented different results obtained on virtual human elbow joint.



**Figure 13.** The results obtained on virtual human elbow joint (Tarniță et al., 2010).

We developed simulations for the main head-neck human system as rotation, lateral bending, flexion-extension, mandible movements or implant behavior studies (Figure 14) (Van der Horst, 2002).

Based on the models obtained for skull and dental implant, in the first time, was defined also, the kinematic and external loading study simulations. The external forces, the reactions, the anatomical soft components can be approximate with software

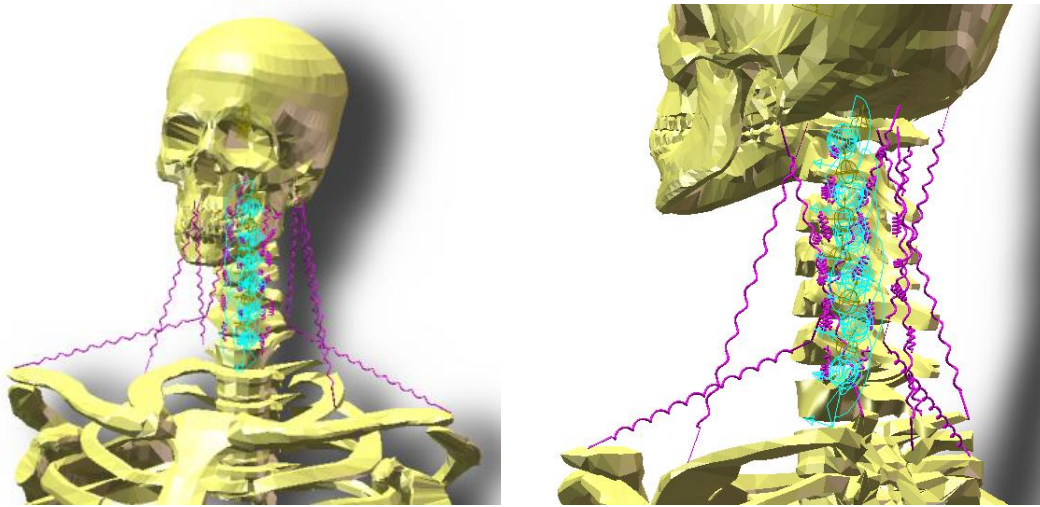
equivalents as springs, dampers, mechanical joints and contacts (Maltese et al., 2007).

The dynamic and kinematic simulation can give the entire behaviour of the each assembly components. In Figure 15 were presented the main frames of the simulation movie.

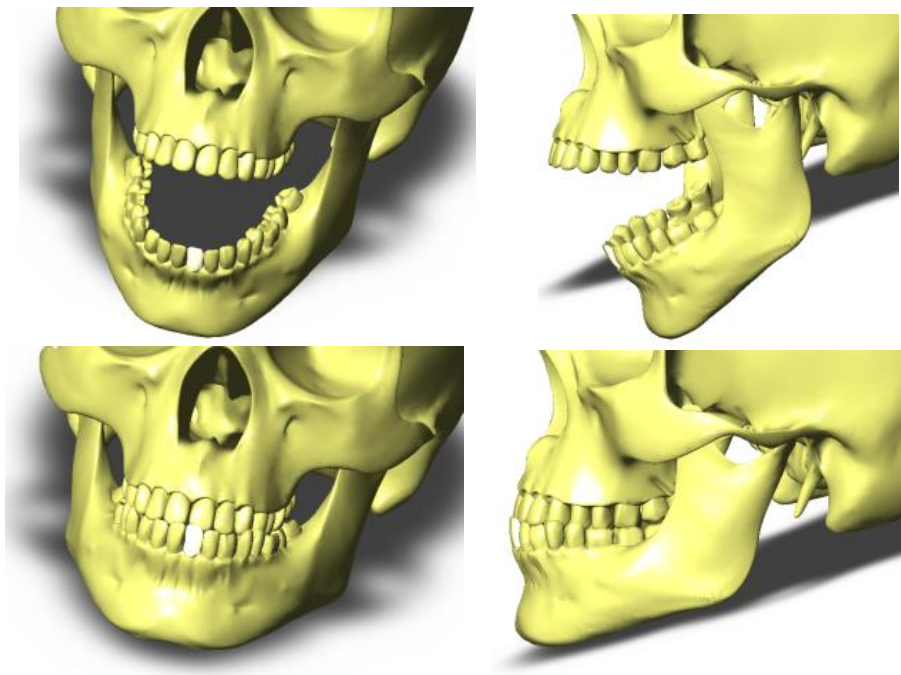
After the simulation it can be obtained important dates as displacements, velocities and accelerations for each component and other parameters as the

contact force between the “in vitro” real tooth and ceramic tooth with implant components. Each component can be “extract” from the assembly using the forces and torques which “give” the connections with the main model composed by bones and dental implant components. Using the auctioned torques and

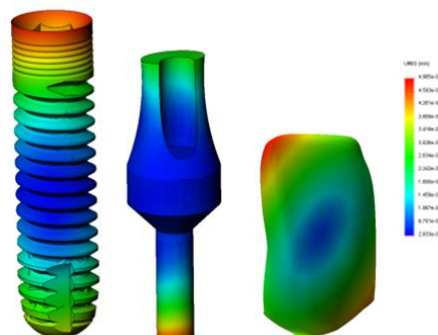
forces cases, each component of the analysed main model can be studied using an appropriate finite element method (FEA) (Weber 2008). The FEA results can give important data for further discussions and analysis (Drago et al., 2010).



**Figure 14.** Virtual simulations made on head-neck human system (Ciunel et al., 2013).



**Figure 15.** Frames of the kinematic simulation of the complete model for the skull and dental implant.



**Figure 16.** The results obtained on virtual model for the implant components.

## 7. Discussion and Conclusion

The elbow is one of the most complex joint from the human body, but this paper proves the mechanical studies can be made starting from anatomical knowledges. The behavior of the virtual elbow can give the important informations which can be used in the fields of robotics, medicine sciences and medical robotics. Also, on the virtual elbow joint can be attached virtual prosthetic elements for virtual post-surgery simulations. The obtained models were completed with the mass properties and the virtual bones had, in that moment, the same inertial characteristics as the real bones. Additionally, can be obtained different comparing diagrams for analysis and discussions.

Also, on the virtual knee joint can be attached virtual prosthetic elements for virtual post-surgery simulations. The simulation program permits the obtaining of some kinematical, statically or dynamical results in a short time with a high precision. Thus, it can obtain the position, velocity and acceleration variation versus time for any biomechanical system. In the studied case, these variations permit the obtaining of other important function parameters.

It can be obtained the forces in joints, which could require an ample calculus or special equipment, permit the obtaining of some important parameters, which define the entire kinematical behavior.

For dental implants, based on the FEA results we can have a very good conclusion to modify the initial 3D model for different types of implants. This process will be held in an integrated complex simulation environment, studying many situations, as: a complete bio-mechanical analysis, made as a nonlinear and dynamic study as a simulation of chewing process; kinematic and dynamic study can give important results which can be used in a complete finite element analysis and will be determined the complete behavior of the bones and implant components. Also, based on the kinematic and FEA results will be optimized the shape of the implant components. In the final step, the optimized shape will be supposed to a complete analysis and simulation.

These programs offer important databases for analysis with finite elements or processing simulation programs. The utilization of these programs is easy and, starting from a three-dimensional CAD model, permit the rapid obtaining of some results, which, usually, could require complex and expensive devices. In conclusion, the virtual bones that were studied can be used as prototype model for the studies regarding elbow, knee, head-neck system with applications in medical researches.

## Acknowledgment

This work was partially supported by the grant number 9C/27.01.2014, awarded in the internal grant competition of the University of Craiova, Romania and by LLP 2012-1-TR1-LE005-35166 BioDent.

## Conflict of Interest

No conflict of interest was declared by the authors.

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