ASSESSMENT OF A LARGE VOLUME MAXILLOFACIAL CBCT SYSTEM – FROM BIOMECHANICAL POINT OF VIEW – AS A TOOL TO BUILD PATIENT CUSTOMIZED BIO-MODELS

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Abstract

The number of patients diagnosed with cancer is reaching a scarily high number worldwide. This is no different in the area of mandible cancer. Unfortunately Hungary is quite high up in the ladder. The registered known number of patients with mandible cancer and the associated number of death occurrences are also showing significant data in the country. However it is easy to diagnose, alcohol consumption and smoking or just bad oral hygiene really pushes the statistics. Inside the oral cavity, in case of mandible cancer and late diagnosis the only viable solution is the bone resection.

To determine the extent of the cancer and to carefully plan the surgery procedure or in case of models which were created for biomechanical examinations, the medical science more and more often uses the image based processes and tools. Next to the realistically built models a more punctual mechanical parameter simulation becomes possible.

It is highly important that the necessary information is extracted from the patients with the least stress. With the shortest time and smallest radiation the image must be made in a way that the scan can be well evaluated and it is usable.

Within the current examination in the medical field of imaging methods a gold standard MSCT and a specifically in the head-neck region used CBCT methods will be compared specifically from biomechanical modelling point of view. During the comparison the gray value was examined by the use of a cadaver head.

The results show that the gray values provided by CBCT differs slightly from the MSCT values that is considered as reference. The more extent absolute error occurs with less frequency. Based on these facts the CBCT can be used for the density based material comparison for biomechanical models with less radiation dose.

Keywords: mandible, cadaver, gray value, bone

Introduction

Worldwide the cancer is becoming one of the main problems of our time. It can be found within all the layers of our society. As of 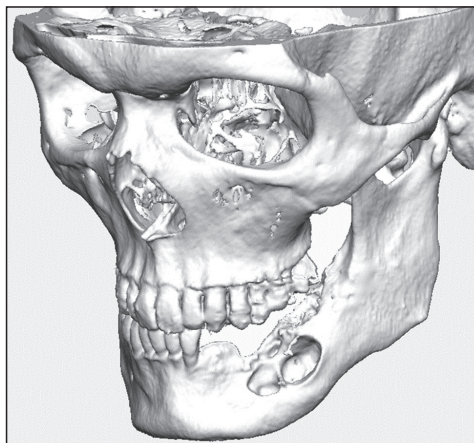the cure there are many question marks. The situation is no different in our homeland, in Hungary either. Unfortunately considering only the oral cavity region, the situation becomes even worse. Hungary has a critically high number of diagnosed oral cavity cancers and the connected occurrence of death. This

bad ranking is generated, although the oral cavity cancer is one of the easiest to detect and diagnose. The screening can be done within a regular dental examination and the control can be done by the family or factory doctor as well. The oral cancer is increasingly present among the people older than 50 years. Potential danger for the development of the cancer is the inadequate food consumption (originated from the lower social status), neglected dental hygiene, alcoholism and smoke. Despite the easy screening possibility a high portion of the patients get diagnosed too late, when the symptoms are causing actual pain. When the mandible is also effected, normally surgery and therefore the dissection of the bone affected by the cancer is unavoidable. This dissection can affect the complete or just partial cross section of the bone. As the result of the surgery the mechanical load carrying capacity of the mandible is changed as well as the self image of the patient.

To determine the exact size of the defect, in the medical field imaging methods are used. Nowadays aside from the varying possibilities the use of CT (Computer Tomography) is becoming more general *(Figure 1)*.

The output from the CT based on the generated image can be very diverse. With and adequate tissue segmenting and based on the extent of the cancer the doctor can make a concrete plan for the surgery, this way drastically reducing the time needed for the surgery and the amount of trauma that will affect the patient.[1–4] The data can be used for biomechanical modelling as well.

The CT method was first used in 1972 in clinical environment. During the imaging the CT uses the X-Ray radiation, which is collected by detectors. The X-Ray radiator and the detectors are also revolving around the patient. The CT, just as the X-Ray, is based on the ra-

Figure 1. Mandibular tumor

diation weakening; however CT can show a radiation weakening of a volume unit more precisely. During the processing one pixel equals to the radiation weakening of a volume unit coefficient, which is than assigned to the gray value. The different tissue domains can be perfectly separated; however the domain that can be seen with bare eyes is very narrow, therefore a windowing method is used.

The CBCT (Cone Beam Computer Tomography) is specifically developed tomography for the head-neck region. The picture series is created by tapered radiation beam rays, which is 2 dimensioned and after this the 3 dimension image is created.

Some of the benefits of CBCT are that it is a smaller device; its costs can be 5 times smaller than the traditional medical grade CT (MSCT). Partially this is a reason for the cheaper examination cost as well. It is not necessary to have special mounting, cooling or even electrical infrastructure. It is important to highlight, that during the CBCT examination the radiation load can be 100 times smaller on the patient as in case of the MSCT, even in same or higher resolution. The processing of the image is also faster. Of course with all the

benefits there are some limitations as well that should be considered when using the CBCT, for example the less punctual gray value or the not always optimal hard and soft tissue contrast.

Methods

The goal of this study is a validation and verification with maxillofacial cadaver, in the meaning that a large volume in-office CBCT provides reliable data compared to a medical grade MSCT as a gold standard technology. Based on the gray value that is provided by picturing methods adequate tissue segmenting and material properties with the use of density transfer functions can be defined.[5] This will be specifically important for the geometrical model and later the virtual mechanical simulation as input information source.

For this examination a toothless, in formaldehyde fixated old female cadaver head with 4 approximately 20 mm layer put on each other was used. This was provided by the Department of

Human Morphology and Development Biology, Budapest, Hungary. The preparation of the cadaver head was also carried out in the same institute. During preparation of the head in predetermined focus points within the layers known density elements [in 0.93–2.70 g/cm^3 domain], Polyoxymehylene (POM) 1.415 [g/cm^3], Polyethylene (PE) 0.93 [g/cm^3], Borosilicate glass 2.21 [g/cm^3] and aluminum (Al) 2.70 [g/cm^3] were concentrically placed inside and outside of the oral cavity. These elements made the evaluation easier. The elements considering the geometry consisted of 5 mm diameter spheres (aluminum and glass) and 5 mm height and diameter helicons (POM and PE) *(Figure 2)*.

The same sample was scanned with CBCT and MSCT without any change. In case of the CBCT the precision of the device is not satisfactory defined based on the gray value scale. During the examination as reference, a calibrated, seemingly old constructed, 8 layered MSCT (General Electric, LightSpeed Ultra 8, GE Medical Systems, Waukesha, Wis) was selected, which was compared to the
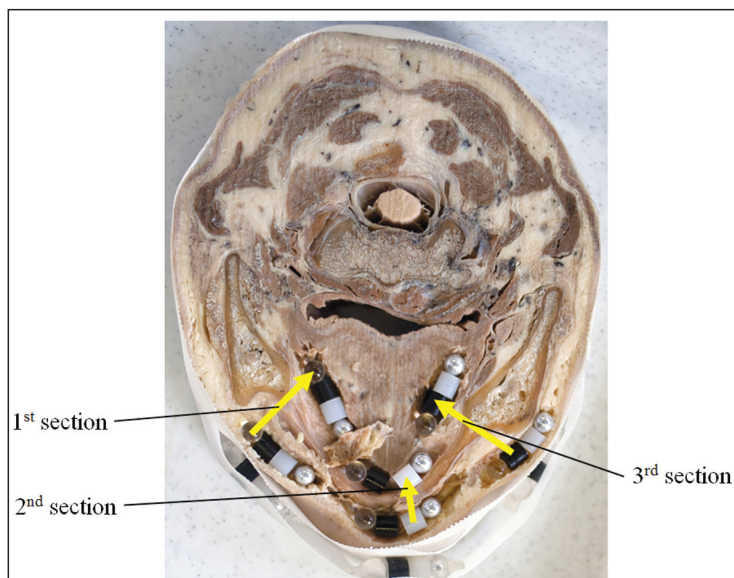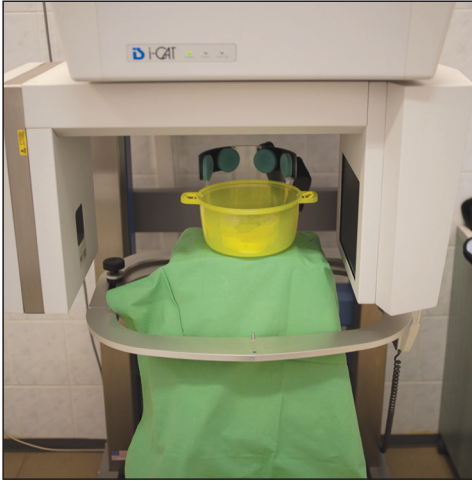

Figure 2. Examined sections on cadaver

CBCT with 120 KeV were calibrated with 36 mAs with $0.25 \times 0.25 \times 0.25$ mm spatial resolution.

With these parameters the scanning times and parameters in the clinical practice were represented in case of both devices. These values are important parameters for the patient. During the measurements the comparison of the density data were based on the gray values. The density was measured in function of the distance in 3 randomly selected elements in the linear section in case of both tomographies. The measurement was done between 1-1 identical reference elements in the horizontal plane *(Figure 2)*. After this the results were compared. The cadaver sample after the scanning was delivered back to the Department of Human Morphology and Development Biology (Budapest, Hungary).

Figure 3. Preparing CBCT scan

Results

During the examination with 3 orientations, sections between 1-1 reference materials were examined in case of both CTs. When examining the sections in predefined 0.25 mm steps, gray values were collected and compared. In the 3 different sections the gray values were graphed in the horizontal plane between same reference elements. With the same step values the differences between the CT considered and graphed with absolute values, the deviation between the devices can be seen very transparently. With the help of absolute differences, their frequency of occurrence was also examined and graphed in a histogram with the relative sum of frequency *(Figures 5–7)*.

Figure 4. Preparing MSCT scan

CBCT (i-CAT, Xoran Technologies, Ann Arbor, MI) *(Figures 3–4)*.

Exclusively only the parameters used in the clinical practice were considered for the comprehensive examination. This means with 120KeV adaptive acquisition protocol, adjusting the beam current between 160–230 mAs, BONEPLUS algorithm was used for the scanning. The layer thickness in the everyday practice is 1.25–2.5 mm, which is highly important for the radiation hygiene and for the low radiation load of the patient in case of the MSCT. Based on this the layer thickness was defined to be 1.25 mm, 0.488×0.488 mm pixel per axial layers with 0.625 pitch. The

From the diagram it can be seen that the average gray value deviation considering the 3 sections is between 72 and 98. It can be further concluded from the histogram of the absolute gray value deviation of the sections, that
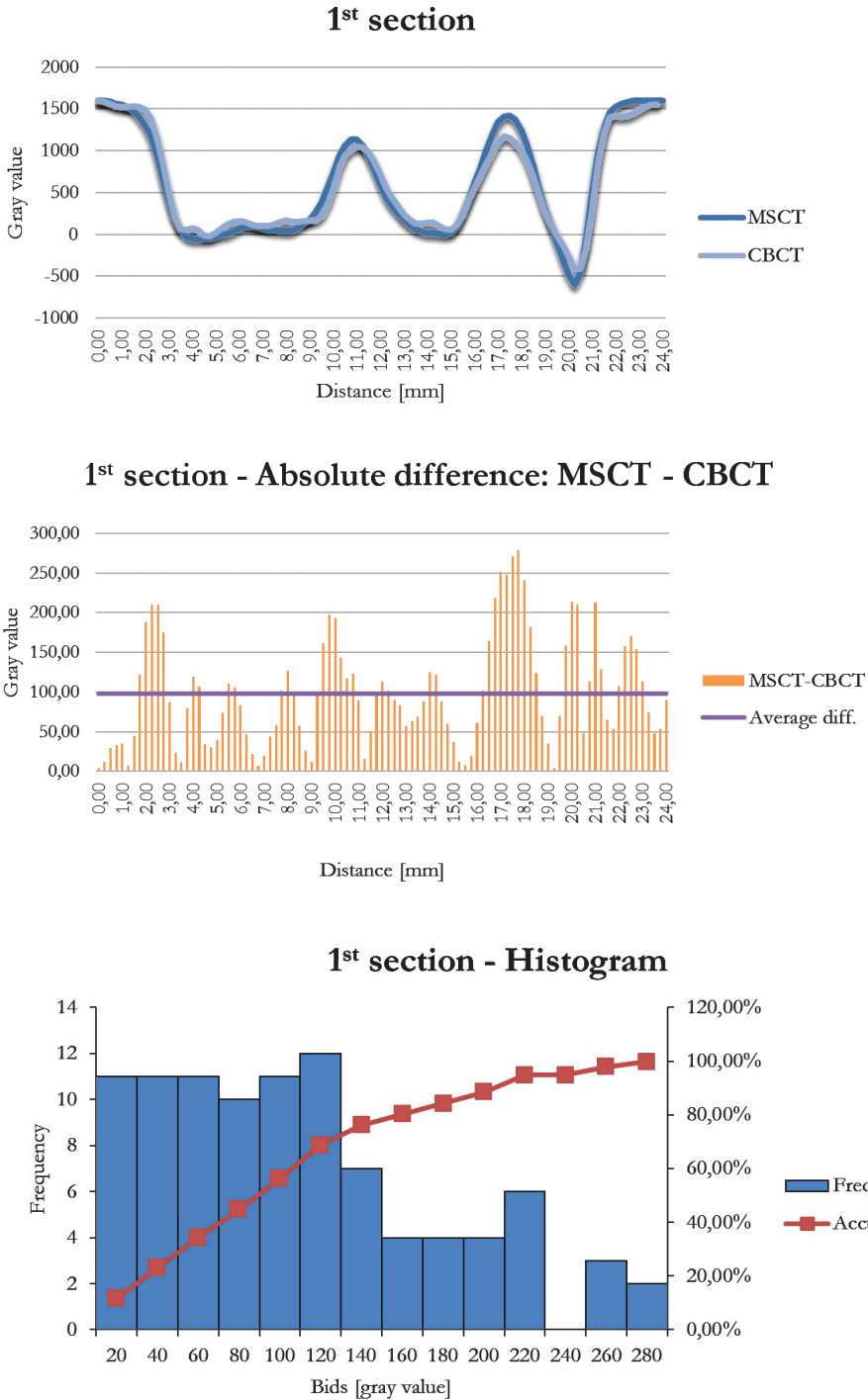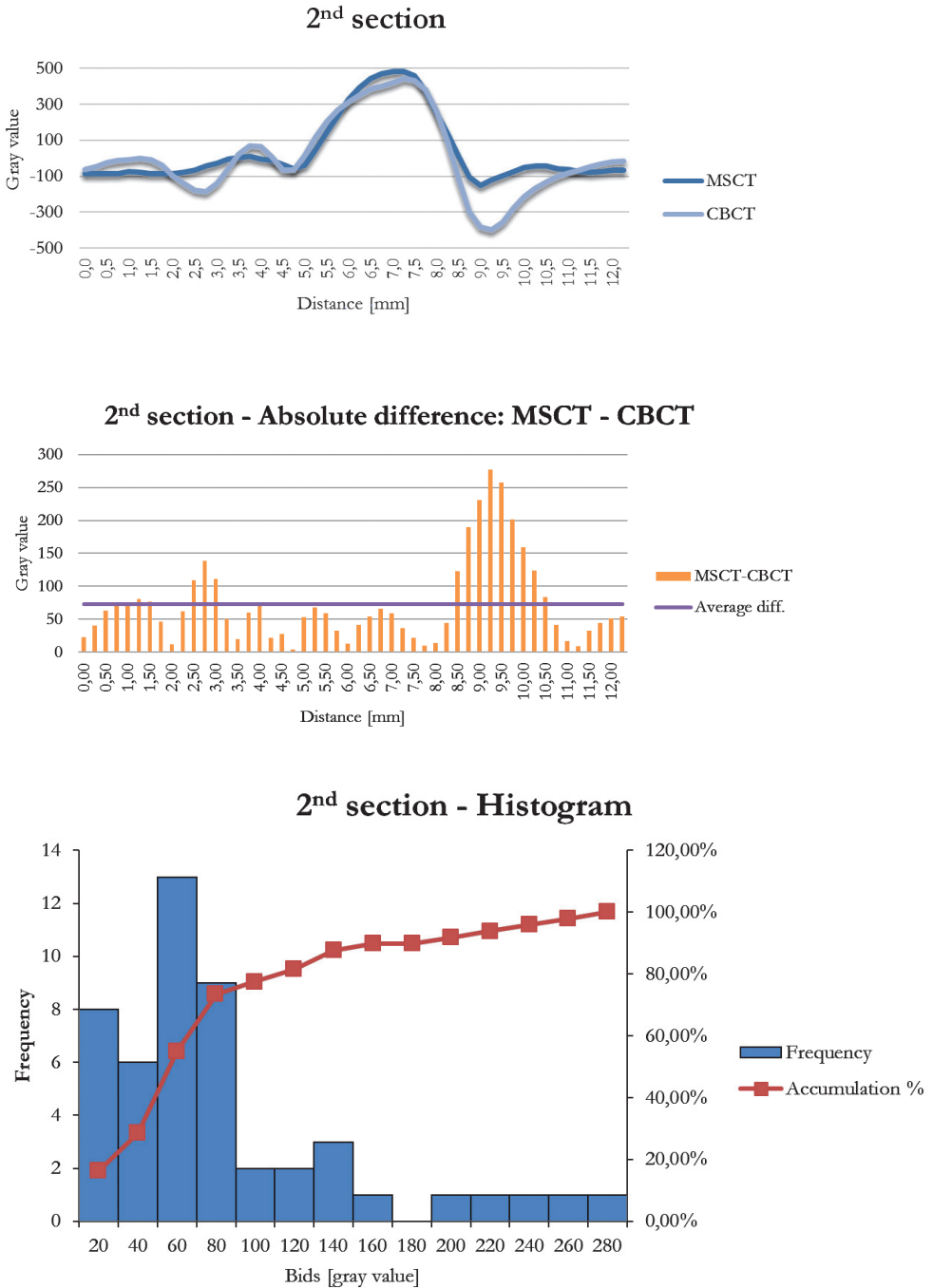
1st section

1st section - Absolute difference: MSCT - CBCT

1st section - Histogram

Figure 5. 1st section results

2nd section

2nd section - Absolute difference: MSCT - CBCT

2nd section - Histogram

Figure 6. 2nd section results

3ʳᵈ section

3ʳᵈ section - Absolute difference: MSCT - CBCT
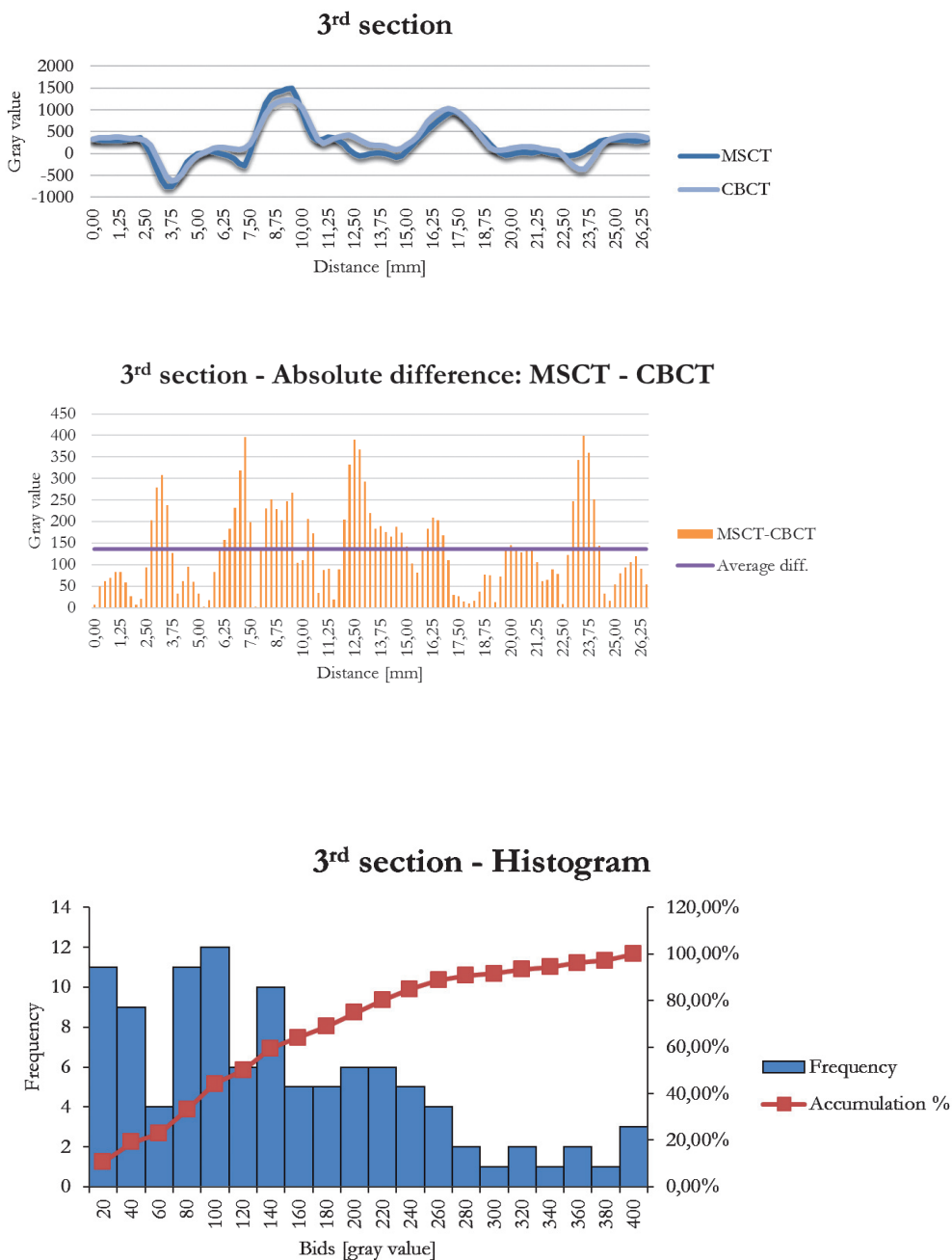

3ʳᵈ section - Histogram

Figure 7. 3ʳᵈ section results

140 gray value and smaller deviations are more frequently occurring, hence between the two CT the frequency of the higher gray value mistakes is lower *(Figures 5–7)*. Based on the use of both CT with clinical parameters the gray value differences can be attributed to the difference in resolution until a certain level. While MSCT worked with average values with 1.25 mm sections, the CBCT had more values. This concludes that in certain cases in can be more precise.

The gray values are very important for the determination of the density of each allocations. In the field of biomechanical modelling and simulation the definition of material properties with density based transfer functions provided by imaging methods are becoming more and more popular based on the current state of the art. These models can be more precise for biomechanical simulations.[6,7] The CBCT output data compared to MSCT (gold standard) can be adequate for biomechanical modelling, further considering that in case of the patient the radiation load can be 100 times smaller and the cost is also reduced. The differences between the two CTs during the creation of the simulation models with the mechanical parameters setting make little deviation.

Summary

In the research two devices used in the medical field, the MSCT and CBCT were compared considering clinical parameters with the use of cadaver human head applied with reference elements. During the examination the CTs were compared based on the gray values. The deviation of the gray values provided by the CBCT is rather small compared to the MSCT that is considered as reference. Based on these facts it can be concluded that the CBCT can be used for material comparison during the biomechanical modelling with transfer functions used on the gray values.

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