Coll. Antropol. **24** Suppl. (2000) 1: 15–20
UDC 572.77-001.001.53
Original scientific paper

Model for Computer Simulation of Bone Tissue

D. Milčić[1], J. Keros[2], J. Saucha[1], Z. Rajić[3] and R. Pezerović-Panijan[4]

[1] Department of Applied Mechanics, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, Croatia
[2] Department of Dental Anthropology, School of Dental Medicine, University of Zagreb, Zagreb, Croatia
[3] Department of Pedodontics, School of Dental Medicine, University of Zagreb, Zagreb, Croatia
[4] Department of Histology and Embryology, School of Medicine, University of Zagreb, Zagreb, Croatia

A B S T R A C T

The paper deals with the dependence of the torsional moment on the angle of the compact bone torsion in laboratory animals and humans. Based on the data for laboratory animals obtained by measurements, the data on dependence of the torsional moment and the angle of torsion were predicted for humans. The measurements were carried out in four groups of laboratory animals. One was the control group, and the other three groups were treated by various vitamin D_3 metabolites. The same measurements were performed also in only one group of humans, due to the impossibility to treat humans with vitamin D_3 metabolites. The functional relationship between the angle of torsion and the torsional moment for all the groups of animal bone tissue were determined by measurements, and results were used to predict the reaction of the human compact bone tissue if treated by vitamin D_3 metabolites.

Introduction

Our experiments were performed in laboratory animals and in a control group of humans. Based on the data for laboratory animals, the data on the relationship between the torsional moment and the angle of torsion were assumed for the compact bone in humans[1–4].

The data obtained by treating the compact bones of laboratory animals were used as the basis for predicting the reaction of the human compact bones when treated by various metabolites of vitamin D_3[5,6]. A computer program was developed for this analysis[7–12]. The program enables a complete insight into the data obtained by measurements, which

Received for publication June 19, 2000.

are presented in tables and figures. The program can also simulate the behavior of the human compact bone subjected to various torsional angles.

Sample and Methods

The experiment used to obtain data consists of a mechanical part (mechanism for creating torsional load) and the compact bones of laboratory animals. A total of 28 laboratory animals were divided into four equal groups. Three groups of animals were treated with various metabolites of vitamin D_3: 1.25 dihidroxycholocalciferon {1.25–$(OH)_2$ D_3} and 24.25 dihidroxycholocalciferon {24.25–$(OH)_2$ D_3}, and the remaining group was used as a control group which was not treated with any metabolites of vitamin D_3. The purpose of this experiment was to predict the behavior of the human bone when treated in the same way as animal bones since it is not possible to perform such an experiment in humans.

For simplification purposes, the following was assumed:

- transversal isotropy of the compact bones,
- the modules of the elasticity in the radial and the tangential directions perpendicular to longitudinal axes are equal.

Torsional load was chosen because of the fact that the cross section of the compact bone is much smaller than its length. Linear interpolation algorithms were used to analyze the data obtained by measurements and to make all the necessary assumptions of the possible behavior of human bones. The data used in the program were stored in a Microsoft Access database. Microsoft Visual Basic package served as a platform for developing the computer program.

Results and Discussion

All the data obtained by measurements, and the data obtained from Mathematica as a result of interpolation were stored in the database. The database was directly linked to the realized program. The way the data were represented in the program and the results of the interpolation process were affected by every change of data either obtained by measurement or directly made in the database by the user.

The realized program is divided into the following four main parts:

- program information,
- graphical comparison,
- table presentation,
- graphical presentation.

The first part gives brief information about the program and visually describes the part of the human body (tibia) dealt with by the program and the laboratory measurements. In the help window the user can learn how to use the program, and basic mathematics used for simulation. A brief description of the laboratory experiment is also given.

In the second part of the program the user can interactively, using mouse (with scroll bar), change the torsional angle and observe the dynamic change of data of the torsional moment in dependence on the angle of torsion for the tissue of human compact bone in the first window. Separately, in the other window the same dependencies are shown for laboratory animals. This part of the program provides information on the assumed behavior of the human compact bone when submitted to various torsional angle loads and different metabolites of vitamin D_3.

On the right side of the window »The graphical comparison« it is possible, in the part described as »Choose specific groups«, to choose a group for which we want to show the data in the chart. This

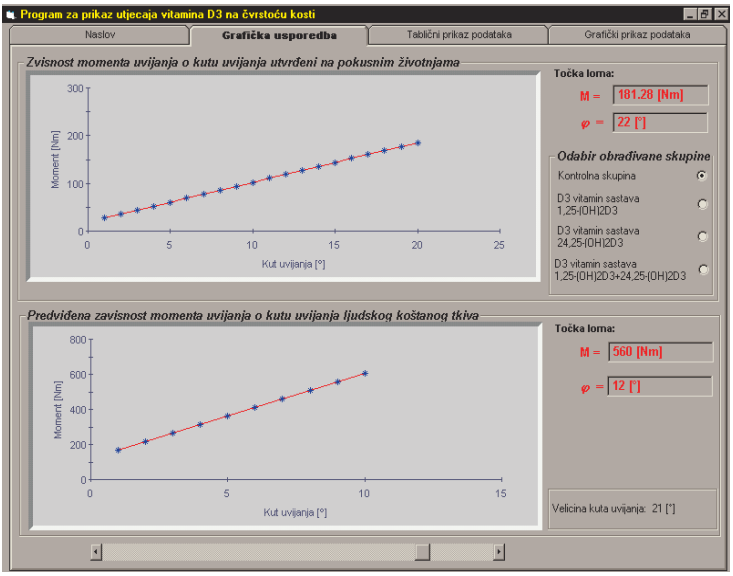


Fig. 1. Graphical comparison with the torsional moment depending on the angle of the compact bone torsion in laboratory animals and in humans.

control part also gives us information about vitamin D_3 metabolites that were used in control animals during the experiment.

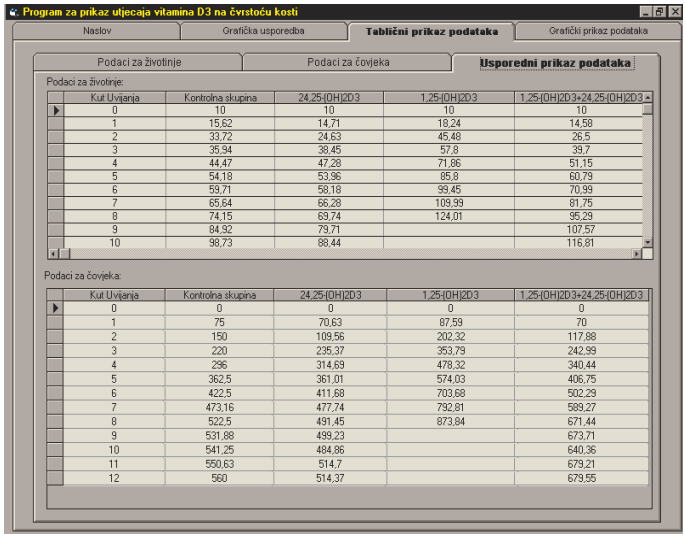
When the break point of the human or animal bone is reached (bone fracture), simulation stops and the values of the implied torsional angle and the torsional moment are shown. The values are presented in different colors on the right side of the window (»The point of fracture«) and the chart line-presenting dependence between the torsional moment and the torsional angle cannot be continued beyond the break point. (Figure 1).

»The table presentation« (Figures 2a and 2b) is the third part of the program. It gives the user a possibility to compare the data obtained by measurements stored in Microsoft Access Database regarding the type of vitamin D_3 metabolites. The data from the database can be viewed in various forms combining the following data:

- for human bone, obtained by measurement (control group),
- for animal bone, obtained by measurement,
- for human bone, calculated by the program.

Different selection of various types of metabolites of vitamin D_3 shows the user different groups of data obtained by measurements. The user can review the data on laboratory animals separately for each group of animals treated with various metabolites of vitamin D_3. It is also possible to view the data for the human bone sample (control group). These data can be viewed simultaneously with the data predicted by the program on how the human bone will behave.

Data stored in the database can also be viewed in the graphical form in the



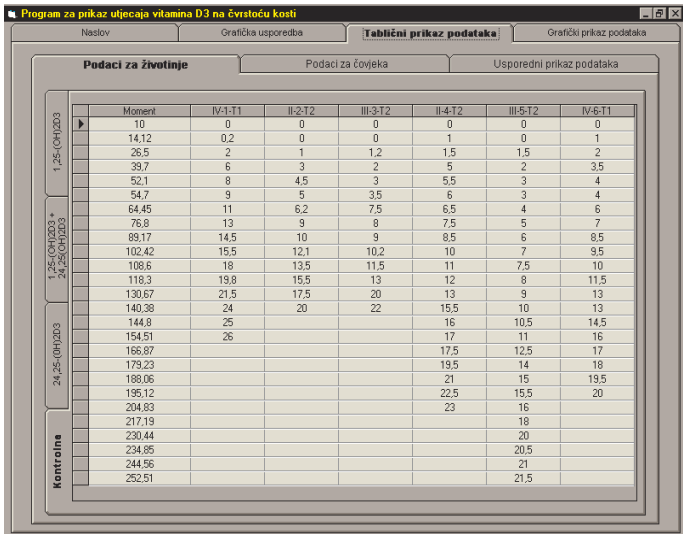


Fig. 2a. and 2b. »Tables presenting« results of the torsional moment depending on the angle of torsion.

fourth part of the program. Various forms of the graphical presentation are available. The user can select the preferred graphical presentation form using command options at the bottom of the window.

The supporting data graphic presentation forms are:

- plot (data are presented as array of dots connected with lines, Figure 3a),
- bar (data are presented as thick bars),

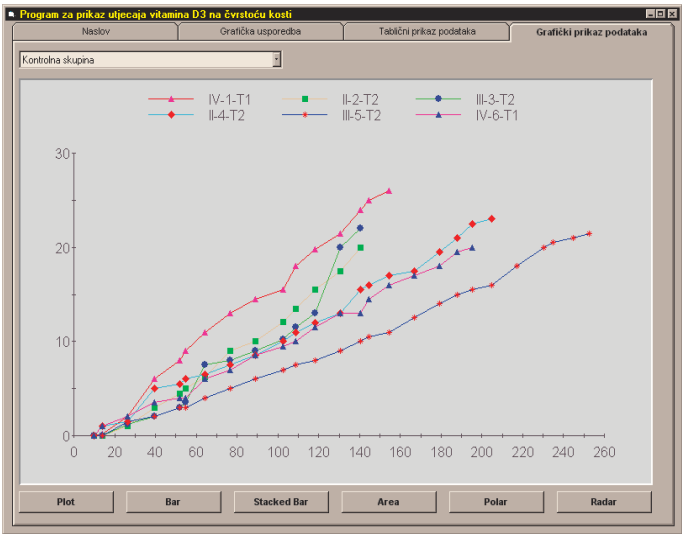


Fig. 3a. »Plot« chart of the torsional moment depending on the angle of torsion.

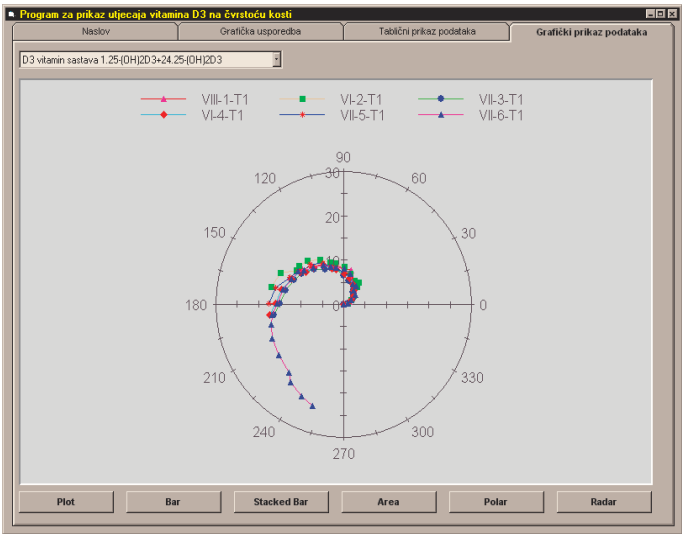


Fig. 3b. »Polar« chart of the torsional moment depending on the angle of torsion.

- stacked bar (data are presented as thin bars),
- area (data are presented as dots with a shaded enclosed area),
- polar (Figure 3b),
- radar (similar to polar presentation).

During graphical presentation it is also possible to change groups of data according to the type of metabolites of vita-

min D_3. The main idea of this work was to try to explain the influence of various types of vitamin D_3 metabolites on the human compact bone using data obtained from the experiment on laboratory animals as reference.

Based on the data from the experiment and the data from the program it is evident that the amount of various metabolites of vitamin D_3 directly changes the physical properties of the compact bone. All the conclusions are based on the data obtained from a comparatively small number of tested laboratory animals. This is due to the fact that the maintenance of laboratory animals is costly. Conclusions would be more accurate if a greater number of laboratory animals were used. The conclusions from this work will be used as the basis for further work in this area.

REFERENCES

1. FUNG, Y. C.: Biomechanics-mechanical properties of living tissues. (Prentice-Hall, New York, 1993.) — 2. GOLDSTEIN, S. A., J. Biomechanics, 11 (1987) 1055. — 3. KREYSZING, E.: Advanced engineering mathematics. (John Wiley and Sons, New York, 1993). — 4. KAUFELD J.: Access 97. (IDG Books Worldwide, Harrisonburg, 1997). — 5. TURNER, C. H., D. B. BURR, Bone, 7 (1993) 595. — 6. VUKIČEVIĆ, S., C. BAGI, G. VUJIČIĆ, B. KREMPIE, A. STAVLJEVIĆ, M. HERAK, Bone and Mineral, 1 (1986) 383. — 7. MILČIĆ D.: Analysis of mechanical properties of bone tissue based on its microstructure. M.S. Thesis. In Croat. (Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, 1997). — 8. MUFTIĆ O., Strojarstvo, 6 (1973) 34. — 9. PERRY, G, B. HATFIELD: Visual Basic. (Unleashed Sams Publishing, Indianapolis, 1995). — 10. JURČEVIĆ T., O. MUFTIĆ, Coll. Antropol., 22 (1998) 585. — 11. LOVASIĆ, I., T. ŠKARIĆ-JURIĆ, B. BUDISELIĆ, L. SZIROVICZA, Coll. Antropol., 22 (1998) 307. — 12. ULIJASZEK, S. J., J. A. LOURIE, Coll. Antropol., 21 (1997) 429.

D. Milčić

Department of Applied Mechanics, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, I. Lučića 5, 10000 Zagreb, Croatia

MODEL ZA KOMPJUTORSKU SIMULACIJU KOŠTANOG TKIVA

SAŽETAK

U radu je analiziran moment uvijanja u ovisnosti o kutu uvijanja tkiva zbite kosti u pokusnih životinja i čovjeka. Temeljem podataka dobivenih mjerenjem u životinja pretpostavljeni su podaci ovisnosti momenta uvijanja o kutu uvijanja za čovjeka. Mjerenje je provedeno na četiri skupine tkiva zbite kosti pokusnih životinja. Jedna skupina je bila kontrolna, a tri skupine su bile obrađivane različitim metabolicima vitamina D_3. Istovjetno je mjerenje provedeno na samo jednoj skupini tkiva zbite kosti čovjeka, zbog nemogućnosti tretiranja čovjeka metabolicima vitamina D_3. Pri mjerenju su utvrđene funkcionalne veze između kuta uvijanja i momenta uvijanja za sve skupine koštanog tkiva životinja. Na temelju tih rezultata pokušalo se predvidjeti kako bi se čovjekova zbita kost ponašala kad bi se tretirala metabolicima vitamina D_3.