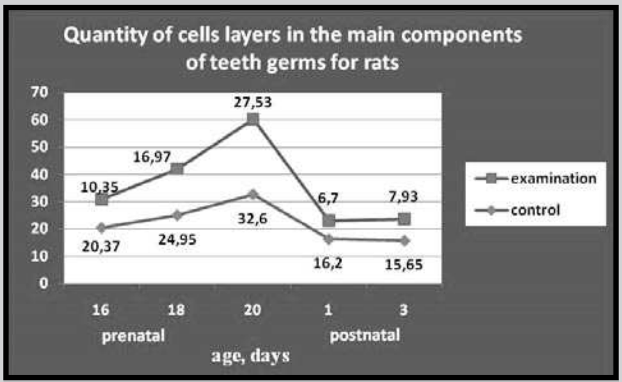

FIG.2. Quantity of cells layers in the main components of dental germs for rats.

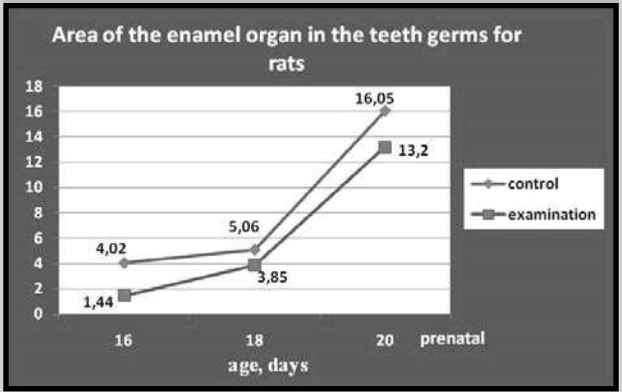

FIG.3. Area of the emamel organ in the dental germs for rats.

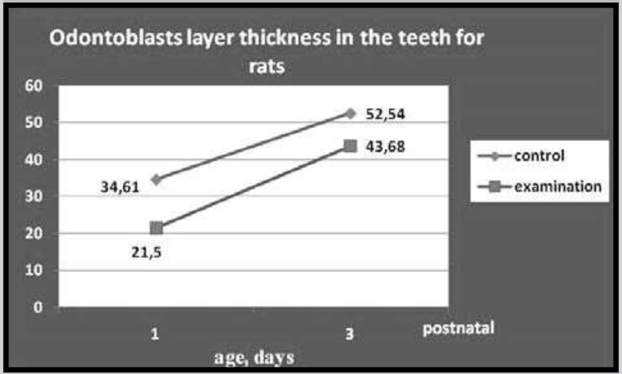

FIG.4. Odontoblasts layer thickness in the dental germs for rats.

foetuses and in the controls the indices were 1,44*±0,10 and 4,02±0,66μm^2l (p<0,001); in 18-day old foetuses 3,85±0,46 and 5,06±0,51μm^2 (p>0,05); in 20-day old 13,20±0,62 and 16,05±0,70μm^2 (p<0,01). The differences are statistically significant, except those ones in the 18-day old foetuses (FIG.3).

In the postnatal period, the odontoblast layer thickness showed maximal changes compared to those ones in other basic tooth germ structures. In 1-day old experimental rats and in the controls the indices were 21,50±1,27 and 34,61±2,94µm (p <0,001); in 3-day old 43,68±2,31 and 52,54±2,60µm (p<0,05) respectively. Indices differences are statistically significant (FIG.4).

Conclusion

IRLD reduced proliferative activity, cellular layers number and, in the majority of cases, tooth germ structure thickess; caused oedema, vacuolization, discomplexation, cell differentiation delay.

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* All parameters of squares text must be multiplied by 10^4

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FINITE ELEMENT ANALYSIS OF ONCOLOGY KNEE ENDOPROSTHESIS

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Abstract

This paper presents a finite element simulation of an oncology knee-joint endoprosthesis in a various degrees of flexion. The simulation has been made in accordance with an ISO 14243 [1-3]. A model of the knee implant (produces by ProSpon, s.r.o. [4]) consists of following parts: femoral stem, femoral replacement, femoral component, PE bushings, and tibial plateau. Results for four positions of flexion (1.53deg, 8.13deg, 15.31deg and 26.33deg) gave better understanding of strain and stress distribution along the endoprosthesis and pointed out also the most crucial areas requiring the attention. These foundlings are useful for individual design of the knee-joint prosthesis and for further development.

[Engineering of Biomaterials, 89-91, (2009), 9-11]

Introduction

Finite element method (FEM) has become a useful tool while study of several reasons of implant's fractures and defects. It is also a valuable and effective tool for biomechanical devices development. Quite fast and easily modifiable models allow studying wide range of problems (static, dynamic) while using different boundary conditions (type of loading).

Fractures and malfunctions of joint and bone implants has different causes. Generally, they can be sorted by two causes – biological and mechanical. Among the biological sources of implant demages, especially implant loosening and infection are well described in literature. In contrary, a stem fracture or a UHMWPE parts defect are typical causes of mechanical defects (see FIG.1).

To understand better the mechanical reasons for oncology knee implants destruction, the presented study has been made. All boundary conditions are in accordance with ISO 14243-3: 2004 [3], where a manner of mechanical testing is defined.

FIG.1. Mechanical defects of oncology knee endoprosthesis.

Materials and methods

For presented nonlinear contact static analyses, solved in Abaqus CAE, an oncology knee endoprosthesis made by Prospon [4] has been chosen. The implant is made from titanium alloy Ti6Al4V. Femoral (and tibial) replacements are manufactured from UHMWPE - ultrahigh molecular weight polyethylene, PEEK-OPTIMA® is used for sliding bush. Implants are manufactured individually for each patient.

Following TABLE 1 summarize material properties of all parts. Ideally plastic material model of UHMWPE is more described in FIGURE 2.

	Young modulus [MPa]	Max. tensile stress [MPa]	Poisson's ratio
TiAl6V4	113800	900	0,34
PEEK	3650	90	0,44
UHMWPE	820	100	0,44

TABLE 1. Material properties.

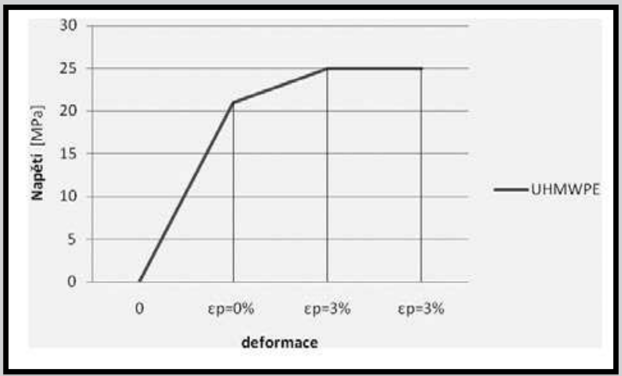

FIG.2. Ideally plastic material model of UHMWPE.

As already mentioned, all boundary conditions are in accordance with ISO 14243-3: 2004 [3], where a manner of mechanical testing is defined. Four phases of loading cycle have been chosen, flexion of 1.53 deg, 8.13 deg, 15.31 deg and 26.33deg. Corresponding magnitudes of loading (axial) force F are summarized in TABLE 2. Following FIGURE 3 simplifies the applied boundary conditions.

Knee flexion [deg]	1,53	8,13	15,31	26,33
Axial force F [N]	1887	2433	2600	950

TABLE 2. Axial force magnitudes.

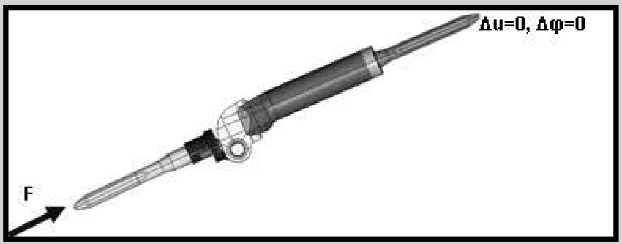

FIG.3. Boundary conditions applied to model of oncology knee endoprosthesis.

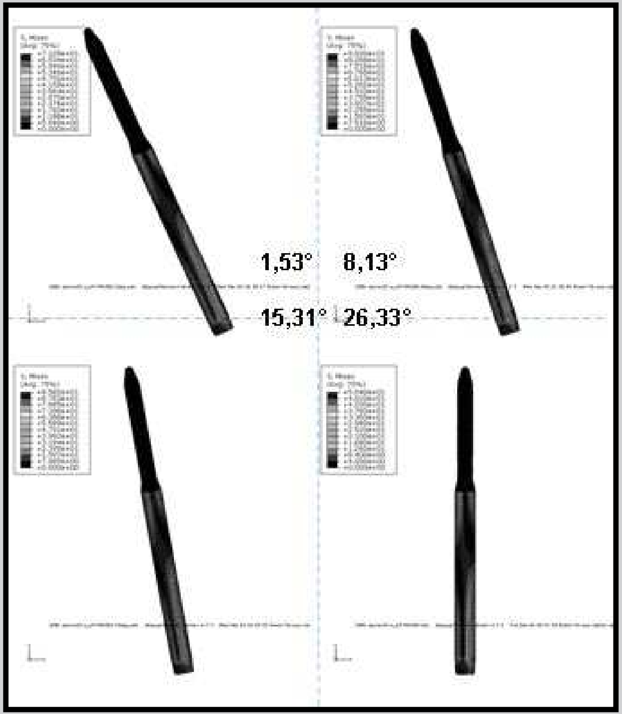

FIG.4. Stress distribution (von Mieses theory) on surface of femoral stem [MPa].

Results

Type of loading given by ISO 14243-1 [1-3] caused corresponding response in all parts of the knee oncology endoprosthesis. The most critical areas on the implant follow.

Stress distribution on surface of femoral stem (FIG.4) is highly influenced by two factors: firstly a magnitude of a loading force and secondly its direction. Augmented values are always in fixations represented by a femoral component. Second important area is on a proximal end of femoral implant fixation which is the most common place of stem break due to high bending.

UHMWPE bushings in a "hinge" between the femoral component and tibial plateau are maybe the most critical plastic part of the endoprosthesis. Though the values between 16-28 MPa (FIG.5) are reached, it is only a case of limited number of elements so these results can be supposed to be "mesh errors". Nevertheless, these parts demand special attention and further study to eliminate an occurrence of PE wear. Especially dynamic tests taking into account cyclic loading would give better insight into the problem.

Femoral component (FIG.6) and tibial plateau (FIG.7) in case of hinge-type endoprosthesis are not as loaded as in case of anatomical total endoprosthesis. Some differences in stress distribution for different loadings are noticeable. For all types of axial forces, maximal stresses for titanium alloy are not reached.

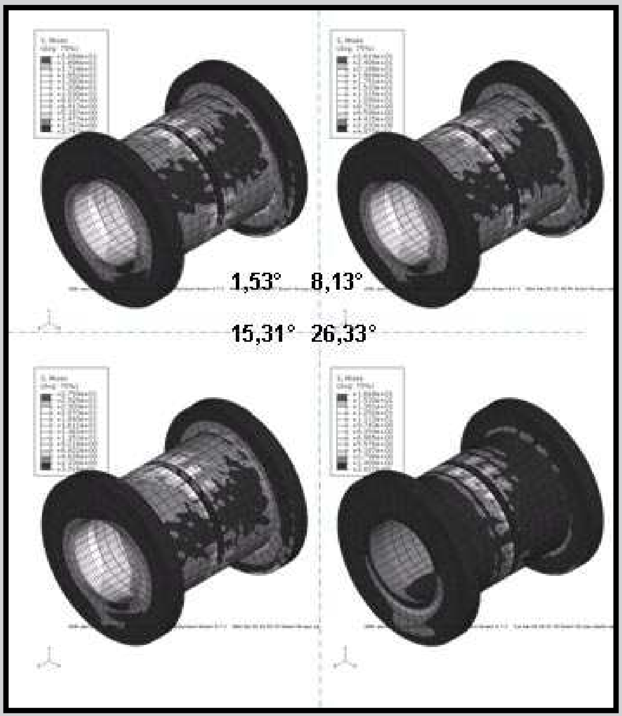

FIG.5. Stress distribution (von Mieses theory) on surface of UHMWPE bushings [MPa].

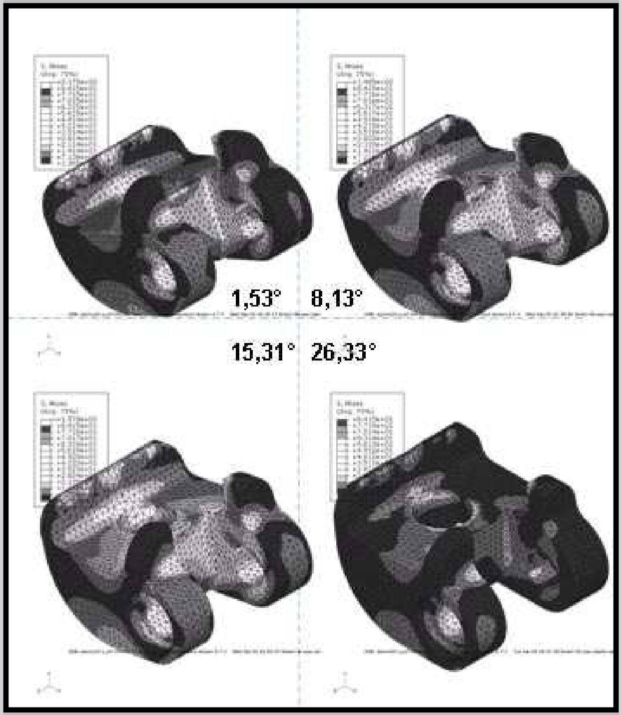

FIG.6. Stress distribution (von Mieses theory) on surface of femoral component [MPa].

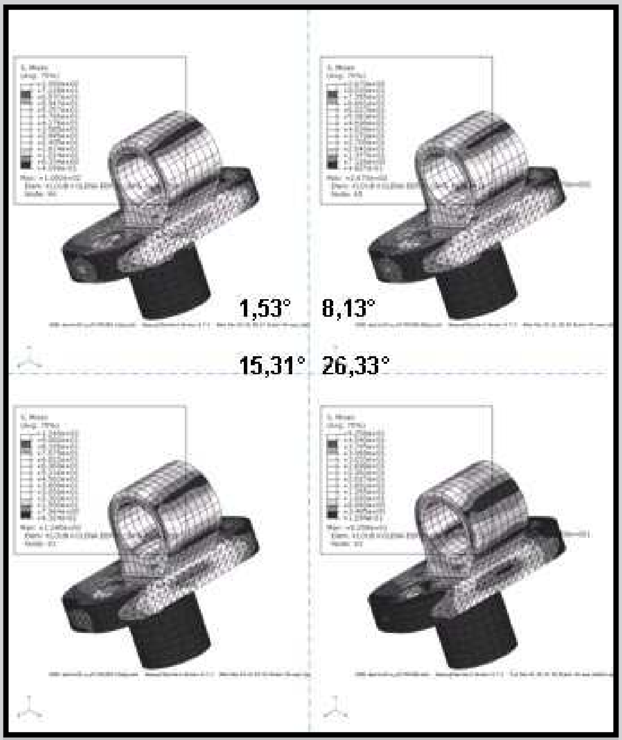

FIG.7. Stress distribution (von Mieses theory) on surface of tibial stem [MPa].

Conclusions

One of the most common reasons of joint endoprosthesis malfunction leading to a reoperation is a mechanical defect or an implant loosening (or their combination). Appropriate design of the implant can dramatically eliminate this risk. As a useful tool for endoprosthesis development, a finite element method can be used, providing that the anatomical relation or mechanical test standards are kept.

A goal of this paper was to make up a computer simulation of oncology knee implant loading during the mechanical test defined by ISO 14243 [1-3]. The results pointed out the most critical areas of the endoprosthesis, i.e. UHMWPE bushings and femoral stem made of titanium alloy. The analyses made for four degrees of flexion (1.53 deg, 8.13 deg, 15.31 deg and 26.33deg) can be used for simulation of various designs of the endoprosthesis. Since the oncology implants are produced as an individual replacement, finite element method represents a time and money saving method of the implant production.

Acknowledgements

This research is supported by a grant of Ministry of Industry and Trade of the Czech Republic: MPO FI-IM4/125.

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