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STRESS ANALYSIS OF CONTACT OF FEMUR AND COLLAR OF TOTAL HIP-JOINT ENDOPROSTHESIS

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The experimental analysis of the influence of the polyethylene layer on the stress state on the femur surface was carried out. The measuring method was based on application of an extensometer for measurements of surface strain. The stress state of intact femur was compared the stress state after the fitting of total hip-joint replacement (THR) with polyethylene layer. The experimental results were compared with former research [2] of the interaction between THR and femur.

1. Introduction

Replacements of the hip-joints, the most important joint in the human body, have been used in our country since the end of the sixties even in the cases for patients with heavily pathological joints. the function of this joint and its replacement is being afforded considerable attention, with the purpose of ascertaining the functionality of the replacement until the end of the patient's life. Although technically the application of the hip-joint endoprosthesis has been highly successful, there still remain a number of problems caused by the interaction between elastic bone tissue and the rigid stem of the replacement. Total hip-joint replacement (THR) Poldi, which are used in our country, are applied in coxa valga. After implantation the endoprosthesis collar is very often in contact with bone cement only. This state can bring two possible complications:

1. Bone cement is overloaded which can cause exceeding of compressive strength and its failure resulting in ***stem loosening***.
2. After the neck resection the cortical bone is not axially loaded in the calcar region, which can cause a significant reaction to hip- joint implantation, so-called ***calcar resorption***. It is a process in which the bone tissue in the calcar region is resorbed to greater or lesser extent [1]. It is assumed that one of ***the reasons of resorption*** consists in the ***change of the stress state in the bone tissue*** which takes place after the endoprosthesis implantation.

For many years ***V.Smetana***, Orthopaedic Clinic of the 2nd Faculty of Medicine, has been using a ***polyethylene layer under the endoprosthesis collar*** during reoperation of THR Poldi (Fig.1). In the case of reoperation the egg-shaped polyethylene layer with hole for a stem substitutes already resorbed bone in order that the lower extremity would not shorten. The polyethylene layer is produced in three sizes with different thicknesses 5, 15 and 0 mm.

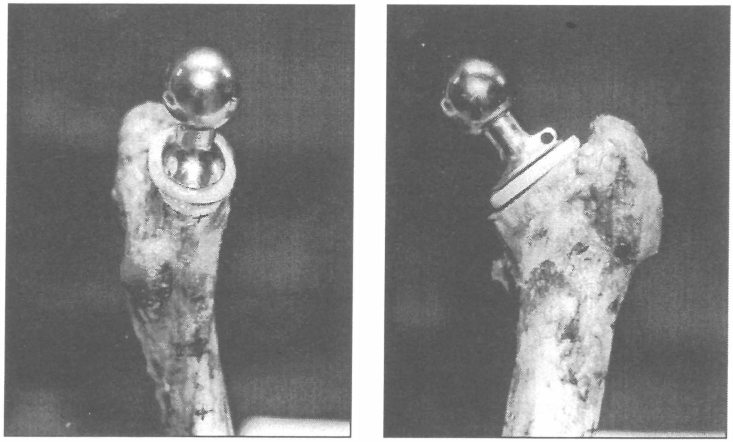

Fig.1. Egg-shaped polyethylene layer under the endoprosthesis collar

2. Materials and Methods

The purpose of our experimental analysis was to evaluate qualitatively the change of strain on the surface of the femur under quasistatic loading up of 2500 N taking place after implantation of the endoprosthesis with polyethylene layer under its collar. the research carried out was concerned with two way of endoprosthesis fitting :

1.close non-cemented connection of the implant with the bone;

2.after the preparation of the bone cavity the stem of THR was cemented.

The material for experimental research was obtained from cadavers. Immediately after dissection the femur was wrapped up in towels wet saline solution and frozen to a temperature of -25°C. The same method of specimen preservation was used also between individual phases of the measurement. The freezing of the specimens in moist state has no statistically significant effect on mechanical properties of the bone tissue.

For experimental investigation the femur condyles were embedded in acrylic resin. The lower part of the loading system was formed by two circular steel plates with a steel ball between them, thus representing a hinged support. The loading force was transmitted to the head of the femur by modified polyethylene acetabulum. This arrangement represented a statically determinate system. The load was produced by the INSTRON 4301 tester. The purpose of the experimental analysis was to evaluate qualitatively the local changes of strain on the femur surface under quasistatic loading of 2500 N taking place after implantation of the endoprosthesis with polyethylene layer under its collar. The measuring method was based on application of an extensometer for measurements of surface deformations. In given case an 2620-603 Instron extensometer with gauge length $l_o=10$ mm and maximum extension $\Delta l_o = \pm 1.0$ mm was used. Surface strains in each chosen place on the medial and lateral sides of the femur were measured by the extensometer in successive loading cycles. The extensometer was oriented in the direction of principal strain, known from previous studies using rosette strain gauges [1]. We have decided to use extensometric measurement because of easy and speedy relocation of the gauge from one measuring position to another. Moreover, gluing strain gauges to the greasy bone surface is laborious and takes a long preparation. There is also danger of strain gauge damage during endoprosthesis application and, consequently, the loss of previously measured values. After intact femur strain measurements were taken the same method was applied to measuring on the femur with implanted THR with polyethylene layer.

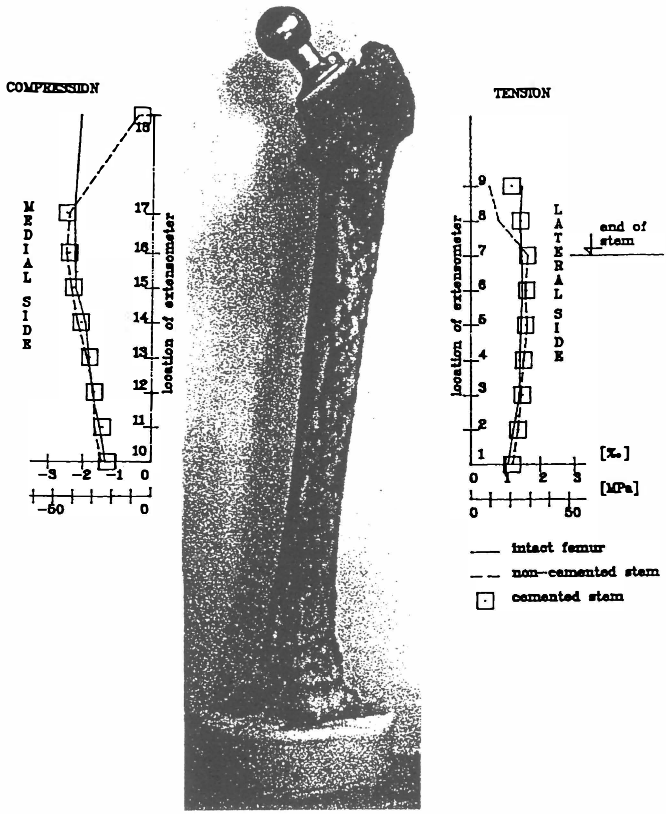

Fig.2. Results of measurements by Instron extensometer

3. Results

The results of the experimental analysis are shown in the Fig.2. The solid line characterises the measurement data of the intact femur. The conversion to stress is based on the simplifying assumption of homogeneity and isotropy of the bone with modulus of elasticity E=17,6 GPa. The deformation diagrams for intact femur and for the femur fitted with endoprosthesis have the same pattern, but significantly different in the proximal part. The highest value for intact femur was measured in the calcar femoris region. After the application of the prosthesis this value dropped considerably. The deformation value measured on the medial side in the highest point (No. 18) dropped to 20% of its initial value in the case of the non-cemented prosthesis, and to 16% in the case of the cemented prosthesis. Also the deformation value ascertained on the lateral side in the non-cemented endoprosthesis was about half the deformation value ascertained with intact femur and the femur with applied cemented prosthesis.

4. Conclusion

On the basis developed experimental method we have ascertained the change taking place as a result of alloplasty of cemented endoprosthesis with polyethylene layer under the collar. We have obtained the influence of the polyethylene layer by means of comparison with the results of previous research. It was found out in [2] that the stress reduction on the medial side proximally depends on the method of prosthesis application, i.e. on contact of the collar with the bone. If the collar does not bear properly on cortical bone, which is often this case, the place shows zero stress value in the direction of femur axis, which is a highly unfavourable state. ***The polyethylene layer enables the transfer of the load from the prosthesis collar to the bone in all cases, so that the bone will be always under stress. This favourable interaction suppresses the origin of resorption.***

References

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