Experimental stress analysis of a femur with orthopaedic implants

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Calculation of Load Distribution Between Bone and Prosthesis Stem by an Analytical Method; Comparison of Several Stem Types

P. M. Calderale, M. M. Gola, and A. Gugliotta

The mechanical design of an efficient coupling between a femural shaft and a hip prosthesis stem is a rather complicated task, even if undertaken in simplified conditions; the aim of this work is to propose an analytical method that allows one to calculate the mechanism by which flexion is transmitted, having as varying parameters the moments of inertia of bone and prosthesis, the coupling length, and the bone–cement compressive stiffness. The method originates a computer program that is of some order of magnitudes smaller than other ones based on the finite element technique and much faster to run and to analyze; it calculates the coefficients of a series of orthogonal Legendre polynomials that express the distributed load exchanged between stem and bone, assuming that the total elastic energy is a minimum. To evaluate the accuracy of the method, experiments are performed on simple test specimens composed of a straight stem inserted in a dummy simulating the bone and analyzed both by surface photo-elasticity and strain-gage techniques. Calculations are then performed on several stems of the most-used hip prostheses mounted with cement in a femur: results are shown graphically, and the behavior of the various stems is then compared. Finally, the role of the proposed method for the design of new stems is put into evidence.

Experimental Stress Analysis of a Femur with Orthopedic Implants

R. Huiskes, P. C. M. v. Heugten and T. J. J. H. Slooff

To study stresses and strains, to analyze the mechanical influence of various orthopedic implants, and to obtain reference data for analytical and finite element method analyses of the mechanical behavior of long bones, strain gauge measurements on a loaded femur, intact as well as provided with implants, were performed. A femur was fixed into a laboratory setting and provided with 112 strain gauges of three filaments each. Forces in three directions and couples around three axes were applied on the head and the trochanter major. Principal and equivalent stresses were calculated from the measured strain values. Altogether 66 measurement series were executed on the intact femur and the same femur with several types of Küntscher nails, femoral hip-endoprostheses, with and without cement, and an AO-plate. Nonlinear mechanical behavior of the bone proved to be caused by large deflections; the bone material was found to behave by approximation linear elastically. The experimental values were compared with predicted values based on classical beam theory, for which the geometry of the bone

was accurately measured. The beam model proved to be quite acceptable. The mechanical influences of the various implants were extensively studied. It was found for instance that neither the Küntscher nails nor the AO-plate provided torsional stiffness, that certain types of uncemented hip-endoprostheses move in the medullar cavity, and that the force introduction through the endoprostheses can lead to high and unnatural stress concentrations.

Biomechanical Study of the "Rozi" External Frame Fixator in the External Fixation of Long Bones

V. Kostovski

The "Rozi" external frame fixator when used in frame fixation permits a permanent elastic compression that can be measured on the site of fracture in both the axial and transverse planes. This compression can be varied and measured with each variation. It therefore permits compression in comminutive fractures of long bones. The "Rozi" external frame fixator weighs only 400 g and is therefore light and not bulky. All biomechanical studies were performed on animal skeletons by an extensometric technique using an electrical gauge. These studies showed that the "Rozi" external frame fixator exerts a force equal to 6–9 kp/cm^2 on the entire surface of the fracture. The "Rozi" external frame fixator does not allow flexion, sliding, or rotation of the fractured segments. The best applications of this fixator are in comminutive fractures and septic pseudarthrosis of the tibia. A study of 24 cases showed complete mobilization of the injured member one day after operation, allowed the subject to walk with a crutch 7–10 days after the operation, and without a crutch after three weeks.

Biomechanics at the Shoulder Joint and its Replacement

R Kölbel, G. Bergmann, and A. Rohlmann

Balanced phasic action of rotator and deltoid muscles matched to changing positions and geometry of joint bodies provide stability and transmission of normal loads at the joint surfaces. After replacement by a fixed fulcrum joint implant stability depends on design features and materials. Load transmission changes as does the resultant force. We investigated: 1) stability against dislocation of two implant prototypes and the effect of wear on stability, 2) significance of the position of the fixed center of rotation on muscle leverage, 3) stability of the fixation to the bone. *Results*. Joint designs with sufficient ranges of movement are stable up to 700 N (tensile load) and dislocating torques of up to 10 Nm. Wear caused by simulated movements under physiological loads (10^7 cycles) has little effect on stability. The physiological position of the fixed center of rotation is preferable. The fixation to the scapula supports loads of up to 500 N applied at 90° to the neck of the implant. *Conclusions*. Strength of the fixation to the bone is critical. Unlimited transmission of accidental torques could cause failure of the fixation. The built-in stability of the designed implant is therefore limited to transmission of torques below 9Nm. Beyond this value the implant dislocates to avoid fracture of the fixation. Other dimensions of the design are matched to this value.