PRESSURE-INDUCED PERIPROSTHETIC OSTEOLYSIS: A RAT MODEL

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Relevance to Musculoskeletal Conditions: The initiation of prosthetic loosening may have different causes. To understand them may help preventing failures in prosthetic surgery.

Introduction
Early migration, shape and position of a prosthesis predict late clinical failure. These factors appear unrelated to wear particles 1. High intracapsular pressures have been reported after total hip arthroplasty. It has also been established that intracapsular pressures are more often elevated in hip joints with loose prosthetic components 2. Recent animal experiments have indicated that oscillating fluid pressure can lead to osteolysis 3. Such a mechanism could explain osteolytic lesions around stable cemented or uncemented femoral components. However, in previous experiments, external non-physiologic saline solutions were used to generate the pressure. We now apply hydrostatic pressure fluctuations to bone via body fluids, by compressing a loosening-membrane-like tissue adjacent to bone.

Materials and Methods
The newly developed pressure chamber (figure 1) consists of a titanium plate, which was implanted 33 days prior to loading, and a pressure piston, which was connected to the plate in a second operation 5 days prior to loading. The whole construct is placed subcutaneously. The plate has a round hole, which holds a Ti-plug until the second operation, so that no tissue could fill it while the plate was being osseointegrated. The pressure piston is made of titanium surrounded by a plastic lining. It is fixed within the plate hole after removing the plug at the second operation. When the piston is in place there is a 1mm wide space between the piston and the cortical bone. This space comprises a pressure chamber. By applying force on the piston, load is transmitted to the tissue underneath the piston inside the chamber. This is done through the skin with a dynamometer. When loading is interrupted, the piston returns to its original position by means of a spring. The excursion of the piston movement does not reach the bone. The top of the piston is covered with a rubber cup to prevent tissue from interfering with the moving parts.

6 Sprague-Dawley rats were operated on at the proximal tibia. The tibial cortex was abraded corresponding to the central plug and the construction was implanted. After 28 days of osseointegration the pressure piston was applied. 5 days were given for fibrous tissue to grow into the chamber. Thereafter, a cyclic pressure of 0.6 MPa was applied to this tissue by 20 cycles twice a day with a frequency of 0.17Hz. The rats were killed after 5 days of loading. Histological sections were produced at a right angle to the loaded surface.

Results
In over 100 similar non-pressurized specimens of previous studies, we have never seen resorption zones, but in all 6 pressurized specimens of this experiment a dramatic bone resorption was found. The original cortex was almost entirely resorbed, but new woven bone had formed deeper in the marrow and walled off a cystic lesion. The periphery of the lytic zone always showed large numbers of active osteoclasts. The zone itself contained granulomatous tissue with fibroblasts, macrophages and capillaries, but very few polymorphonuclear or round cells. Away from the lesion the vitality of the bone seemed undisturbed.

Discussion
This new experimental model shows again that a moderate hydrostatic pressure rise at a bone implant interface leads to considerable bone resorption. The model therefore seems to be suitable to further investigate the origin of lytic processes at the bone implant interface.

In this experiment, we used repeated mechanical loading of an interface with a 1mm soft tissue layer between metal and bone. The compressive force was lower than what bone can resist mechanically, but apparently it had caused a hydrostatic pressure by squeezing the fibrous tissue next to the bone. This hydrostatic pressure initiated bone resorption close to the tissue space. The histological appearance ruled out infection as a possible cause of the osteolysis.

References:

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Figure 1: Pressure chamber at different stages of implantation. Implant in position at proximal rat tibia.

(a) Titanium plate 28 days after insertion. A flat cortical bone surface has formed under the plug.

(b) Piston is mounted at a second operation 5 days prior to loading. A soft tissue layer will form between piston and bone.

(c) Piston is loaded (arrow), but can not reach the bone. Increased hydrostatic pressure causes bone resorption.

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