Introduction
Orthopedic research has shown that total arthroplasty of the knee or the hip has a decreasing effect on the density of the adjacent bone. This is caused by two main factors: 1) the operation-related immobilization of the limb, and 2) the stress-shielding phenomena, where the stress distribution on the bone is changed due to the installed artificial joint [1,2]. This postoperative osteoporosis increases the risk of periprosthetic fractures. In addition, the loosening and detachment of the prosthesis induces major complications [3]. These risks can be reduced by developing more physiological artificial joints.

One crucial factor in making the prosthetic joint more physiological is the bone-prosthesis—interface. Amorphous diamond (AD) coating has turned out to be as a promising biomaterial in artificial joint, due to excellent biocompatibility, longevity and versatility [4]. However, the potential of AD coating in the bone-implant—interface, inducing differences in osseointegration, has not been studied extensively. The aim of the present study was to investigate the potential of AD coating of titanium implant for the osseointegration in the rat femur.

Materials and Methods
The materials used in this study were plain titanium (n=6) and diamond coated titanium (n=6) pins. The coatings were deposited at the Univ. of Kuopio using the techniques described in Ref. 4. The surfaces of the pins were smooth (R_a≈0.2 µm) and nonporous. The implants were 1.9 mm and 20 mm in diameter and length, respectively.

This pilot project consisted of 12 rats. The animals used in the study were male rats of the Wistar breed and approximately four weeks of age. At this age the growth of the rats has started to slow down, and we were able to maximize the environmental similarity of the samples. The animals were first divided in two major groups; those with plain titanium implants and those with a AD-coated implants. These groups were then divided in three; the zero-samples were sacrificed immediately after the operation to set the reference, and two groups were sacrificed four and twelve weeks after the operation, thus giving a perspective of the progress of osseointegration on a 0-12 week time span.

The rats were first placed under general anesthesia by using halothane. Then the knee joint of the rat’s right hand leg was opened with a longitudinal incision on the lateral side of the patellar ligament. After revealing the femoral joint surface, a hole was drilled in to the bone marrow cavity. The implant was then inserted lengthwise into the femur through this hole. Then the joint capsule was closed, as well as the skin incision. The rats were treated with powerful opiate analgesics postoperatively to make sure that they would use the operated hind leg as normally as possible thus assuring the weight distribution on the leg as physiological as possible.

After the animals were sacrificed, the femurs were prepared for the microscopy. Samples were dehydrated, infiltrated and embedded in methylmethacrylate, and transverse cut were made for the blocks. The final thickness of the slice after grinding was approximately 20 µm. Light microscopic images of the samples were obtained (Fig. 1), and the samples were analyzed with the AnalySIS—software. The percentage of the implant covered by the new bone and the thickness of the new bone layer shielding the implant was measured.

Results and Conclusions
In the four-week group of the AD-coated implants an average of 43.7 ± 11.6% of the implant surface was covered by a layer of new bone. The mean thickness of the bone layer was 11.4 ± 3.9 µm (Fig. 2). The corresponding values for the four-week group of the plain titanium implants were 16.6 ± 21.1% and 4.6 ± 5.5 µm, respectively (Fig. 2). In the twelve-week group of the AD-coated implants an average of 78.2 ± 2.5% of the implant surface was covered by a layer of new bone. The mean thickness of the bone layer was 30.1 ± 2.6 µm (Fig. 2). The corresponding values for the group of plain titanium implants were 73.0 ± 2.6% and 26.3 ± 1.8 µm, respectively (Fig. 2).

Due to the small number of the samples, no statistically significant differences can be yet proven. However, a clear difference can be seen in the osseointegration of the plain titanium and the AD-coated titanium. We also discovered that the plain titanium-bone interface had large amounts of fibrous tissue along with the bone. This fibrous tissue was close to nonexistent at the AD-bone interface.

Based on this preliminary study, the AD coating gives a better osseointegration than the plain titanium implant, and could be used as a coating for total hip and knee joint prostheses. However, further research is still needed to better validate these preliminary results.

References

Fig 1. Examples of light microscopic images of a) a plain titanium and b) an AD-coated titanium implant in rat femurs after 4 weeks of implantation. New bone shields substantially better the AD-coated titanium implant than the plain titanium implant.

Fig 2. Thickness of the new bone adhering to the titanium and AD-coated titanium pins after 0, 4 and 12 weeks of implantation. The AD-coated pins indicate better osseointegration than the plain titanium implants.