THE RESORBABLE CALCIUM PHOSPHATE CEMENT ALPHA BSM IN A SHEEP TIBIA SEGMENTAL DEFECT

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Introduction:
The filling of large bony defects remains a challenging problem in Orthopaedics. Due to the known drawbacks of auto- and allografts there has been a continues interest in artificial bone graft substitutes. Among the currently available materials, injectable calcium phosphate cements have shown promising results in experimental and early clinical experience. One new representative of this group of materials is αBSM, which has mechanical properties similar to cancellous bone. Mostly the indication for these materials has been the filling of metaphysial deffects. It was the purpose of this experiment to investigate its performance in a diaphysial defect. The material reported here is part of a larger investigation with several other experimental groups, which was performed in two research centers. In order to save animals for control groups, these animals were only operated in one center. Apart from the race of the sheep, identical procedures were used in both institutions.

Methods:
Approval of the local animal research comitee was obtained. A total of 22 adult sheep with a miniumum age of 2 years was used for this study. Under general anaesthesia a 3 cm subperiostial defect of the left tibia was stabilized with a specially designed unreamed tibia nail with static interlocking (3 screws proximal and distal each). Three experimental groups were formed according to the mode of defect filling:

<table>
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<th>Group</th>
<th>Weight (±Stdev)</th>
<th>Percent of intact</th>
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<tbody>
<tr>
<td>αBSM</td>
<td>53.3 (±3.6)</td>
<td>(n=8)</td>
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<tr>
<td>Empty defect</td>
<td>50.0 (±5.1)</td>
<td>(n=8)</td>
</tr>
<tr>
<td>Autograft</td>
<td>55.4 (±8.2)</td>
<td>(n=8)</td>
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The difference in the weights of the animals was not significant. Autologous cancellous bone graft was harvested from the posterior iliac crest. α-BSM was prepared according to manufacturers specification Its handling after mixing is similar to toothpaste. The material was injected to fill the defects between the corticotomies. Within 15 mm the material sets to its final strength. After the operation animals were kept in runs without restrictions. After three months of follow-up time the animals were sacrificed by lethal injection and both tibiae were harvested from each animal. After resection of the soft tissues the nails were removed and the specimens were potted in stone cast for biomechanical testing. A torsional test to failure at 20°/min was performed. The results were expressed as percent of the intact contralateral side. After biomechanical testing the specimens were immedietaly transferred into 70% Alcohol and then processed for undecalced histology. From each specimen one 50 µm slide, which contained the whole defect and adjacent bone was evaluated by light- and UV-microscopy as well as by contact microradiography. Statistical analysis was performed with the winks software package. Group means were compared with analysis of variance and the Newman-Keuls posthoc test. Frequencies were compared with chi-square analysis.

Results:
No animals had to be excluded from the study. All sheep were walking on the first postoperative day. Full weight bearing without a limp was observed by 6 to 8 weeks for all sheep. At the time of sacrifice all animals in the αBSM and all but one in the autograft group showed radiographic union and four of the six defect specimen showed a non-union. No dislocation of the main fragments occurred. Also most of the transplanted αBSM appeared to be resorbed and replaced by newly formed bone at the end of follow up. Macroscopic evaluation showed no signs of foreign body reaction or infection. In the αBSM group the healing callus appeared larger than in all other groups.

As expected the empty defects showed the lowest maximum torque at failure and stiffness values upon biomechanical testing. The best results were observed for the αBSM, even when they were compared with autograft. The data for the biomechnical test results are summarized in Fig. 1.

The difference between the groups was significant. Similar results were observed for the stiffness values. Fluorescence microscopy showed new bone formation within and around the bone graft substitute, which appeared to progress mainly from the corticotomies but also from the surrounding soft tissues. Light microscopy revealed no foreign body reaction. Fragments of the αBSM were still visible, but it appeared that the majority of the original material had been resorbed. Contact microradiographs confirmed these findings. The newly formed bone appeared to be woven, but was already in a process of remodeling. From these microscopic findings it appeared obvious, that the mechanical strength of the defect was almost exclusively explained from the strength of the newly formed bone. Both control groups showed the expected histological findings.

Discussion
The animal model used in this study has several advantages. 1) The sheep tibia is a single weight bearing bone (the sheep has no fibula), 2) Its dimensions and bone physiology allow conclusions for the clinical situation, 3) The same specimen can be used for biomechanical testing and histology, 4) Non-union will almost always occur if the defect remains unfilled. The results presented here a very favourable for a bone graft substitute and mechanical test results appear to be better than cancellous autograft which remains the gold standard for bone transplantation. One possible explanation for the superior mechanical test results may be the large callus diameter, which increases the polar area moment of inertia. We are concerned about the large standard deviation of the mechanical test results. This may indicated a large intraindividual difference in the extent of new bone formation. One drawback of this material appears to be its mechanical strength. Already on the 4 weeks x-rays a fragmentation of the original solid block was visible. This would indicate that a stable osteosynthesis will always be required in conjunction with the use of this material.

We conclude from our results that in our model αBSM was able to bridge a large segmental defect in the sheep tibia with better mechanical properties than cancellous autograft. To our knowledge this has not been previously found for any bone graft substitute, not even in conjunction with growth factors. This material may be promising for clinical use.

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[The authors have not received anything of value from a commercial or other party related directly or indirectly to the subject of my presentation.]