VECTEBRAL STRENGTH AND STIFFNESS AFTER KYPHOPLASTY OF OSTEOPOROTIC SPINE FRACTURES

INTRODUCTION
Osteoporotic vertebral fractures represent an enormous public health burden. They cause significant pain and may lead to disability and a decrease in quality of life. Vertebroplasty, in which the fracture is stabilized by injecting bone cement into the vertebral body, has gained acceptance over the past years as treatment of these fractures. Feasibility and safety of the procedure has been well established, however, major complications do occur, often related to cement leakage. Kyphoplasty is a variation on this technique, in which a void is created in the fractured vertebral body, reducing the pressure needed to inject cement into the vertebral body. This technique may also restore some height of the collapsed vertebral body. The rate of complications may be lower in this technique compared to conventional vertebroplasty.

In this study we assessed the vertebral strength and stiffness in kyphoplasty after height restoration in cadaver fractured vertebra. An experimental tool (ExT) was used, creating a void and expanding the vertebra. The influence of amount of vertebral height loss and amount of vertebral height restoration was also determined.

MATERIALS AND METHODS
From four human cadaver vertebral columns, 25 intact vertebrae were obtained (10 lumbar vertebra, 15 thoracic vertebra). Age of the subjects was between 78 and 93. All four vertebral columns were strongly osteoporotic at inspection. This was confirmed by a DEXA scan.

Preoperative crush sequence: In 21 vertebra anterior wedge fractures (Denis type 1B, AO type A1.2) were created by displacement controlled eccentric external force. The preset amount of height reduction was 35%. Force (N) necessary to achieve height reduction was recorded during the entire crush sequence, and visualized in a force/displacement diagram. The vertebra was loaded at low speed (5 mm/min) to avoid dynamic effects. In addition, to verify crush methods from literature and to draw comparisons between the results of known literature with our trials, four vertebra were compressed to only 25% height reduction. Our hypothesis is that when the vertebra is crushed with a height reduction of 25%, the cortical walls remain intact and will still contribute significantly to the post-crush strength and stiffness. Therefore the reconstruction with PMMA will have less influence on the post crush strength and stiffness.

Height restoration and cementing technique: A spine surgeon trained in the kyphoplasty technique undertook all the ExT insertion and height restoration trials. A bilateral transpedicular approach was used. Height was restored within 0.5 mm of the original height (confirmed by X-ray and anterior height measurements) under a compressive load of 50-100 N. After height restoration the load simulator was unloaded and bone cement was inserted immediately. Of the four vertebrae that were crushed to only 25% vertebral height, two vertebrae were reconstructed as described above. Another two vertebrae were not reconstructed after 25% height reduction to test the post fracture strength of an untreated vertebra. The cement selected for the trials was the Parallax cementing system.

Postoperative crush sequence: The strength and stiffness of the VB after height restoration and curing of the cement was determined by fracturing the vertebra again in a postoperative crush sequence identical to the preoperative crush sequence. Strength and stiffness were compared with there original pre-operative values. In the two vertebra in which height restoration was not attempted, “post-fracture strength and stiffness” of the VB was determined after unloading the vertebra and letting it recoil for 15 minutes.

Statistical analysis: Results are presented as mean and standard deviation of the mean (SD).

RESULTS
All vertebrae in the 35% height reduction group were restored to at least 100% of their original height (102 ± 2%) and filled with cement. Figs. 1 and 2 show the force/displacement graph as obtained in two vertebrae. The fracture of the cortex is clearly visible in the force/displacement graph as a sudden drop in the force. Mean maximal compression force during the initial crushing sequence was 1200 ± 496N. After reconstruction mean maximal compression force was 935 ± 340 N, a decrease of 16 ± 30%.

Ventral body stiffness is derived from the force/displacement graph just before reaching the first failure (max. force) of the vertebra. Mean stiffness during the initial crushing sequence was 233 ± 126 N/mm. After reconstruction mean stiffness was 93 ± 45 N/mm, a decrease of 52 ± 28%.

As shown in the figures, endplate-to-endplate PMMA filling seems to result in a better reproduction of the pre-fractured results. Two vertebrae were deformed with 25% of their original height but not restored. A lower maximal force at the initial crushing sequence was observed: 715 ± 233N; maximal force at the second crushing sequence was 680 ± 141N. Results in the other two vertebra, that were deformed with 25% of their original height, but were restored to their original height were remarkably similar. In these vertebrae, maximal force at the initial crushing sequence was 865 ± 190N; maximal force at the second crushing sequence was 690 ± 14N.

DISCUSSION
Based on literature data, post-operative strength and stiffness were expected to be similar or higher compared to preoperatively. However, in our study postoperative strength and stiffness were lower than expected. After fracturing, height restoration and cementing, post-operative vertebral body strength was 80-90% compared to preoperatively. Average postoperative stiffness was 40-50% compared to preoperatively. Several differences in study design may account for the differences in results. First, in our study only clinically relevant osteoporotic anterior wedge fractures were created (AO 1.2). In most other studies the fracture types are not clearly defined and vary from non-wedge VB endplate impaction (AO 1.1) to complete burst fractures (AO 3.3). The strength and stiffness of a wedge fracture before reconstruction may be higher, resulting in a relatively larger decrease in postoperative strength and stiffness. Second, in other studies vertebral height was decreased only by 25%. If no fracture but only plastic deformation had occurred, this will probably influence the postoperative results strongly, as shown in this study. Third, the reconstruction technique: In our study a void was created in the sagittal plane before cementation. However, endplate-to-endplate cementation was not an objective in our study protocol. Although other studies suggested that the inserted amount of PMMA has minor influence on postoperative strength and stiffness, our results strongly suggest that endplate-to-endplate filling may profoundly enhance postoperative vertebral strength and stiffness. Kyphoplasty methods should be optimized to reach this cement filling status.

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