Introduction: Balloon vertebroplasty with PMMA cement is successful for the pain treatment of osteoporotic compression fractures.[1] In traumatic burst fractures it has received attention as a supplement to pedicle-screws to reinforce the anterior column. Recurrent kyphosis and/or secondary procedures may be prevented if the fractured vertebral body is restored to its physiological shape and augmented with bone cement. Recent in vitro work demonstrated balloon vertebroplasty, after posterior instrumentation, to be feasible and safe in traumatic fractures, but no data are available on the risk of bone displacement or the risk of cement extravasation.[2] It has been suggested that repositioning of bone and leakage of cement is prevented by intact longitudinal ligaments. In the current in vitro study, traumatic fractures with flexion and rotation components, known to have a high incidence of longitudinal ligament lesions, were created in human cadaveric spines and treated with balloon vertebroplasty after pedicle-screw instrumentation. A new but validated imaging modality, 3D rotational X-ray (3DRX) imaging, was used to quantitatively evaluate anterior and posterior bone displacement and cement leakage during various phases of the experiment.[3] Furthermore, the relation of longitudinal ligament continuity with bone displacement and chance of cement leakage was evaluated.

Material and Methods: Ten fresh human cadaveric spines (T8-S1) without osteoporosis, were obtained (mean age 65 years, m/f ratio: 8/2) and bisected to create twenty specimens. A weight-dropping device (20-25 kg from 1.50 m) was used to create burst fractures. In the first ten specimens, axial torque was applied before impact while for the other ten, 45 degrees of flexion was applied. Fractures were given a basic AO classification. All were reduced and stabilized with pedicle-screws and rods (BWM, Stryker Howmedica). The goal was to get anatomical alignment and provide some distraction, as in regular clinical practice. Subsequently, balloon vertebroplasty was performed with calcium phosphate cement (BoneSource, Stryker Howmedica). The cement was not pressurized. A 3DRX dataset was obtained (INTEGRIS BV5000, Philips Medical Systems) for the following phases: intact (Tmax), fractured (Tfractured); after insertion of the balloons but before inflation (Tdeflation); after optimal reduction of the endplate with the balloons inflated (Tinflated); after deflation of the balloons but before cement injection (Tdeflation); 10 minutes after injection of cement (Tcement). Mid-sagittal and parallel images at 5.0 mm were reconstructed on a workstation and exported to a PC. Dedicated 2D/3D modeling software (Rhinoceros v3.0, Seattle) was used for drawing reference points on the corners of the vertebral body and allow analysis of (see also Figure 1):

- The Posterior Bone Displacement (PBD), defined as the maximum posterior distance (mm) between bone fragments and the line drawn from the posterior corners of the vertebral body;
- the Anterior Bone Displacement (ABD), defined as the maximum anterior distance (mm) between bone fragments and the line drawn from the anterior corners of the vertebral body.

Results: The fractures created were: 4 A-type, 4 B-type and 12 C-type. Ligament damage (partial/completa rupture) was sustained in all but two fractures. The mean pressure in the balloons was 50.0 ± 17.6 psi. No significant differences in pressure were observed between the left/right balloons, between fractures created with rotational/axial force, or between the thoracic/lumbar level. The total mean balloon volume was 7.2 ± 1.3 ml at thoracic level and 13.6 ± 2.6 ml at lumbar level. The mean amount of cement injected was 12 gram at the thoracic level and 23 grams at the lumbar level. No associations between balloon volume and amount of cement injected were found in relation to the fracture type. A small amount of cement leakage was seen in one lumbar A-type fracture with intact ligaments. The overall changes of PBD and ABD were significant (p<0.05) at both levels for all consecutive phases. Figure 2 shows the mean PBD with standard deviations.

Discussion: In this study, we demonstrated the limited amount of bone displacement resulting from balloon vertebroplasty after pedicle-screw instrumentation in traumatic fractures with and without damaged longitudinal ligaments. Furthermore, discontinuity of longitudinal ligaments was shown not to be an extra risk factor for cement leakage. A shortcoming of our model could be that the longitudinal ligaments were damaged during inflation of the balloons. However, we did not observe any phenomenon, such as snapping or a sudden decrease in balloon pressure during the experiment, that indicated to this mode of failure and therefore we do not think that this was an issue. From the results of the current in vitro work, it is suggested that balloon vertebroplasty may safely be used, in terms of bone displacement and cement leakage, in traumatic fractures where damage to the ligaments is to be expected.

References: