Chapter 10

Indications and experience with balloon kyphoplasty in trauma

The safety and treatment possibilities of balloon kyphoplasty have rapidly led to the use of this technique in traumatic vertebral fractures. Initially balloon kyphoplasty was used in osteoporotic patients who sustained a fall and a subsequent traumatic fracture; however, the general rules of balloon kyphoplasty also apply in trauma cases and the guidelines shown above remain valid. Although we now have a safe and effective method of restoring vertebral height and reducing the fracture, the injectable bone substance is still an issue, especially in trauma. In general there is consensus that polymethylmethacrylate (PMMA) is safer in the elderly, as it is not resorbed or remodeled, but in young patients consensus has not yet been found on whether the use of PMMA in traumatic fracture is safe. During the past five years resorbable calcium phosphate cements (CPC) have therefore gained in popularity. In this chapter we summarize knowledge of the use of balloon kyphoplasty with resorbable CPC in traumatic fractures in young patients.

Balloon-assisted endplate reduction combined with vertebroplasty for the treatment of traumatic vertebral body fractures

J.-J. Verlaan, W. J. A. Dhert, and F. Cumhur Oner

Current approaches and techniques for the treatment of traumatic vertebral fractures

The optimal treatment of traumatic thoracolumbar fractures has, in the absence of properly conducted trials, been fiercely debated and, despite numerous publications showing lower levels of evidence in the past four decades, no consensus currently exists [Thomas 2006; Verlaan and Diekerhof 2004; Wood 2003]. Most spine surgeons will agree that the majority of A.1 and A.2 fractures (according to the AO classification by Magerl et al.) can be treated without operative intervention; A.3 fractures sometimes require surgery and B-type or C-type fractures almost always require surgery for good outcome [Magerl 1984; Vaccaro 2005]. Some discussions in the literature have focused on the best surgical approach for fracture reduction and fixation. In a recent systematic review of the literature it was noted that scientific evidence does not favor any particular surgical approach and preferences are most likely to be based on personal or institutional experiences [Thomas 2006; Verlaan and Diekerhof 2004]. It can be concluded from the literature that posterior short-segment fixation is currently the easiest surgical technique with relatively minor complications and generating good-to-excellent results in the majority of cases [Korovessis 2006; Verlaan and Diekerhof 2004]. However, for some fractures, especially complete vertebral body burst fractures (A.3.3), posterior short-segment fixation has sometimes been noted to be less successful [McCormack 1994]. In a radiological investigation of cadaveric traumatic fractures
by Oner et al., it was hypothesized that some types of disk space disruption may result from the traumatic impact and can subsequently lead to secondary kyphosis as a consequence of disk subsidence through the fractured endplate into the vertebral body [Oner 1998]. Radiological observations of clinical cases correlated with these experimental findings that changes in disk space morphology often result after traumatic fractures [Oner 1999]. Furthermore, in fractures apparently sufficiently reduced on initial radiographs, it was shown that recurrent kyphosis may occur as a result of intervertebral disk intrusion into the burst vertebral body [Oner 1998]. A study by Speth et al. subsequently confirmed these findings in a cohort of patients with traumatic burst fractures treated with posterior reduction and fixation [Speth 1995]. It was demonstrated in a series of experimental studies that disk space redistribution resulting from intrusion into the vertebral body could be prevented by proper endplate reduction and intravertebral augmentation of the resulting sub-endplate void [Verlaan 2002]. The technique for achieving endplate reduction was by direct reduction with inflatable bone tamps and injection of CPC. The studies that led to the procedure for fractured endplate reduction and vertebral body augmentation are the topic of the current chapter.

### Experimental and clinical studies for the development of transpedicular augmentation techniques of the anterior spinal column in traumatic fractures

**First steps in developing a direct reduction technique for burst fractures**

In 1999 the authors developed the concept of using balloons for endplate reduction in traumatic burst type fractures (balloon-assisted endplate reduction, BAER), combined with vertebroplasty (VTP). The predominant safety concerns were potential displacement of bone fragments towards the spinal canal after expansion of the inflatable bone tamps and subsequent leakage of cement in the spinal canal through the damaged posterior vertebral body wall. It was postulated that primary reduction of the burst fracture by ligamentotaxis and subsequent fixation with a rigid pedicle screw construct would prevent this displacement. The technique was first tested in a human cadaveric fracture model [Verlaan 2002]. Traumatic burst fractures were created in 23 non-osteoporotic thoracolumbar specimens. The fractures were reduced using short-segment pedicle screw constructs, and the endplates were subsequently reduced using transpedicularly introduced inflatable bone tamps (KyphX, Kyphon Inc.). The cavities that resulted after deflation and removal of the balloons were filled with CPC (BoneSource®, Stryker Orthopedics) consisting of equimolar amounts of dicalcium and tetracalcium phosphate which, when mixed with saline, form hydroxyapatite. Plain radiographs (anteroposterior and lateral) and magnetic resonance images (MRIs) were obtained from the specimens after fracturing, after reduction and posterior stabilization, and after the BAER/VTP procedure. Distraction of the fractures by pedicle screw instrumentation resulted in a reduction of both anterior and posterior wall displacement but did not reduce the central impression of the fractured endplate, probably because of persistent hydrostatic intervertebral disk pressure. After BAER and VTP the impression of the central endplate was significantly decreased. See also Fig. 61 for a chronological series of fluoroscopical images obtained during the experimental procedure. The maximum posterior wall displacement caused by BAER was 1.3 mm. No cement leakage outside the vertebral body could be detected during the procedure or after examination of the sectioned specimens. It was concluded that BAER and VTP might be safely used as a less invasive technique for anterior column reconstruction for selected burst-type fractures.

**The choice of cement as a bone-void filler. An animal model for vertebroplasty**

After optimal reduction of the fractured endplates with BAER, the ensuing cavity in the vertebral body should be filled with a material strong enough to resist the hydrostatic expansive force from the adjacent disks, and preferably not interfere with fracture healing. Autologous bone could be used, but experience with transpedicular spongioplasty as additional treatment to posterior fixation suggests that graft necrosis frequently develops [Alanay 2001; Verlaan and Diekerhof 2004]. Furthermore, crushed bone may not be strong enough when used for this application. Traditionally, PMMA cement has been used successfully for vertebroplasty in osteoporotic compression fractures [Heini 2000]; however, it might not be a good idea to inject PMMA cement into fresh traumatic fractures, as its permanent presence between bone fragments would preclude bone