Treatment Strategies in Thoracolumbar Vertebral Fractures: Are there Indications for Biomaterials?

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Abstract

Treatment concepts in thoracolumbar vertebral fractures include conservative treatment, internal fixator, and vertebral body replacement with implants and autologous bone grafts. The role of biomaterials in these concepts is unclear. Specific properties of biodegradable osteosynthetics seem not to be suitable for an employment in spine surgery. Growth factors may get significant importance in future when the risk of ectopic bone formation in the neurogenic canal is abandoned, particularly in combination with artificial bone substitutes. Bioresorbable bone substitutes are widely in use in vertebro- and kyphoplasty at this time and seem to replace bone cements. In vertebral body replacement they are employed to enlarge the amount of autologous cancellous bone, but not as stand-alone implants. As in many other fields, the use of biomaterials in thoracolumbar spinal injuries will rapidly increase in future.

Key Words

Spine surgery · Spine · Biomaterials

Eur J Trauma 2006;32:253–257

DOI 10.1007/s00068-006-6014-4

Introduction

Injuries to the thoracolumbar junction are most common in human spine injuries. The borders of conservative and operative fracture treatment are still matter of discussion and the indications, which are not to be discussed here, are changing [7] while the opposite general goals are out of doubt. These are at first protection of neuronal structures, second regain of load bearing and third repair of the alignment of the injured spinal segment and the entire vertebral column [1].

There are clear indications in the operative treatment of thoracolumbar vertebral fractures concerning dorsal, ventral, and combined procedures. The dorsal implantation of an internal fixator leads to primary stability; in case of neurological deficits the same approach allows laminectomy, decompression, and revision of dura mater, spinal cord, or cauda equina, respectively. It enables the surgeon to straighten up compressed vertebral bodies and, in case of distraction injuries, to perform a tension banding of the dorsal structures. Ventral procedures are used to completely or partially replace a compressed and destroyed vertebral body by means of a tricortical bone block, in some cases combined with a plate fixator, or of a cancellous bone-filled cage, respectively. Vertebral body replacement is needed to restore load bearing. Dorsal and ventral procedures can be performed combined and both conventional open and minimal invasive. They aim at to regain and maintain the kypholordotic form of thoracic and lumbar spine and to correct scoliotic torsion (Figure 1).

Beneath metallic implants, transplantation of autologous cancellous bone and bone blocks harvested from fibula, ribs, or pelvis do play an important role in this concept. The following overview will take a critical look at possible indications for the use of biomaterials in thoracolumbar spine fracture treatment. In this connection, materials and substances are addressed as biomaterials, which represent artificially enhanced or

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Received: January 22, 2006; revision accepted: May 19, 2006.

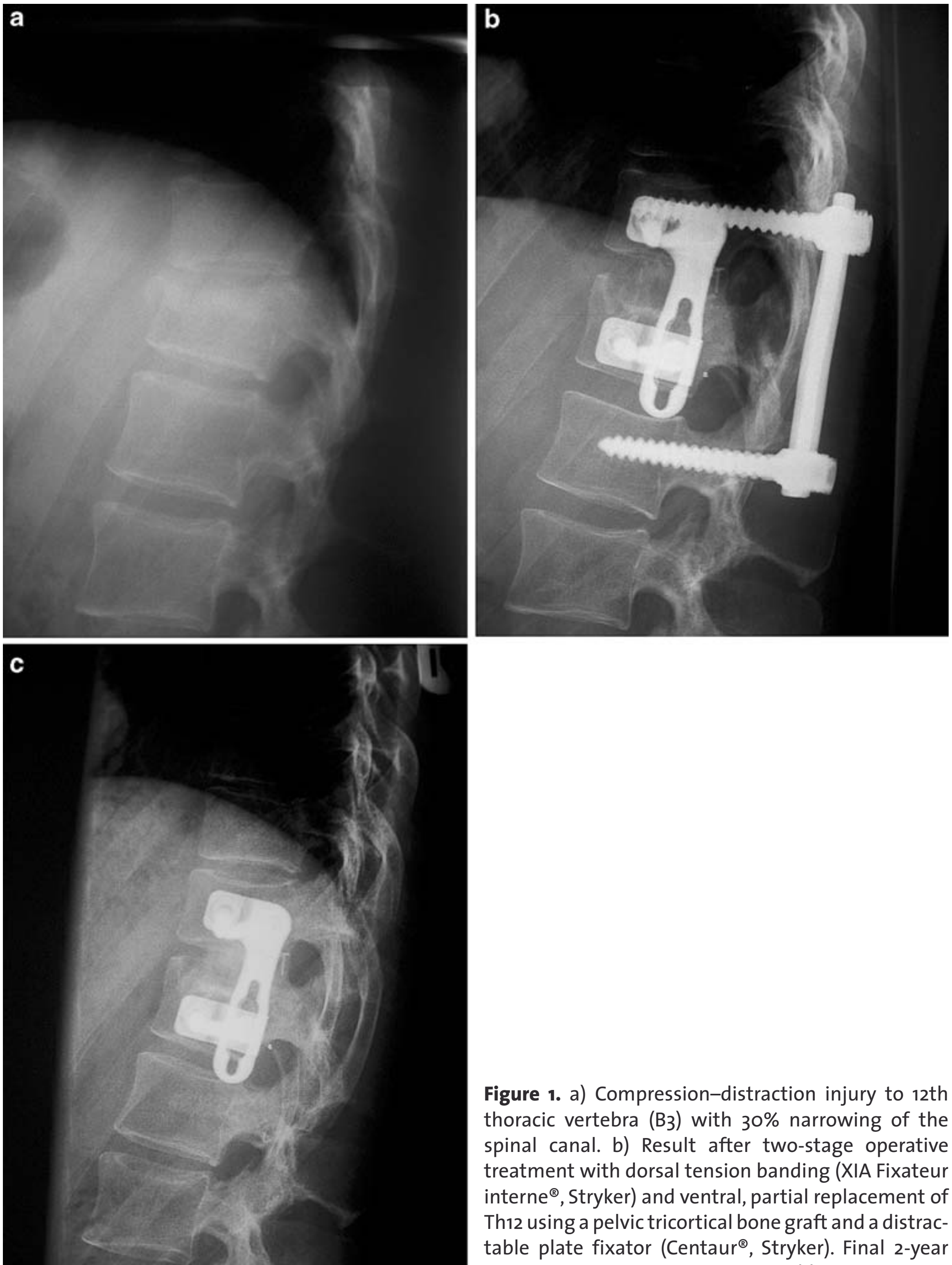

Figure 1. a) Compression–distraction injury to 12th thoracic vertebra (B3) with 30% narrowing of the spinal canal. b) Result after two-stage operative treatment with dorsal tension banding (XIA Fixateur interne®, Stryker) and ventral, partial replacement of Th12 using a pelvic tricortical bone graft and a distractable plate fixator (Centaur®, Stryker). Final 2-year result after dorsal implant removal (c).

produced endogenic substances or materials, that are subject to resorption, degradation, or any other form of incorporation [19].

Biomaterials

All in all three groups of materials and products meet this definition of biomaterials. Their relevance for spine surgery is going to be evaluated in the following (Table 1).

Biodegradable Osteosynthetics

Implants, available at this time, are made of polylactides, polyglycolides, their co-polymers, and a few more materials. They are used in various indications in traumatology and orthopedics [3]. Most often they are applied as thread and anchor systems or other refixation devices in articular surgery, for example, for open or arthroscopic Bankart or rotator cuff repair in shoulder surgery or meniscal refixation or crucial ligament graft anchoring in knee surgery [6]. The disintegration partly takes place as hydrolysis, partly as phagocytic resorption. Osteosynthetics in a closer sense is only available for unloaded fracture sites and there are several reasons, that they are not an equivalent substitute for metallic implants in spine surgery [8].

So, degradable polymeric implants do not offer a sufficient primary stability to receive heavy loads affecting the spinal column [22]. They go out of shape under mechanical load irreversibly [3]. Last but not least, there is no sufficient knowledge about degradation behavior of massive and voluminous work pieces, required in spine surgery.

Growth Factors

Genetic engineered growth factors (BMP-2 and BMP-7) or their endogenic-enhanced extracts, such as platelet-rich plasma (PRP), respectively, at this time are used in

Table 1. Currently available biomaterials, substances, and bone substitutes.

Biodegradable osteosynthetic materials	Polylactides
	Polyglycolides
	Polydioxanon
	Polyorthoester etc.
Growth factors	rh-BMP-2
	BMP-7 (OP-1)
Resorbable bone substitutes	Hydroxyapatite
	ß-Tri-calcium-phosphate

complex and complicative cases of trauma and orthopedic surgery. Particularly, there are experiences in open fractures and non-unions of the tibial shaft [4]. They are not accepted to be suitable as a stand-alone method in spine surgery [10].

At this time it is not conceivable that growth factors, injected into a compressed, instable vertebral body, should be able to take the place of surgical measurements such as mechanical erection and stabilization, decompression of the spinal canal or evacuation of a destroyed intervertebral disc. A special problem may arise from ectopic bone formation, often noticed in muscular or connective tissue after peripheral local application of growth factors. Used next to the vertebral canal these ectopic bone formations may cause severe complications by comprimising neurogenic structures [17].

Nevertheless, it can be anticipated that combinations of growth factors with autologous cancellous grafts or bioresorbable bone substitutes will increase fusion rates in vertebral body replacement in future [15]. Our own investigations on bone integration of BMP-2-coated hydroxyapatite-ceramics underline this expectation (Figure 2).

Bioresorbable Bone Substitutes

Donor site morbidity in autologous bone grafting is one of the most important arguments for the use of bioresorbable bone substitutes, besides the limited availability of endogenic material. In bone substitutes an excellent biocompatibility and dynamics of resorption and degradation, perfectly adapted to the velocity of new bone formation, are requested. A material with osteoconductive properties would represent an ideal solution. In fracture treatment of limbs tri-calcium-phosphate and hydroxyapatite are well-introduced materials, meeting those requirements.

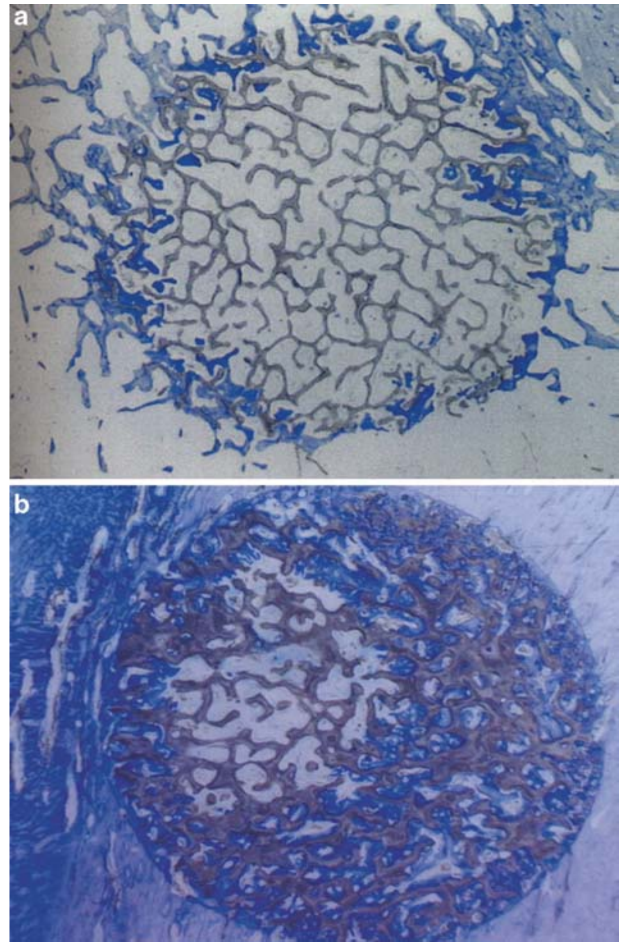

Figure 2. Toluidin-blue staining after press-fit implantation of a hydroxyapatite cylinder. (Endobon®, Biomet-Merck, Mini-Pig, Tibia). Dark blue: new formatted woven bone. a) conventional cylinder b) rh-BMP-2-coated cylinder.

In orthopedic and traumatological spine surgery significant amounts of autologous bone grafts are needed in ventral procedures, such as corporectomy and vertebral body replacement. This would be an optimal indication for bioresorbable bone substitutes [2]. But, even in cancellous bone grafting, which is the "golden standard" nowadays, there is the recurrent problem of insufficient fusion at the ground-plate — graft junction. It has to be investigated, if bone substitute materials can reach or increase fusion rates of autologous grafts, or not. Furthermore, it is not clear, if after corporectomy, cages filled up with solely bone substitutes may reach fusion rates as cages filled up with autogenous cancellous bone [12].

Implant coating may increase stability of dorsal augmentation, which was nicely shown by Schultheiss and co-workers [20].

But, until now, there is not enough data about those topics, so at this time in our hands the use of bioresorbable bone substitutes is restricted to the enlargement of endogenic material. Pastous preparations are not suitable for that. We prefer materials with minimum of primary stability, for example granula of tri-calcium-phosphate or hydroxyapatite.

Bioresorbable bone substitutes are recently used in vertebro- and kyphoplasty, but their high viscosity often leads to problems with the application. Nevertheless, they have advantages compared with bone cements (e.g. polymethylmethacrylat, PMMA). Higher prim-ary stability, stiffness and rigidity are inherent in bone cements, but this is accused to cause destabilization and therefore subsequent pathological fractures of neighbored vertebral bodies [11–13]. This especially arises in osteoporotic fractures, an upcoming problem in the next decades [21]. First experimental studies concerning the use of calcium phosphates after balloon kyphoplasty in thoracolumbar fractures are promising [16, 23]. Mermelstein and co-workers [14] were able to show that the addition of calcium phosphate cement into the fractured vertebral body through a transpedicular approach improves the stiffness of a transpedicular screw contruct, but up to now clinical data is too small for a general recommendation [5].

A special indication for resorbable bone substitutes will arise in the operative treatment of inflammatory spine diseases as a completion of radical surgical debridement. The combination of nanoparticular hydroxyapatite and calcium sulphate in form of compressed pellets (Perossal®, Osartis) permits high local dosage load with various antibiotics. There is experimental and clinical experience with vancomycin, clindamycin, gentamycin, and rifampicin. Furthermore, osteoconductivity of nanoparticular hydroxypatite promises an accelerated osseous recovery of the inflammatory destabilized bone [18]. First experiences in spine surgery are promising, whereas in limb surgery, we have to look at this method with restraint [9].

Conclusions

Amongst the biomaterials mentioned before, at this time nothing is entitled to be used in spine surgery, regularly. Biodegradable osteosynthetic materials miss primary stability for the forces, appearing at the human spine. They are of sufficient stiffness, but they fail in cyclic weight bearing.

Growth factors are not suitable for a stand-alone use in spinal injury treatment. But, after adequate experience in the application of growth factors in other indications and when the problem of ectopic bone formation in the spinal canal is abandoned, they will be a precious supplement of vertebral body replacement with autologous bone grafts. Growth factors can be expected to increase fusion rates.

It is this problem of failed intervertebral fusion again, which decreases the chance that bioresorbable bone substitutes alone can take the place of autologous bone grafts. So in our hands bone substitutes are used to enlarge the mass of cancellous bone, harvested, to fill up bony defects of the spinal column. On the contrary they already have begun to replace bone cements in vertebro- and kyphoplasty.

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