

Incomplete incorporation of morselized and impacted autologous bone graft

A histological study in 4 intracorporally grafted lumbar fractures

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Morselized and impacted bone allografts are used successfully in hip and knee revisions, but experiments using bone chambers indicate that impaction actually can delay ingrowth of new bone into a graft. To understand the remodeling and incorporation process of morselized and impacted grafts, we studied the incorporation of morselized impacted autografts in lumbar fractures histologically.

4 patients were operated on for Th XII-L1 fractures. The fractures were stabilized by VSP plates and transpedicular screws in the vertebrae above and below the fractured one. Autologous bone graft was

packed into the fractured vertebral body through one of the pedicles. After 18–20 months, the plates were removed and biopsies were obtained from various locations in the fractured vertebra. All fractures were at this time clinically and radiographically healed. Histologically, in all cases, large areas of the autograft in the vertebral body were unvascularized and partially or entirely necrotic. As with morselized bone in hip revisions, evaluation of graft incorporation requires histological examination. Full osseous incorporation of a graft is not always necessary for a good clinical result.

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Morselized and impacted allografts are used in the surgical treatment of aseptic loosening in hip prostheses associated with osteolysis (Gie et al. 1993, Slooff et al. 1984, 1996) with excellent clinical results (Ling 1996), but with little knowledge about the biological process. In the treatment of lumbar fractures, morselized bone grafts have been used to fill out the vertebral body, which may reduce the risk for recurrence of a lumbar kyphosis (Daniaux et al. 1991). In these operations, autologous grafts are used instead of allografts. In a previous study using bone chambers in rats, we found that ingrowth of new bone into the graft is delayed by impaction (Tägil and Aspenberg 1998). We used the lumbar fracture operation as a human model to study graft incorporation histologically. The conditions for incorporation are more favorable with an autograft and can be viewed as a "best-case scenario" for what to expect from an impacted allograft. Any failure of incorporation would indicate that an allograft is even more likely to fail.

Patients and methods

4 patients with a traumatic vertebral fracture in the thoracolumbar junction were operated on using a posterior approach. In all fractures, the vertebral body was severely compressed in kyphosis, but the posterior cortex of the body was intact. Reduction of the fractures was accomplished by instrumented distraction between the two neighboring intact vertebrae and transpedicular manipulation of the endplates. Autologous morselized cancellous bone was harvested from the posterior iliac crest. It was packed into the bony defect of the fractured vertebral body through one of the pedicles, using a funnel and an impaction instrument. Two transpedicular VSP plate-screw devices (AcroMed, Cleveland, USA) were applied fixating the vertebrae above and below the fractured one. No intercorporal or posterolateral graft was used and no resection of the intervertebral disc was performed. Destroyed ligamentum interspinale and ligamentum flavum were removed. The patients used a thoracolumbar brace for 4 months.

Visual impression of tissue composition (%) in the fractured and grafted vertebrae at various biopsy sites

Case	Biopsy location ^a	Normal marrow	Fibrotic marrow	Necrosis
1	A	10	70	20
	B	30	30	40
	C	0	0	100
2	A	0	60	40
	B	10	50	40
	C	0	0	100
3	A	60	30	10
	B	55	25	20
	C	25	25	50
4	A	35	35	30
	B	10	40	50
	C	20	20	60

^a A pedicle, B transitional zone between pedicle and vertebral body, C vertebral body

After 18, 18, 20 and 20 months, respectively, the internal fixators were removed. Using a Michell-trephine, 4 biopsies were taken from each patient under fluoroscopic control. One biopsy was obtained from the vertebral body above or below the fractured one, through the screw-hole. In the fractured vertebral body, biopsies were taken from the pedicle used for bone grafting, the transitional zone between the pedicle and the vertebral body and from the center of the vertebral body. The specimens were fixed in 4% formalin, decalcified, embedded in paraffin and stained with hematoxylin and eosin. Central sections of the specimens were used for histology.

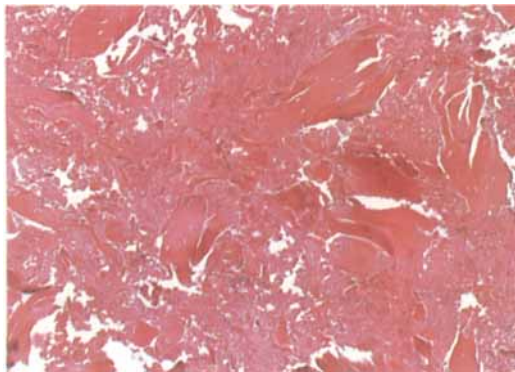


Figure 1. Dead bone and necrotic debris with no signs of revascularization.

Results

Clinical and radiological examinations showed that the 4 fractures were healed uneventfully at the time of implant removal. On histological examination (Table), the entire biopsy of the grafted vertebral body was necrotic in 2 cases (Figure 1). In the other 2 cases, the central part of the biopsy was necrotic, and a mixture of living bone and necrotic debris was present in its periphery. Here, living bone with a normal-looking marrow could be found next to areas with dead bone and necrotic marrow. Areas with living and dead bone could also be found surrounded by fibrovascular scar tissue, replacing the marrow (Figure 2). A similar mixture was noted in the transitional zones and in the pedicles of all cases. In the pedicles of the vertebrae adjacent to the fractured and grafted ones, there were also areas of necrotic bone and fibrotic marrow close to the screw canal.

Discussion

The clinical impression of the Slooff-Ling allografting technique in hips is that it works very well. The allografts appear stable enough to withstand the forces of walking with the newly-inserted prosthesis. Although migrating more than primary arthroplasties (Franzen et al. 1995, Sandquist et al. 1996), follow-up series have shown excellent clinical results for up to 9 years (Ling 1996, Slooff et al. 1996). Radiographically, the grafts seem to remodel and within the first

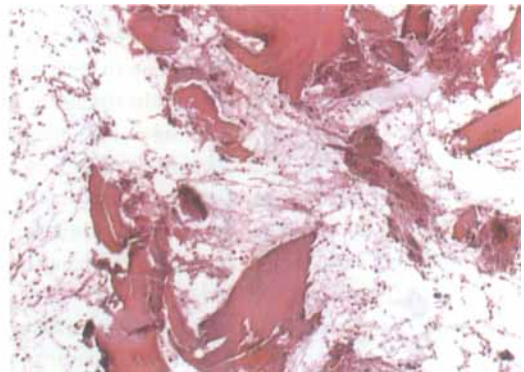


Figure 2. Dead bone graft with no signs of new bone apposition in a vascularized fibrotic stroma

year a neocortex is often visible. However, few studies have dealt with the incorporation on histological examination, and the correlation between radiography and the histological finding is unclear (Gordon et al. 1985). In clinical reports on histological analysis of the allografts (Ling et al. 1993, Heekin et al. 1995, Nelissen et al. 1995, Ullmark and Linder 1998), a picture similar to ours is seen, with islands of regenerating living bone, mixed with areas of necrotic remnants of the graft but with no signs of remodeling. Even though a very osteogenic material was used in our study, i.e., autologous cancellous graft, we found little, if any, remodeling in the center of the fractured vertebral body as long as 18-20 months after the operation. Large areas were avascular.

The advantage of autografts over allografts, apart from immunological effects (Stevenson et al. 1996), is that some stem and osteoprogenitor cells survive within the graft. These cells then proliferate and differentiate so that the remodeling depends not only on ingrowth by host cells (Bonfiglio 1958, Basset 1972, Gray and Elves 1979). Initially, the grafted cells depend on diffusion to survive until the graft is revascularized. The grafted volume in our material was large (5-10 cm³), and probably the diffusion distance from the nearest capillaries too large for cells to survive in the central portion of the graft. In a spinal fusion model in rabbits, a delayed maturation was seen in the center of the fusion mass (Boden et al. 1995). The authors of that study observed different temporal sequence and spatial pattern of the gene expression of bone-related proteins centrally and peripherally in the fusion mass, with a time lag centrally that parallels the lag in histological healing (Morone et al. 1998). This indicates that there exists a "critical volume" of an autologous bone graft for the cells in the center to survive. This critical volume might be smaller for impacted grafts, due to diffusion hindrance and perhaps also delayed revascularization. Moreover, the trauma of the morselization and impaction procedure, although necessary to increase the initial mechanical stability, might be deleterious to the grafted cells.

It has been suggested that the incorporation of morsellized impacted allografts depends on favorable mechanical loading (Gie et al. 1993). In the fractured and fixated vertebra, the loading pattern

is unknown, but some stress-shielding must be anticipated. The VSP devices are rigid, especially in flexion and lateral bending, but less stable in axial rotation (Slosar et al. 1995). Therefore, relatively more shear forces than compressive ones may act upon the graft. The largest part of the load is probably taken up by the device, but the load carried by the healing graft increases as it stiffens with time (Kanayama et al. 1997).

Our findings not only have implications for the use of impacted autografts in lumbar fractures, but also raise questions concerning the importance of graft incorporation in impacted morselized allografts used in hip arthroplasty revisions. Perhaps it is not necessary for the graft to be remodeled, as long as it is not being resorbed, or the resorption is not going to fast. It could still serve as a dead, but mechanically functioning load-bearing interponat, with a gradual transition in space from complete necrosis, through a composite of dead bone in living fibrous tissue to living cancellous bone.

Further studies, especially regarding the correlation between mechanical stability and histological graft appearance are required, not only to judge the need for intracorporeal bone grafting in thoraco-lumbar fractures, but also to understand better the biological and mechanical advantages and disadvantages of the morselized and impacted allograft. Autografts that do not bear load should probably not be compacted.

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