SPINE Volume 27, Number 13, pp E329–E333
©2002, Lippincott Williams & Wilkins, Inc.

Healing of Autologous Bone in a Titanium Mesh Cage Used in Anterior Column Reconstruction After Total Spondylectomy

Tomoyuki Akamaru, MD, Norio Kawahara, MD, Hiroyuki Tsuchiya, MD, Tadayoshi Kobayashi, MD, Hideki Murakami, MD, and Katsuro Tomita, MD

Study Design. Autologous bone inside a titanium mesh cage, used as an anterior strut in a reconstruction after total spondylectomy, was histologically examined in a postmortem specimen.

Objectives. To determine whether the autologous bone inside the titanium mesh cage attained fusion and remodeling in a combined reconstruction, consisting of an anterior titanium mesh cage with posterior multilevel instrumentation, after total spondylectomy.

Summary of Background Data. There are few previous reports on the histologic analysis of the bone inside a titanium mesh cage when it is used clinically as an anterior column support in a spinal fusion. Attaining biologic bony fusion is desirable for long-term stability after total spondylectomy.

Methods. A postmortem specimen from a 16-year-old boy with Ewing's sarcoma at T6, who died of lung metastasis 16 months after total spondylectomy and combined reconstruction, was analyzed.

Results. Histologic examination revealed many viable cells and normal lamella of trabecular bone formation in the grafted bone inside the mesh. Consecutive trabecular cancellous bony fusion between the grafted bone and the adjacent vertebral bodies was achieved.

Conclusion. Remodeling and fusion of the grafted bone inside the titanium mesh cage was observed. Combined reconstruction using an anterior titanium mesh cage with posterior multilevel instrumentation after total spondylectomy makes it possible to achieve biologic fusion of the bone inside the mesh cage with the adjacent vertebral bodies. [Key words: thoracic spine, spondylectomy, tumor, titanium mesh cage, spinal instrumentation, spinal fusion, histology, bone remodeling] **Spine 2002;27: E329–E333**

Curettage and intralesional resection of malignant vertebral bone tumors are common clinical practice.[10,17,20] Complete en bloc resection of the malignant bone tumor is considered ideal for removal of all residual tumor cells. From these concepts, total en bloc spondylectomy has been developed in recent years.[2,25,27]

Total en bloc spondylectomy is indicated for patients with malignant spinal bone tumors who are expected to survive in the long term.[28] These patients include those with metastasis or aggressive benign tumors. Therefore, long-term maintenance of spinal stability is required in the reconstruction after this procedure.

By contrast, total en bloc spondylectomy presents a complete loss of spinal stability because the ligaments around the vertebrae and vertebral bone are resected totally for excision of the tumor mass, by means of a wide or marginal resection. We believe that bony fusion is mandatory to maintain spinal stability in the long term after total en bloc spondylectomy. Autografts or allografts of large corticocancellous bone or artificial vertebral spacers have traditionally been used for anterior column support to achieve bony fusion in spine surgery.[3,4,15,16,21] However, structural titanium mesh cages have become popular substitutes in recent years.[11,18,23] The titanium mesh cage provides structural support,[12] and therefore morcellated autograft can be used inside the cage before insertion in the expectation of attaining fusion. Our most recent reconstruction techniques include a titanium mesh cage filled with autologous bone. This is positioned as an anterior strut, and pedicle screws are inserted in the two levels above and in the two levels below the spondylectomy.[27] Until now it could not be confirmed that the bone inside the mesh cage was actually fusing to the adjacent vertebral bodies because it was difficult to determine this using radiography.[5,6,19] There are few reports of histologic analysis of the bone in the titanium mesh cage when used in spinal fusions. In this study, we performed a histologic examination of the grafted bone inside a titanium mesh cage in 1 patient who died 16 months after insertion of the cage.

Case Report

After acute onset in November 1996, a 16-year-old boy came to another hospital with back pain and paresis of his lower extremities. Magnetic resonance imaging showed that a tumor lesion at T6 had compressed the spinal cord. He underwent piecemeal resection of the tumor, which was located in the lamina from T5 to T7, and decompression of the spinal cord. The histologic analysis of specimen material collected during the operation revealed an Ewing's sarcoma. After this operation, his paralysis improved and he was able to walk without canes. After surgery, the patient received three courses of adjuvant chemotherapy consisting of cyclophosphamide (5400 mg), adriamycin (120 mg), bleomycin (120 mg), methotrexate (180 mg), vincristine (3 mg), and actinomycin D (3 mg).

He came to our hospital in March 1997. At that time, the tumor lesion was located only at the T6 vertebral body (Figure

From the Department of Orthopaedic Surgery, School of Medicine, Kanazawa University, Kanazawa, Japan.
Acknowledgment date: December 17, 2001.
Acceptance date: January 21, 2002.
Device Status/Drug Statement: The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.
Conflict of Interest: No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

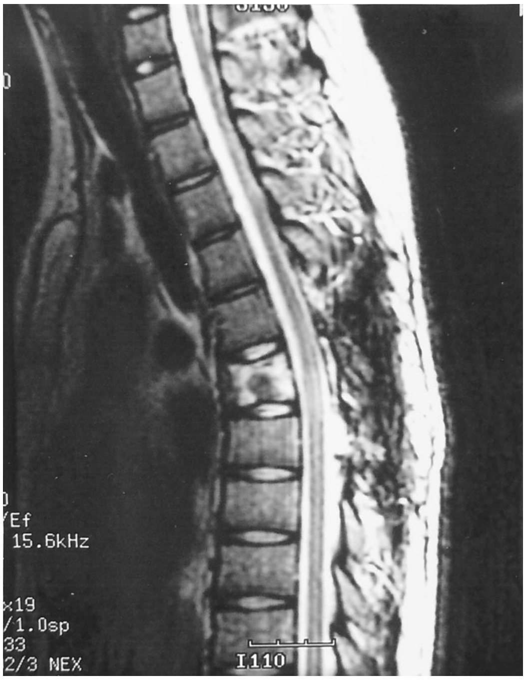

Figure 1. T2-weighted sagittal magnetic resonance image showing an increase in intensity in the T6 body when the patient first came for treatment in March 1997. Laminectomy had already been performed. The tumor lesion was solitary; no other tumor lesion was detected.

1). Magnetic resonance imaging of the spine detected no other tumor lesions. No metastatic tumors were detected by a technetium-99m scan or by whole-body computed tomography (CT). To reduce local recurrence as far as possible and to increase survival, in April 1997, en bloc corpectomy of the remaining portion of T6 was performed via a posterior midline approach. The vertebral body and the anterior and posterior longitudinal ligaments were completely resected by use of a T-saw.[25–27] The spinal column was completely interrupted at this level because the posterior elements had already been resected during the previous operation in 1996. The reconstruction included a Harms titanium mesh cage (Depuy AcroMed, Raynham, MA)[11,18] filled with morcellated autologous iliac cancellous bone. The cage was positioned as an anterior strut. Before en bloc resection of the anterior column of the vertebra, the pedicle screws and rods were inserted in the two levels above and the two levels below the spondylectomy (Figure 2). The posterior instrumentation was adjusted to slightly compress the inserted titanium mesh cage. A few pieces of iliac corticocancellous bone were put around the titanium mesh cage. The surgical time was approximately 13 hours, and blood loss was approximately 1200 g.

After surgery, the patient received three courses of chemotherapy consisting of cisplatin (630 mg), adriamycin (150 mg), and caffeine (7776 mg), and three courses of local radiation therapy at T5–T7 consisting of 30 Gy in total. The Harms titanium mesh cage and the bone inside the cage were included in the area of radiation therapy. The patient was able to walk, and neither local recurrence nor metastasis could be identified for 7 months after the total spondylectomy.

However, 7 months later, in November 1997, paresis of the patient's lower extremities occurred again. Magnetic resonance imaging showed that the recurrent tumor in the thoracic spine was compressing the spinal cord.

Although palliative surgery (curettage of recurrent tumor) was carried out seven times, and four courses of chemotherapy consisting of ifomide (44.7 g), etoposide (VP-16, 900 mg), methotrexate (300 mg), caffeine (30.132 mg), bleomycin (48 mg), cyclophosphamide (1948 mg), and actinomycin D (2 mg)

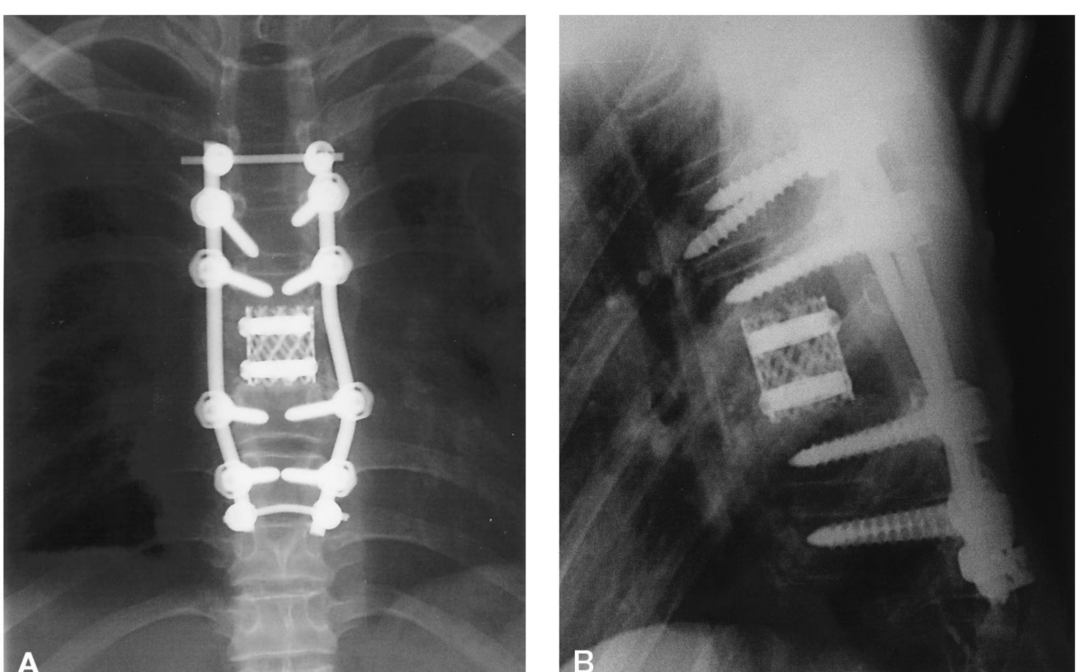

Figure 2. **A** and **B,** Total spondylectomy was carried out; reconstruction included a Harms titanium mesh cage, filled with autologous iliac cancellous bone, positioned as an anterior strut with posterior pedicle screws inserted in the two levels above and in the two levels below the spondylectomy.

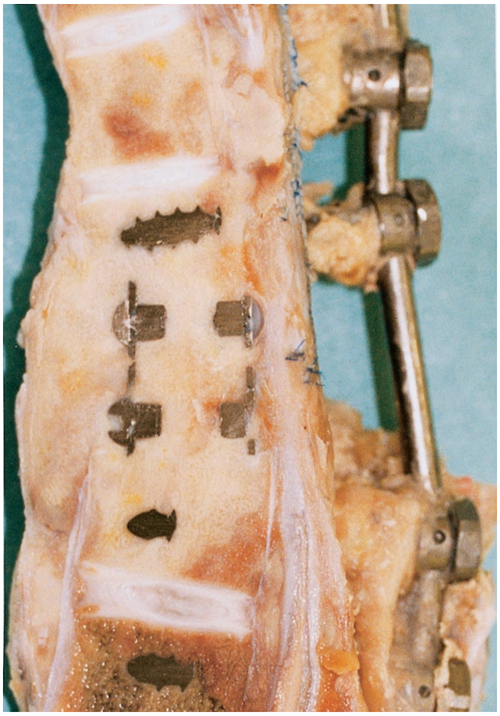

Figure 3. Postmortem dissection specimen. Solid fusion with the adjacent vertebral bodies was determined by manual palpation. Solid bone occupied the mesh cage.

were given, the tumor invaded the dura mater. Complete paresis of the lower extremities occurred in April 1998.

An additional three courses of radiation therapy were given to the thoracic spine (T1–T7) and the spinal cord (4900 Gy in total). However, the radiation therapy was unable to halt the progression of tumor. Lung and brain metastases that had first appeared on CT in July 1998 worsened. The patient died of lung metastasis in August 1998, 16 months after the total spondylectomy had been performed in April 1997. During these 16 months, neither instrumentation failure nor loosening of the titanium mesh cage was observed by radiography.

Histology. The grafted bone inside the Harms titanium mesh cage was analyzed histologically. Solid fusion with the adjacent vertebral bodies was observed by manual palpation (Figure 3). Histologic examination disclosed many viable cells and normal lamella of trabecular bone formation in the bone inside the mesh cage (Figure 4). Consecutive trabecular cancellous bony fusion between the grafted bone and the adjacent vertebral bodies was observed. Remodeling of the bone inside the mesh was apparent.

■ Discussion

To our knowledge, this is the first report to confirm remodeling of the grafted bone inside a titanium mesh cage when the procedure is used clinically. The development of total en bloc spondylectomy has given patients with spinal malignant tumor some long-term local control.[1,2,25,27,28] However, from the biomechanical point of view, total en bloc spondylectomy results in complete loss of spinal stability. Thus, postoperative reconstruction and bony fusion constitute an important part of this surgery.

Structural autografts, for example iliac crest, fibula, or multiple ribs, have traditionally been used for anterior column support in spinal fusions. In recent years, many

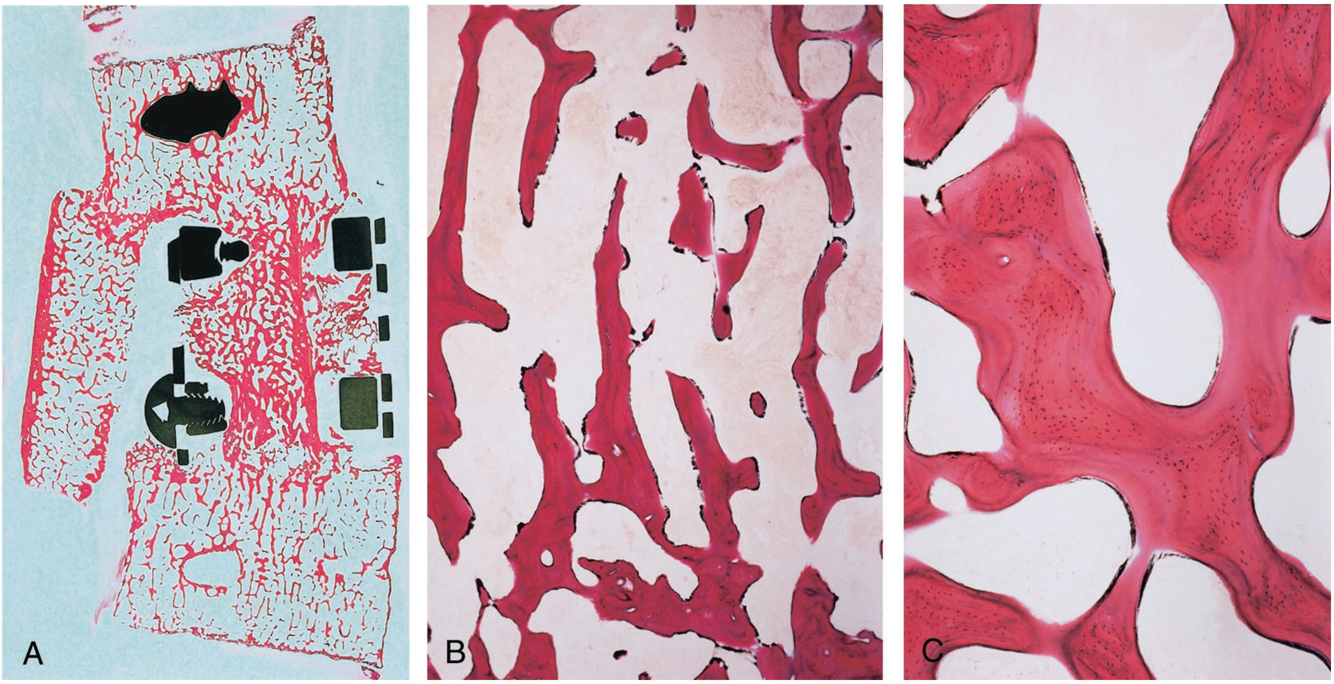

Figure 4. **A,** Histologic section of the bone in the mesh (hematoxylin and eosin). **B,** Junction between the grafted bone in the mesh and the endplate of adjacent vertebral body, showing consecutive trabecular cancellous bony fusion (original magnification, ×20). **C,** Bone at the center of the mesh, showing many viable bone cells, normal lamella of trabecular bone formation, and remodeling of the grafted bone in the mesh (original magnification, ×40).

kinds of titanium mesh cages have become popular as anterior struts.[11,18,23] There are advantages to using titanium mesh cages: varying diameters and heights are available, they can provide great resistance to subsidence,[12] and they can maintain spinal alignment without collapse. Further, titanium mesh cages can be filled with morcellated autograft before insertion in the expectation of attaining fusion.

However, it is impossible to confirm clearly whether the grafted bone inside the mesh cage is attaining fusion by using plain radiography or sagittally reconstructed CT, because the bone inside the mesh cage is obstructed by the metal.[5,6,19] Only a few reports have documented fusion status in structural titanium mesh cages used clinically. Eck et al[6] assessed the intracage fusion in 66 patients by examining plain radiographs and CT scans. They concluded that although it was very difficult to assess, 78% of the anterior levels were judged to be fused. Titanium cages were used as a spacer after corpectomy or an interbody fusion in their cases. Togawa et al[24] described the histologic appearance of biopsy specimens from the grafted bone in four Harms titanium mesh cages and five Brantigan carbon fiber cages that were used as interbody fusions. Those authors showed that the bone graft incorporation was still incomplete because of the presence of fibrous tissue and necrotic bone in most biopsy specimens, although the clinical and radiographic findings were favorable. The previous studies did not include a case of total spondylectomy. The present report is the first to confirm bony fusion histologically in a reconstruction using a mesh cage after total spondylectomy.

It is well documented that local irradiation and chemotherapeutic agents prevent bone remodeling and fusion.[7–9,29,30] Although high doses of local radiation therapy and anticancer chemotherapy were given in this case, good bone remodeling was achieved.

There are only a few biomechanical studies related to the reconstruction method after total spondylectomy.[13,14,22] Ikebuchi[13] investigated the stiffness of multilevel posterior reconstructed spine after total spondylectomy by a finite element method. It was concluded that multilevel posterior segmental fixation had enough stability for primary fixation, but the reconstruction section might fail because of fatigue fracture; therefore, biologic bony fusion was required for long-term maintenance of stability. Oda et al[22] concluded that the addition of the Kaneda SR systems as an anterior instrumentation to posterior pedicle screw instrumentation increased the rigidity of fixation and provided a superior biomechanical construct in biomechanical tests using human cadaver spines. However, we do not believe that it is necessary to achieve high fusion stiffness because the aim of applying instrumentation is to produce biologic bony fusion. In this case, a reconstruction that combined an anterior titanium mesh cage with autologous bone graft and posterior multilevel instrumentation after total spondylectomy achieved fusion of the morcellated bone inside the mesh cage with the adjacent vertebral bodies.

■ Key Points

- This is the first report to confirm histologic remodeling of the grafted bone inside the titanium mesh cage when used clinically.
- Reconstruction using an anterior titanium mesh cage with posterior multilevel instrumentation after total spondylectomy achieved biologic fusion of the bone inside the mesh cage with the adjacent vertebral bodies.

Acknowledgement

The authors thank Dr. William C. Hutton of the Emory Spine Center, Decatur, Georgia, for manuscript review and helpful suggestions.

References

1. Abe E, Kobayashi T, Murai H, et al. Total spondylectomy for primary malignant, aggressive benign, and solitary metastatic bone tumors of the thoracolumbar spine. J Spinal Disord 2001;14:237–46.
2. Boriani S, Biagini R, Lure FD, et al. En bloc resection of bone tumors of the thoracolumbar spine: A preliminary report on 29 patients. Spine 1996;21:1927–31.
3. Bridwell KH, Lenke LG, McEnery KW, et al. Anterior fresh frozen structural allografts in the thoracic and lumbar spine. Spine 1995;20:1410–8.
4. Buttermann GR, Glazer PA, Hu SS, et al. Revision of failed lumbar fusions: A comparison of anterior autograft and allograft. Spine 1997;22:2748–55.
5. Cizek GR, Boyd LM. Imaging pitfalls of interbody spinal implants. Spine 2000;25:2633–6.
6. Eck KR, Bridwell KH, Ungacta FF, et al. Analysis of titanium mesh cages in adults with minimum two-year follow-up. Spine 2000;25:2407–15.
7. Gal TJ, Munoz-Antonia T, Muro-Cacho CA, et al. Radiation effects on osteoblasts in vitro. Arch Otolaryngol Head Neck Surg 2000;126:1124–8.
8. Galler C, Epstein JB, Guze KA, et al. The development of osteoradionecrosis from sites of periodontal disease activity: Report of 3 cases. J Periodontol 1992;63:310–6.
9. Gerster JC, Bossy R, Dudler J. Bone non-union after osteotomy in patients treated with methotrexate. J Rheumatol 1999;26:2695–7.
10. Hammerberg KW. Surgical treatment of metastatic spine disease. Spine 1992;17:1148–53.
11. Harms J. Lumbosacral fusion with Harms instrumentation. In Margulies JY, ed. Lumbosacral and Spinopelvic Fixation. Philadelphia: Lippincott-Raven, 1996:529–38.
12. Hollowell JP, Vollmer DG, Wilson CR, et al. Biomechanical analysis of thoracolumbar interbody constructs. Spine 1996;21:1032–6.
13. Ikebuchi K. Biomechanical study of the spine after total en bloc spondylectomy [in Japanese]. J Juzen Med Soc 1998;107:537–46.
14. Kanayama M, Ng JT, Cunningham BW, et al. Biomechanical analysis of anterior versus circumferential spinal reconstruction for various anatomical stages of tumor lesions. Spine 1999;24:445–50.
15. Kaneda K, Asano S, Hashimoto T, et al. The treatment of osteoporotic-posttraumatic vertebral collapse using the Kaneda device and a bioactive ceramic vertebral prosthesis. Spine 1992;17(8Suppl):S295–303.
16. Kaneda K, Takeda N. Reconstruction with a ceramic vertebral prosthesis and Kaneda device following subtotal or total vertebrectomy in metastatic thoracic and lumbar spine. In: Bridwell KH, DeWald RL, eds. The Textbook of Spinal Surgery, 2nd ed. Philadelphia: Lippincott-Raven, 1997:2071–87.
17. Kostuik JP, Errico TJ, Gleason TF, et al. Spinal stabilization of vertebral column tumors. Spine 1988;13:250–6.
18. Lowery L, Harms J. Titanium surgical mesh for vertebral defect replacement and intervertebral spacers. In Thalgott JS et al., eds. The Manual of Internal Fixation of the Spine. Philadelphia: Lippincott-Raven, 1996:127–46.
19. McAfee PC, Boden SD, Brantigan JW, et al. Symposium: A critical discrepancy–a criteria of successful arthrodesis following interbody spinal fusions. Spine 2001;26:320–34.

20. McLain RF, Kabins M, Weinstein JN. VSP stabilization of lumbar neoplasms: Technical considerations and complications. J Spinal Disord 1991;4:359–65.
21. Molinari RW, Bridwell KH, Klepps JK, et al. Minimum 5-year follow-up of anterior column structural allografts in the thoracic and lumbar spine. Spine 1999;24:967–72.
22. Oda I, Cunningham BW, Abumi K, et al. The stability of reconstruction methods after thoracolumbar total spondylectomy. Spine 1999;24:1634–8.
23. Ray CD. Threaded titanium cages for lumbar interbody fusions. Spine 1997;22:667–80.
24. Togawa D, Bauer TW, Brantigan JW, et al. Bone graft incorporation in radiographically successful human intervertebral body fusion cages. Spine 2001;26:2744–50.
25. Tomita K, Kawahara N, Baba H, et al. Total en bloc spondylectomy for solitary spinal metastases. Int Orthop 1994;18:291–8.
26. Tomita K, Kawahara N. The threadwire saw: A new device for cutting bone. J Bone Joint Surg 1996;78A:1915–7.
27. Tomita K, Kawahara N, Baba H, et al. Total en bloc spondylectomy: A new surgical technique for primary malignant vertebral tumors. Spine 1997;22:324–33.
28. Tomita K, Kawahara N, Kobayashi T, et al. Surgical strategy for spinal metastases. Spine 2001;26:298–306.
29. Young DR, Shih LY, Rock MG, et al. Effect of cisplatin chemotherapy on extracortical tissue formation in canine disphyseal segment replacement. J Orthop Res 1997;15:773–80.
30. Young DR, Virolainen P, Inoue N et al. The short-term effects of cisplatin chemotherapy on bone turnover. J Bone Miner Res 1997;12:1874–82.

Address reprint requests to

Katsuro Tomita, MD
Department of Orthopaedic Surgery
Kanazawa University School of Medicine
13-1 Takara-machi, Kanazawa, 920-8641
Japan
E-mail: seikei@kenroku.kanazawa-u.ac.jp