Space-occupying bone lesions present orthopedic surgeons with clinical and operative challenges. Multiple reconstructive procedures have proven successful for small bone lesions but lack the structural support necessary for reconstruction of larger lesions. This study reports the clinical outcomes of patients undergoing excision and reconstruction of large bone lesions with allograft cortical struts without additional internal fixation.

This retrospective outcomes study reviewed patients who underwent surgical curettage and cortical strut allograft reconstruction of any space-occupying bone lesion. Clinical, surgical, and imaging data were collected. The primary outcome measures were lesion healing, graft incorporation, long-term pain, return to activity, and presence of complications/recurrences.

Seventeen patients met the inclusion criteria. At least partial lesion healing and allograft incorporation was identified in 15 of 17 lesions. Of the 15 patients who did not sustain a recurrence, only 1 did not return to full activities. Mean lesion volume was 107 cc. Average follow-up was 19.6 months. Two recurrences were identified, and no other major complications were identified.
Allograft cortical strut reconstruction of large bone lesions is successful in returning patients to baseline functional status of the extremity with minimal to no long-term pain without the need for internal fixation devices, thus avoiding hardware-related pain. Benign bone lesions present orthopedic surgeons with a unique combination of clinical and operative challenges. Eradication of the lesion and limiting recurrence while preserving bone integrity and extremity function are the main goals of treatment. Surgical curettage and bone grafting is a common technique for addressing these challenges. When bone lesions are large (larger than 60 cc) or near joint surfaces and require therapeutic curettage, large structural defects result in the remaining bone, compromising its integrity. Reconstruction and stabilization of the defect are necessary to avoid pathologic fracture, function loss, lesion recurrence, or other complications. Reconstruction options to fill the defect following curettage include autograft, allograft, and/or synthetic bone void fillers. Each type of graft material has unique biologic and mechanical properties. In a majority of cases, additional internal fixation is needed to support the graft.

Although autograft bone is a viable option for reconstruction, harvest site morbidity and inadequate quantity of graft have influenced surgeons to seek other sources.1 Other restoration options include freeze-dried cortical allograft, freeze-dried cancellous allograft, partially decalcified allograft, synthetic plaster-of-paris pellets, calcium sulfate, calcium phosphate, and granular tri-calcium phosphate.1-4 Although these reconstruction substitutes provide adequate treatment for small lesions, they lack structural support required for treatment of large or periarticular lesions.4 Numerous studies have explored these options, yet all procedures have limitations.1-4

Allograft cortical struts, commonly a segmental section of fibula, have recently been cited as a treatment option when the lesion is too large for the previously mentioned bone graft substitutes.6 When reconstruction options require structural support, the cortical allograft is sized to tightly fit into the intramedullary canal region of the lesion. The allograft is then placed into adequate position parallel to the mechanical axis of the bone. No hardware or fixation is used to secure the graft, thus avoiding the need for subsequent surgical removal of retained hardware and avoiding the possibility of hardware-associated pain.5,7 Cortical strut allografting alone is not a universal technique. Cortical graft is more structurally supportive compared with cancellous graft and exhibits slower rates of incorporation.3,5,7-10 The slow incorporation rate of cortical allograft can also be advantageous when treating benign lesions, like fibrous dysplasia, which frequently recur.11,12 The incomplete resorption of cortical allograft provides continued mechanical stability, permitting adjacent healing. The purpose of this study was to report the authors’ results of hardware-free, intramedullary cortical allograft strut reconstruction in the management of large or periarticular benign bone lesions.

Primary outcomes include both stability of the surgical reconstructive procedure as evidenced by allograft incorporation and lesion healing, and surgical site complications. Secondary outcome measures include preservation of extremity function, which is defined by long-term pain and postoperative activity level.

**Materials and Methods**

This institutional review board–approved study was a retrospective chart review describing the radiographic and functional outcomes after curettage and allograft cortical strut bone grafting of benign lesions in a series of 17 patients. Inclusion criteria were patients with a large (larger than 60 cc) or periarticular benign bone lesion who underwent curettage and fresh-frozen cortical strut allograft reconstruction without internal fixation by the senior author (S.D.W.) between June 1998 and January 2010 (Figures 1-2). The typical surgical procedure included corticotony and aggressive...
curettage of the lesion with intramedullary impaction of the allograft strut for reconstruction.

Clinical data collected from patient medical records included type of lesion/diagnosis, previous intervention (operative or nonoperative), imaging studies (radiographs [pre- and postoperative and follow-up], computed tomography scans, and magnetic resonance imaging), and operative intervention details (size of materials [cortical allograft, crushed allograft, hardware] and additional materials used). Postoperative clinical data were also collected, including fracture incidence, local recurrence, postoperative complications, pain, and activity level (none, some limitation, normal activity). If a recurrence was identified, the patient was not included in clinical follow-up.

Preoperative radiographs were evaluated for lesion location (specific bone and location within bone [epiphyseal, metaphyseal, diaphyseal]) and size measured in cubic centimeters. A lesion was considered completely healed if preoperative cavitation was obliterated, incompletely healed if residual lytic areas remained, and not healed if no evidence of trabecular formation existed or the graft resorbed. Allograft incorporation was considered to be complete if the graft was completely obliterated, partial if the graft was still visible but had blunted borders, and not incorporated if the contour was unchanged from initial radiographs. Radiographs were reviewed by 2 authors (J.C.T., S.D.W.) separately.

RESULTS
The study population comprised 17 patients (9 females and 8 males) with an average age of 19.7 years (range, 2-62 years). Average patient weight was 127.2 lb, and average body mass index was 22.3 kg/m². Average follow-up was 19.6 months.

Clinical and radiographic review revealed 6 aneurysmal bone cysts, 4 nonossifying fibromas, 3 simple bone cysts, 2 fibrous dysplasias, 1 plasmacytoma, and 1 lymphangiomatosis. Of these lesions, 53% were located in an upper extremity and 47% were located in a lower extremity. With respect to the location within the bone, 82% of the lesions were metaphyseal, 12% were epiphyseal, and 6% were metadiaphyseal. Mean lesion size was 107 cc (range, 21-363 cc). Six lesions failed previous surgical intervention (Table). Average fresh-frozen allograft cortical length was 6 cm (range, 3-10 cm). Regarding strut type, 16 were fibular allograft and 1 was femoral allograft. All lesions were treated with a supplemental bone graft material: 13 were filled with morselized cancellous allograft, 2 with OsteoSet (Wright Medical Technology, Inc, Arlington, Tennessee) pellets, 2 with allograft matchsticks, and 1 with autograft bone graft.

Two patients experienced recurrences. The first patient’s recurrence was a recurrent aneurysmal bone cyst. The recurrence occurred 4 months postoperatively and was treated with revision curettage and allograft strut placement. The second patient’s recurrence was a unicameral bone cyst that recurred as fibrous dysplasia 6 years after the index procedure. His lesion was periacetabular and underwent repeat curettages with calcium phosphate reconstruction at another institution. No surgical site infections or neurovascular complications were identified.

<table>
<thead>
<tr>
<th>Patient No./Age, y</th>
<th>Diagnosis</th>
<th>Lesion Vol, cc</th>
<th>Lesion Healing</th>
<th>Allograft Incorporation</th>
<th>Function</th>
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<tr>
<td>1/16</td>
<td>NOF</td>
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<td>Complete</td>
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<td>40</td>
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<td>Previous level</td>
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<td>4/16</td>
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<tr>
<td>5/17</td>
<td>ABC</td>
<td>136</td>
<td>Partial</td>
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<td>Previous level</td>
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<td>Complete</td>
<td>Partial</td>
<td>Previous level</td>
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<tr>
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<td>Partial</td>
<td>Previous level</td>
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<td>Failed</td>
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<td>None</td>
<td>N/A</td>
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<tr>
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<tr>
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<td>Simple bone cyst</td>
<td>126</td>
<td>Complete</td>
<td>Partial</td>
<td>Previous level</td>
</tr>
</tbody>
</table>

Abbreviations: ABC, aneurysmal bone cyst; N/A, not applicable; NOF, nonossifying fibroma; Vol, volume.
Allograft incorporation and lesion healing in patients without recurrence (n=15) were assessed from each patient’s most recent postoperative radiographs. Nine patients reached a level of complete allograft incorporation, whereas 6 patients reached partial allograft incorporation. Regarding lesion healing, 8 of the 15 lesions were completely healed, whereas 6 were partially healed. None of the partially healed lesions needed repeat surgery and had stable disease. For patients without recurrence, 14 of 15 returned to full activities with little or no pain (Table).

**DISCUSSION**

To the authors' knowledge, this is the first study reporting the successful treatment of space-occupying benign bone lesions in weight-bearing and nonweight-bearing extremities with allograft cortical strut reconstruction for large or periarticular lesions. The goals of this procedure were to eradicate the lesion, provide the patient with minimal long-term pain, and preserve extremity function without the use of supplemented internal fixation and its inherent problems.

The first treatment goal was lesion eradication with preservation of extremity function. Eradication was achieved in all but 2 patients, the first a multiply recurring aneurysmal bone cyst at initial presentation, likely a more aggressive disease process, and the second a unicameral bone cyst that recurred as fibrous dysplasia. The second goal was to reconstruct the defect created by resection, thus permitting early extremity function and return to normal activity levels. The majority of patients returned to their previous level of extremity function with mild to no pain early in the postoperative course with no prolonged immobilization. The only patient who did not return to full function had a plasma- cytoma and continued to have residual pain limiting upper extremity function (Figure 3). This is comparable with the results reported by Shih et al, who found 86% of humeral lesions had no pain. In contrast to Shih et al, the current study data evaluated both weight-bearing and nonweight-bearing extremities, identifying a successful technique in both upper and lower extremities. This technique was successful in treating lesions of any size (larger or smaller than 60 cc) as well as treating periarticular lesions.

Clinically, these rates of healing may seem low; however, they support the perceived biomechanical advantages of the allograft strut. The strut acts as internal support and shares the mechanical load applied to the extremity without the use of metallic implants. The graft was fit tightly in an intramedullary position that permitted load sharing along the weight-bearing axis of the bone. The strut may provide the necessary structural integrity for the patient to return to a normal level of activity although the lesion is not completely healed.

Due to these biomechanical characteristics of the allograft cortical strut, it is reasonable to suggest that partial allograft incorporation and complete lesion healing are the optimal results for this procedure. The lesion should be completely healed to lower the chances of a recurrence as well as to avoid pathologic fracture. Partial allograft strut incorporation permits continued load-sharing capabilities with the host bone (Figure 4). As noted by Shih et al, the strut acts as an internal splint until sufficient healing occurs to permit host bone loading. The value of using an allograft is that repair is an indolent, predictable process. Histological analyses have shown osteonal reabsorption patterns near revascularized haversian canals but not near the peripheral aspect of the osteon. This microscopic finding alludes to the continued biomechanical support from allograft strut use. If the allograft strut is completely incorporated, it can no longer share the load in the affected extremity and may increase future lesion complications. The prolonged incorporation time may be advantageous to allow the lesion to heal fully.

The current study results suggest that patients with fibrous dysplasia may have...
Although this procedure was successful, this series is not without limitations. The population was small and collected over a long time period because surgical oncologic disorders amenable to this treatment are relatively infrequent. A larger, multicenter study may be helpful in further defining the role of this technique. Another limitation is that the surgical technique used is an immeasurable variable that depends on surgeon skill and experience as well as lesion characteristics and patient factors. This technique will vary from surgeon to surgeon and may not be applicable to all lesions.

**CONCLUSION**

The authors do not believe that the allograft strut has any effect on lesion healing but has definite value in reconstruction of the defect created by aggressive curettage needed to permit lesion eradication. Allograft cortical strut reconstruction of any size or perarticular space-occupying benign bone lesion is a highly successful procedure. Based on this study’s data, this procedure produces a limb-sparing, biologic, hardware-free reconstruction in the majority of patients in which it is performed. Allograft cortical strut reconstruction is a beneficial surgical technique for an orthopedic oncologist’s armamentarium when treating benign space-occupying bone lesions.

**REFERENCES**


20. Russo R, Scarborough N. Inactivation of viruses in de mineralized bone matrix. *FDA Workshop on Tissue Transplantation and Reproductive Tissue; June 1995; Bethesda, MD.*