Femoral Ring Allograft for Anterior Cervical Interbody Fusion: Technical Note

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OBJECTIVE: Cadaveric fibula with locking plate internal fixation has been reported to be associated with fewer complications and better long-term results, compared with autologous iliac crest. With the knowledge that cortically dense allografts collapse less with time, new machined femoral ring allografts were developed for anterior cervical fusion after anterior cervical discectomy. We describe the system and the technique for placement.

METHODS: The femoral ring allograft set consists of color-coded graft-sizers that correspond precisely to the size of the precut grafts. The purple set is primarily intended for petite cervical vertebral bodies; the purple sizers and grafts are 11 mm wide and 11 mm deep and vary in height from 5 to 9 mm. The green sizers and grafts are 14 mm wide and 11 mm deep and vary in height from 5 to 11 mm. The blue sizers and grafts are 14 mm wide and 14 mm deep and vary in height from 5 to 11 mm. The rostral and caudal faces of the grafts are corrugated, to improve their holding capacity in the interspace. The bone is sterilely packaged in vacuum-sealed bottles, the tops of which are color-coded and precisely labeled. The set also includes a graft holder (to facilitate insertion into the interspace), impactors, and a barrel-shaped cutting burr (to prepare the endplates for fusion).

RESULTS: After anterior cervical discectomy to treat spondylotic radiculopathy or myelopathy, a femoral ring allograft was inserted, with allogeneic demineralized bone matrix and a locking cervical plate, in 20 cases, with no complications. Use of the system decreased the operating time by an average of 10 to 15 minutes.

CONCLUSION: The femoral ring allograft system is easy to use, and there have been no complications to date. The long-term fusion rate remains to be determined. (Neurosurgery 47:1457–1459, 2000)

Key words: Anterior cervical fusion, Femoral allograft

We previously reported on the successful use of cadaveric fibula and locking cervical plate internal fixation for anterior cervical fusion (12, 13). The complication rate and long-term results observed with this approach are superior to those obtained with autologous iliac crest or cadaveric iliac crest (3, 4, 6–8, 12, 13). Cadaveric fibula most often comes in lengths of 4 to 8 cm and must be cut to the appropriate length to fit in the prepared cervical interspace. A self-contained set including femoral ring allografts of various sizes, for anterior cervical fusion, was recently developed by Sofamor Danek (Memphis, TN) and the University of Florida Tissue Bank (Gainesville, FL). To date, we have successfully used this in 20 cases.

TECHNIQUE AND CLINICAL APPLICATION

The femoral ring allograft set consists of color-coded graft-sizers with handles that precisely correspond to the size of the precut grafts (*Fig. 1, right*). The purple set is primarily intended for petite cervical vertebral bodies; the purple sizers and grafts are 11 mm wide and 11 mm deep and vary in height from 5 to 9 mm. The green sizers and grafts are 14 mm wide and 11 mm deep and vary in height from 5 to 11 mm. The blue sizers and grafts are 14 mm wide and 14 mm deep and vary in height from 5 to 11 mm. The rostral and caudal faces of the grafts are corrugated, to improve their holding capacity in the interspace (*Fig. 2*). The cadaveric femur has been treated with 3% peroxide and freeze-dried. The bone is sterilely packaged in vacuum-sealed bottles, the tops of which are color-coded and precisely labeled. The set also includes a graft holder, to facilitate insertion into the interspace, and impactors (*Fig. 1, left*).

After anterior cervical discectomy and osteophytectomy, with bilateral foraminotomies, to treat cervical spondylotic radiculopathy and/or myelopathy, the cartilaginous endplates are curetted away, to yield bleeding cortical

FIGURE 1. ***Left*** **to** ***right*****, graft holder, two impactors, five** ***green*** **medium graft-sizers (ranging from 5 to 11 mm in height), and five** ***purple*** **small graft-sizers (ranging from 5 to 9 mm in height).**

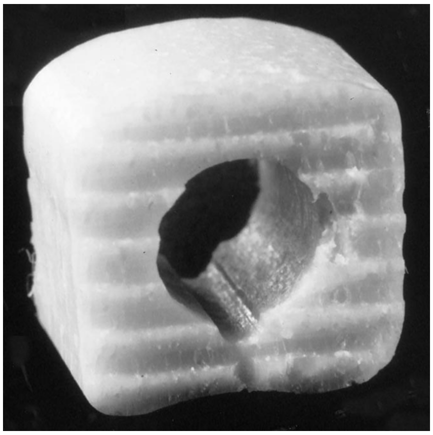

FIGURE 2. Close-up view of the femoral ring allograft, demonstrating the machined corrugated surface.

FIGURE 3. Lateral radiograph obtained at 6 weeks, showing the femoral ring allograft and locking plate in situ.

bone on both margins of the disc space. The anesthesiologist provides longitudinal traction on the neck to distract the interspace. A graft size is chosen to distract the interspace 1 to 3 mm, using the graft-sizers. Before insertion, allogeneic demineralized bone matrix paste is placed in the central hole. The chosen graft is inserted into the interspace and impacted, to countersink it 1 to 2 mm. Cadaveric fibula requires cutting and shaping with a drill, by the surgeon, to fit in the interspace; in our experience, this requires an average of 15 minutes. Therefore, with these sets, the procedure is shortened by 15 minutes in each case and there is no need for a cutting drill bit. All patients who underwent femoral ring graft fusion were also treated with anterior cervical locking plate internal fixation. There have been no complications, and the postoperative follow-up x-rays have demonstrated satisfactory graft and plate placement, with no graft collapse, in all cases (*Fig. 3*). There have been no follow-up monitoring periods longer than 4 months. Clinically, all 14 radiculopathies have improved and 5 of 6 myelopathies have improved.

DISCUSSION

The main reason to place a graft is to sustain interspace height, thus reducing the incidence of symptomatic recurrence (12, 13). Bone densitometry was performed on the femoral ring allografts at Indiana University and revealed a bone mineral density of 0.6 g/cm^2. We previously reported that cadaveric fibula has a bone mineral density of 0.7 g/cm^2 and autologous iliac crest has a bone mineral density of 0.2 g/cm^2 (13). Both cadaveric fibula and femur are significantly more dense than autologous or cadaveric iliac crest and are less prone to collapse, with loss of height, than is iliac crest. This brings into discussion the modulus of elasticity, which is the ratio of normal stress to normal strain in a material. Stress is the force perpendicular to the surface on which it acts, and strain is the change in unit height or area. Therefore, a high modulus of elasticity deforms less than a low modulus in response to a given amount of stress. The modulus of elasticity of bone is most dependent on its mineral content and porosity, i.e., high mineral content and low porosity lead to a high modulus of elasticity (5). This is very important for a cortical cancellous construct such as a tricortical iliac crest or vertebral body, in which the cancellous bone carries between 35 and 55% of the load, depending on the age of the patient. A 25% loss of either the vertical trabecular columns or horizontal trabecular ties of the cancellous bone decreases the strength to 50% of the original strength (2, 11). The process of freeze-drying the tricortical iliac crest does decrease the strength of the cancellous bone in compression loading, leading to a well-documented higher propensity for it to collapse, compared with autologous iliac crest (1, 3, 14). Fibula and femur have a higher bone mineral density, less porosity, and a greater modulus of elasticity than does cortical cancellous iliac crest and thus, as proven, are more resistant to collapse under compression. This high modulus of elasticity can predispose the graft to subsidence if the vertebral bodies bordering the graft have a low modulus of elasticity. This can occur with age-related osteoporosis or overaggressive removal of the cortex under the cartilaginous endplate. The reported rate of subsidence with fibular grafts in anterior cervical fusions without plating after discectomy was 5%, and this process was not clinically significant (9). In our experience with fibula and locking plate anterior fusion, subsidence is radiographically and clinically insignificant after discectomy and becomes clinically significant in only 3% of multisegment cervical corpectomies. Finally, the addition of a rigid plate allows load-sharing, which should decrease subsidence (10).

The combination of fibula, locking plate (for internal fixation), and allogeneic bone matrix fused 99% of the time in our experience (12, 13). The fusion rate for the femoral ring allografts remains to be determined. Whether the corrugation of the two sides of the graft can reduce extrusion without internal fixation is unknown and must be studied. The system is very easy to use and eliminates the need for graft-cutting with a drill bit. The main disadvantage is cost, especially if a multilevel fusion is being considered. A 4-cm fibula graft costs $350.00, a cutting bit costs $80.00, and 15 minutes of operating room time costs $166.00, whereas a single femoral ring graft costs $620.00. The difference in cost is approximately $24 for single-level fusions, but the difference would be $500.00 or more for multilevel fusions. In conclusion, the system is safe and easy to use. Although the cadaveric femoral ring grafts should behave biologically like cadaveric fibula, only long-term follow-up monitoring can establish the true fusion rate.

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REFERENCES

1. An HS, Simpson JM, Glover JM, Stephany J: Comparison between allograft plus demineralized bone matrix versus autograft in anterior cervical fusion: A prospective multicenter study. **Spine** 20:2211–2216, 1995.
2. Bell G, Dunbar O, Beck J, Gibb A: Variations in strength of vertebrae with age and their relation to osteoporosis. **Calcif Tissue Res** 1:75–86, 1967.
3. Bishop RC, Moore KA, Hadley MN: Anterior cervical interbody fusion using autogeneic and allogenic bone graft substrate: A prospective comparative analysis. **J Neurosurg** 85:206–210, 1996.
4. Brown MD, Malinin TI, Davis PB: A roentgenographic evaluation of frozen allografts versus autografts in anterior cervical spine fusions. **Clin Orthop** 119:231–236, 1976.
5. Currey JD: The effect of porosity and mineral content on the Young's modulus of elasticity of compact bone. **J Biomech** 21:131–139, 1988.
6. Espersen JO, Buhl M, Eriksen EF, Fode K, Klaerke A, Kroyer L, Lindberg H, Madsen CB, Strange P, Wohlert L: Treatment of cervical disc disease using Cloward's technique: General results, effect of different operative methods and complications in 1,106 patients. **Acta Neurochir (Wien)** 70:97–114, 1984.
7. Gore DR, Sepic SB, Gardner GM, Murray MP: Neck pain: A long-term follow-up of 205 patients. **Spine** 12:1–5, 1987.
8. Hanley EN, Harvell JC Jr, Shapiro DE, Kraus DR: Use of allograft bone in cervical spine surgery. **Semin Spine Surg** 1:262–270, 1989.
9. Martin GJ Jr, Haid RW Jr, MacMillian M, Rodts GE Jr, Berkman R: Anterior cervical discectomy with freeze-dried fibula allograft: Overview of 317 cases and literature review. **Spine** 24:852–858, 1999.
10. Rapoff AJ, O'Brien TJ, Ghanayem AJ, Heisey DM, Zdeblick TA: Anterior cervical graft and plate load sharing. **J Spinal Disord** 12:45–49, 1999.
11. Rockoff S, Sweet E, Bleustein J: The relative contribution of trabecular and cortical bone to the strength of human lumbar vertebrae. **Calcif Tissue Res** 3:163–175, 1969.
12. Shapiro S: Banked fibula and the locking cervical plate in anterior cervical fusions following cervical discectomy. **J Neurosurg** 84:161–165, 1996.
13. Shapiro S: Banked fibula, the locking anterior cervical plate, and allogeneic bone matrix in anterior cervical fusions following cervical discectomy, in Rengachary S, Wilkins R (eds): *Neurosurgical Operative Atlas*. Park Ridge, AANS, 1996, vol 5, pp 233–239.
14. Wittenberg RH, Moeller J, Shea M, White AA III, Hayes WC: Compressive strength of autologous and allogenous bone grafts for thoracolumbar and cervical spine fusion. **Spine** 15:1073–1078, 1990.

COMMENTS

Shapiro and Bindal have introduced an intriguing strategy for fusion after anterior cervical discectomy. Although this strategy seems appropriate from a biomechanical and technical perspective, it is expensive (including the costs of the plate, allograft, and demineralized bone matrix). The cost, compared with the cost associated with 15 minutes of operating time, does not justify this strategy on the basis of cost-effectiveness. Finally, the fusion achieved with this strategy might be expected to be suboptimal, because of stress shielding and the allogenic nature of the graft material, as well as the poor surface area of contact between the graft and the endplate. The latter statement is based on the flat surface characteristics of the allograft and the elliptical shape of most endplates. This is confirmed by postoperative x-rays (obtained at 6 wk), in which gaps are observed at both the rostral and caudal ends of the allograft, at the allograft endplate junction (*Fig. 3*). Clinical follow-up monitoring of this technique is clearly necessary to assess its true utility.

Edward C. Benzel
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Shapiro and Bindal describe a new, commercially available, anterior cervical interbody allograft system. This system provides a mechanized, color-coded, reproducible method of accurately preparing and placing "premachined" anterior interbody allografts. The additional cost of the system described by the authors must be balanced against the cost savings associated with improved efficiency and decreased operating times. There is a presumption that the clinical and radiological results will be similar to those achieved by the authors with the use of fibular allografts; this must be confirmed with a follow-up report. It should be noted that premachined anterior interbody allografts are not new or uniquely available; however, this is the first system of which I am aware that mechanizes a set of steps to prepare, measure, and place the allografts with reproducible precision.

Stephen Papadopoulos
Ann Arbor, Michigan

The authors describe a set of femoral ring allografts, including the allografts themselves and color-coded graft-sizers used for anterior cervical interbody fusion. We have used this system for more than 1 year and find it extremely easy to use. It reduces operating room time, but it is also somewhat expensive. Furthermore, we frequently run out of the commonly used sizes. When we roughen the adjacent cortical bone, we place the shavings of the endplate in the allograft, which might contribute to better fusion. Overall, I think this is a good system, and the decreased operating room time may offset its additional expense.

Volker K.H. Sonntag
Phoenix, Arizona

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