Harvesting Bone Graft From the Olecranon: A Quantitative and Biomechanical Comparison of Proximal and Dorsal Cortical Windows

Matthew C. Anderson, MD, Alexander C.M. Chong, MSAE, MSME, George L. Lucas, MD, Peter J. Czuwala, MSBE, and Paul H. Wooley, PhD

Abstract

We conducted a study to compare 2 techniques of harvesting ulna bone graft from the olecranon, one using a proximal cortical window (PCW), the other using a dorsal cortical window (DCW), in terms of cancellous bone graft quantity and ulna fracture strength after graft harvest.

Cancellous bone was harvested from 8 pairs of embalmed cadaver proximal ulna. Each side of a matched pair was randomly assigned to graft harvest using either a PCW or a DCW approach. Packed bone volume (PBV) was determined by placing the harvested bone into a 3-mL syringe and compacting it with a quasi-static 25-N load. Biomechanical cantilever bending was performed

on each elbow to determine load at failure (LF). Paired Student *t* tests were used to compare PBV and LF between the experimental and control groups.

The graft PBV obtained from the matched-pair specimens was not statistically different between the PCW and DCW approaches. Ulnas subjected to proximal bone harvest exhibited higher LF than ulnas subjected to dorsal bone harvest, though the difference was not statistically significant.

Compared with bone graft harvest using the traditional DCW approach, harvest using a PCW approach provides similar cancellous graft amounts and exhibits similar fracture resistance.

Although there are many commercially available bone graft substitutes, autologous bone graft remains the material most commonly used to replace deficient bone or augment healing.[1] Numerous sites, including the iliac crest, the olecranon, the distal radius, the fibula, and the proximal ulna, have been used to harvest bone for grafting.[2-5] The most common bone graft harvest site is the anterior iliac crest, which provides a larger volume of available graft material; however, the procedure requires a general anesthetic and preparation of a second surgical site.[2] Donor-site complications of the iliac crest procedure are well documented,[3-5] and patients may have difficulty ambulating when grafts are taken in conjunction with outpatient procedures.[2]

The distal radius is often used as a local source of cancellous bone graft for surgical procedures of the hand and wrist.[2,3,6,7] Both the distal radius and the olecranon have been shown to provide similar volumes of packed cancellous bone, and, in cases in which the distal radius is not available, such as with distal radius fractures, the olecranon is a viable option for local bone graft.[2] Proximal ulna cortical and cancellous bone grafts traditionally have been harvested through a dorsal cortical window (DCW).[2,8-10] However, the DCW is located on the path of most transverse olecranon fractures, and this type of fracture is a common injury of the proximal ulna. Several pathologic transverse olecranon fractures occurring after dorsal graft harvesting have been reported.[8] Nonetheless, having a local source of cancellous bone graft allows use of regional anesthetic techniques and avoids potential morbidities of a distant surgical site. To our knowledge, no biomechanical studies have compared the proximal cortical window (PCW) technique as an alternative to the DCW technique for cancellous bone graft harvest at the olecranon.
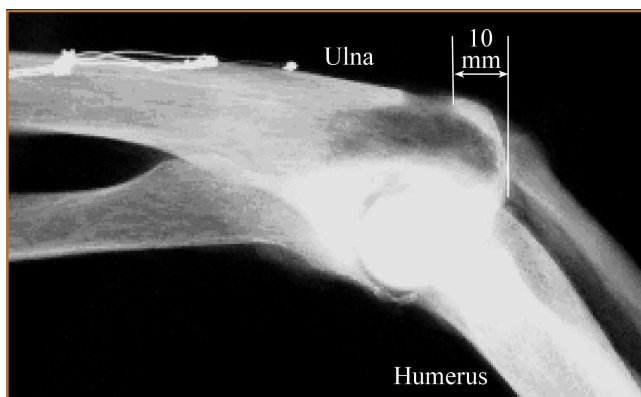
Figure 1. Radiograph of graft harvest through dorsal cortical window.

Figure 2. Radiograph of graft harvest through proximal cortical window.

We conducted a study to determine when harvested ulna bone is stronger, after using the PCW technique or after using the DCW technique, and to determine whether the techniques produced equivalent volumes of cancellous bone graft.

Materials and Methods

This investigation was performed at the Orthopaedic Research Institute in Wichita, Kansas.

Specimen Preparation

Eight pairs of embalmed cadaveric upper extremities (4 male, 4 female; unknown age) were used in this study. All specimens were radiographed to rule out any osseous abnormalities before preparing each specimen for graft harvest. One elbow from each matched pair was randomly assigned to bone graft harvest through a DCW, and the opposite elbow of each pair was assigned to harvest through a PCW. The skin and subcutaneous tissues of each specimen were removed, preserving the triceps tendon, the joint capsule, and the collateral ligaments.

The bone graft harvesting technique was standardized to simulate the clinical setting.[11,12] A trephine 10 mm in diameter was used to create a cortical window, with the border of the trephine placed either 10 mm distal to the tip of the ulna (DCW technique) or 5 mm volar to the tip (PCW technique). For the DCW technique (Figure 1), a longitudinal incision, creating an area of exposed cortex just large enough to accommodate the trephine, was made in the cortex starting 10 mm distal to the tip of the ulna.

For the PCW technique (Figure 2), a split of about 25 mm in length was made in the distal triceps tendon to gain access to the proximal ulna; this approach is similar to that used to place an intramedullary rod.[13] An area of exposed cortex just large enough to accommodate the trephine was created on the proximal ulna. After bone graft harvest, the triceps tendon was repaired using Ethibond size 0 sutures (Ethicon, Cincinnati, Ohio).
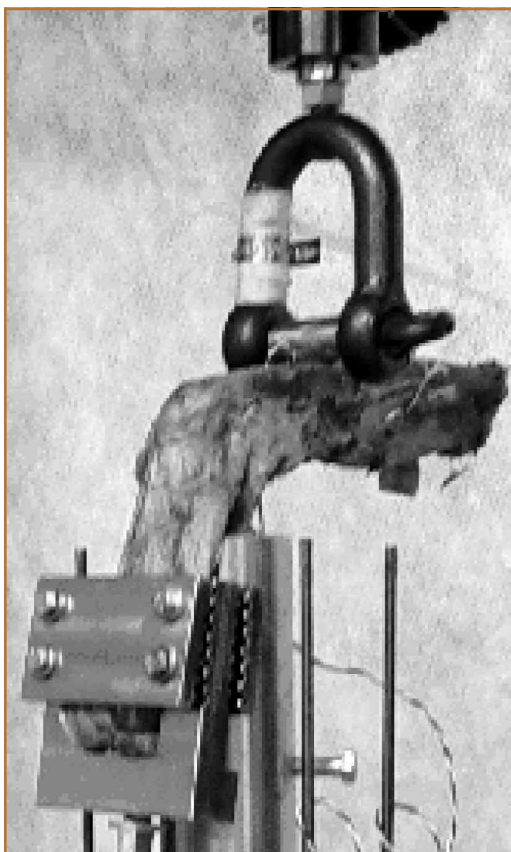
In each specimen, all available cancellous bone from the olecranon was harvested using straight and curved curettes (Codman 23-1046/56; Codman & Shurtleff, Randolph, Massachusetts), taking care not to violate the cortex. Radiographs of the harvested specimens confirmed there was no violation of the cortex at the harvest area.
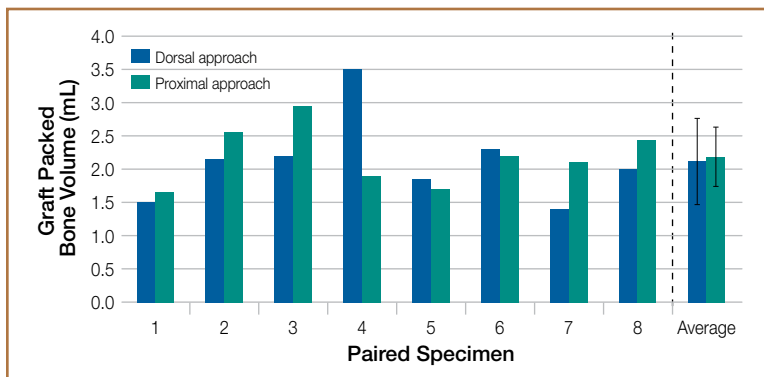
Quantitative Analysis

The volume of harvested cancellous bone graft was quantitatively determined using a modified version of the packed bone volume (PBV) and finger-packed-volume techniques described by Bruno and colleagues[2] and Lindberg and colleagues,[14] respectively. The harvested bone from each specimen (including the morselized cortical window) was placed into a separate 3-mL syringe. A load of 25 N was calculated to simulate maximum thumb pressure on the syringe plunger. For accurate and consistent reproduction of the load used, each syringe was mounted on a servohydraulic materials testing system (MTS 858; MTS Systems, Eden Prairie, Minnesota), and a compaction load of 25 N was applied to the plunger at a rate of 1 N/s. Once the maximum compaction load of 25 N was reached, it was held constant for 3 seconds, and then PBV was recorded. This packing allowed an analysis independent from geometry and intertrabecular spaces of the graft and provided a reliable method of measurement.[14]

Biomechanical Setup and Testing

For determination of ulna bone strength after bone graft harvest, the humerus was proximally locked with exposed length of 4 cm measured from the epicondyle in a custom-designed holding fixture with Bondo-Glass Fiberglass Reinforced Filler (Dynatron/Bondo, Atlanta, Georgia). The holding fixture was positioned and secured on the base of an Instron 4204 testing machine (Instron, Canton, Massachusetts) with the arm inverted. The moment arm was determined for each specimen by measuring the distance from the center of rotation of the elbow to the point on the ulna shaft where the crosshead applied the vertical load, at about 60 mm with the arm flexion angle of 90° as measured by goniometer. The triceps tendon was placed and secured within another custom-designed tissue clamp, which was designed to adjust the elbow flexion angle. The triceps tendon formed an angle of about 18° relative to the long axis of the potted humerus. This experimental setup was similar to the setup described by Prayson and colleagues[15] (Figure 3).

Figure 4. Graph depicting packed bone volume of harvested graft from each matched-pair specimen.

Figure 3. Experimental setup depicting specimen in jig mounted on materials testing system (Instron 4204; Instron, Canton, Massachusetts).
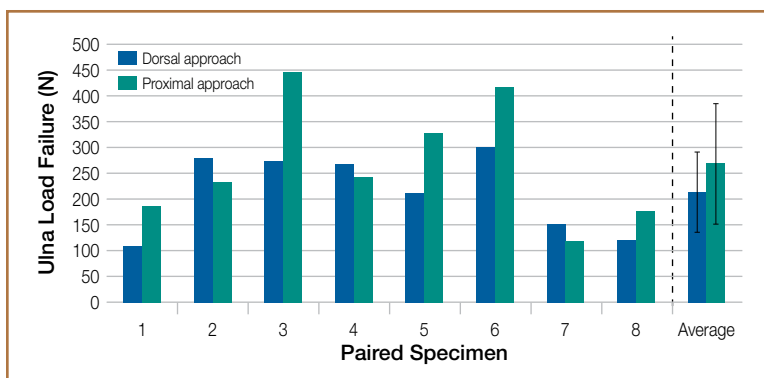
Figure 5. Graph indicating ulna load at failure for each matched-pair specimen.

Any frictional effects during loading were minimized by applying white petroleum jelly (Equate; Vi-Jon Laboratories, St. Louis, Missouri) to the dorsal ulna at the point of load application. Load data were collected while quasi-static loading was applied continuously to the ulna at a crosshead displacement rate of 60 mm/min until failure.

Statistical Methods

Paired *t* tests were used to statistically evaluate the difference between the experimental and control groups with respect to harvested graft PBV and ulna load at failure (LF). Significance was set at $P < .05$.

Results

Mean (SD) PBV of the graft harvested by the DCW approach and the PCW approach was 2.1 (0.6) mL (range, 1.4-3.5 mL) and 2.2 (0.4) mL (range, 1.7-3.0 mL), respectively (**Figure 4**). Overall, these 2 approaches exhibited no statistically significant difference in PBV. Mean (SD) LF was 213 (78) N (range, 107-298 N) for the DCW approach and 268 (117) N (range, 118-444 N) for the PCW approach (**Figure 5**). The difference in LF for matched-pair specimens was 55.1 (81) N. Comparison of these 2 means and the differences in LF revealed that, though the ulnas subjected to proximal bone harvest had higher LF than

ulnas subjected to dorsal bone harvest, there was no statistically significant difference between the 2 approaches. Therefore, the data suggest that the DCW and PCW approaches are essentially equivalent for the parameters under investigation.

Discussion

We measured volume of cancellous bone graft obtained and ulna bone strength after bone graft harvest from either a PCW or a DCW using an embalmed cadaveric model. Our results indicated that, compared with harvest through the DCW, harvest through the PCW produced a similar amount of cancellous graft and equivalent ulna bone strength. Graft harvest from the proximal ulna provides the benefits of using autogenous cancellous graft while avoiding the potential morbidity associated with use of a general anesthetic or a second surgical site. The primary disadvantage of bone graft harvesting from the olecranon is the limited amount of local bone graft available, roughly half that available from the iliac crest, according to Bruno and colleagues.[2] However, the amount of harvested bone graft is usually sufficient for operative procedures of the hand and wrist.[6,7] There are concerns of local complications associated with graft harvest through a PCW. These complications may include triceps tendonitis, bursitis, growth plate injury in skeletally immature patients, and ulnar nerve injury.

In the present study, all specimens failed through the proximal ulna, and there were no triceps tendon avulsions. The surgical approach used for a PCW resembles that used to place an intramedullary nail. Although the PCW allowed for placement of curettes farther distally into the shaft of the ulna, the quality and quantity of bone distal to the coronoid rapidly decreased in these specimens. Placement of a PCW avoids the residual stress riser on the tensile cortex of the ulna.

Previously, cancellous bone graft was quantitatively determined by PBV analysis with 10-mL syringes and maximum thumb pressure applied on the plunger. Bruno and colleagues[2] used the PBV method in applying a uniform load of 40 N, which they selected based on their preliminary trials of finger packing on 10-mL syringes. In our study, we used 3-mL syringes because of the better precision in measuring PBV from the olecranon. From our preliminary trials, maximum thumb pressure on the 3-mL syringe plunger was 25 N. However, the pressure exerted on the harvested bone in a 3-mL syringe was about twice that exerted on the harvested bone in a 10-mL syringe, because of the smaller cross-sectional area of the 3-mL syringe. This higher pressure could have resulted in our PBV values being smaller than those reported by Bruno and colleagues.[2]

Our study had its limitations, including, in particular, use of embalmed cadaveric bones. Calabrisi and Smith,[16] however, found similar compressive strengths for preserved and unpreserved human bone, and other studies have reported that the maximum loading capacities and ultimate tensile strengths of bovine[17,18] and feline[19] bones were not significantly affected by embalming. The relative amounts of harvested bone graft in the embalmed cadaveric bones might be smaller than those from either fresh cadaveric bones or in vivo. In their study of 16 fixed cadavers (age range, 59 to 98 years), Bruno and colleagues[2] found 2.8 (0.7) mL (range, 1.90-4.35 mL) of PBV from the olecranon—similar to our amount, 2.2 (0.5) mL (range, 1.4-3.5 mL). Another limitation of our study is the unknown age of the cadaveric specimen, as the actual volume of bone in vivo may be more than our measured volume, particularly in younger patients without osteopenia. Finally, our study was limited to 8 paired elbows. A larger study, using more cadaveric bones and varying bone density, may more clearly demonstrate differences between these 2 bone graft harvesting techniques.

Despite these limitations, we think meaningful information can be extracted from this study. Our findings indicate that the PCW is an alternative approach to the olecranon as a method of bone graft harvesting in the proximal ulna. This information may be useful when planning cancellous bone harvesting from this site.

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Dr. Anderson is Hand Surgeon, Sanford Orthopedics and Sports Medicine, Sioux Falls, South Dakota. He was a resident at time of writing. Mr. Chong is Research Engineer, Orthopaedic Research Institute, Via-Christi Health, Wichita, Kansas, and Teaching Associate, Department of Orthopaedics Surgery, University of Kansas School of Medicine-Wichita, Wichita, Kansas. Dr. Lucas is Associate Professor, Department of Orthopaedics Surgery, University of Kansas School of Medicine-Wichita, Wichita, Kansas. Mr. Czuwala was Research Engineer, Orthopaedic Research Institute, Via-Christi Health, Wichita, Kansas. Dr. Wooley is Research Director, Orthopaedic Research Institute, Via-Christi Health, Wichita, Kansas; Professor, Department of Orthopaedics Surgery, University of Kansas School of Medicine-Wichita, Wichita, Kansas; and Chief Scientific Officer, CIBOR, Wichita, Kansas.

Address correspondence to: Alexander C.M. Chong, MSAE, MSME, Orthopaedic Research Institute, Via-Christi Health, 929 N St. Francis St, Wichita, KS 67214 (tel, 316-268-5462; fax, 316-291-4998; e-mail, alexander.chong@viachristi.org).

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This paper will be judged for the Resident Writer's Award.