Introduction  Allograft bone use is steadily increasing for joint reconstruction, tumor resection, spine fusion, and fracture care [1]. Cortical strut allografts are used in reconstructive orthopaedic surgery for immediate structural support and biologic reconstitution of bone in the recipient skeleton [2]. Varying procurement and preservation strategies have been developed to provide sufficient bone that is safe for these surgical applications. Prior research has evaluated the effects of the preservation process on the biomechanical properties of cortical bone [3], however no one has focused on the harvest process itself. There is a deficiency of information on the intrinsic strength of strut grafts as well as the variability that may exist between different donors. This study investigated the strength of human femoral cortical strut allografts harvested from matched pairs of femurs and compared the biomechanical properties of struts between donors.

Materials and Methods  Eight matched pairs of human femurs were stored frozen at –60 degrees Celsius. Soft tissue and periosteum were removed prior to freezing. Specimens were transferred to a 20 degree Fahrenheit freezer and allowed to equilibrate before thawing at room temperature. Prior to testing, bone densitometry was performed with a Hologic QDR-4500A on all femurs. One femur of each matched pair was randomly allocated to bending and the other to torsion.

Using prefabricated acetate templates, cortical struts were harvested (using an oscillating saw) from the anterior and posterior sides of the diaphysis of each femur. The bending group had 10 x 2 cm struts harvested, two from the anterior side and two from the posterior side. The torsion group had 18.8 x 2 cm struts harvested to allow for a potted length of 10 cm, one from the anterior side and one from the posterior side. Digital calipers and an autopsy saw were used to trim each specimen to the appropriate dimensions. Strut dimensions were measured with a digital caliper to determine exact length, width, height, and thickness at three points on the strut. Torsional specimens were potted with 2” PVC pipe and polymethylmethacrylate.

All specimens were thawed for one hour prior to mounting and testing on a 1321 servohydraulic Instron machine (Canton, MA). Bending specimens were mounted on supports 50.8 mm apart and tested in three point bending at 0.5 mm/second. Torsion struts were mounted with predrilled screws and tested in torsion at 45 degrees/second. All struts were tested to failure defined as visible breaking correlating with the peak value on the Instron. Peak force, deflection, stiffness, and energy at failure were determined for the struts. A comparison was performed for anterior vs. posterior and proximal vs. distal struts tested in bending using a 2 way ANOVA. An analysis was made of anterior vs. posterior struts tested in torsion using a paired student’s t-test. For all tests significance was set at p<0.05.

Results  In the bending group, there were significant differences in the peak force and energy at failure between the anterior and the posterior struts. [Figure 1] The mean force at failure for the posterior struts was 2964.8 N while the mean for the anterior struts was 2044.8 N (p<0.001). The energy at failure for posterior struts averaged 3.0 N-m while that for the anterior struts was 2.0 N-m (p<0.001). There was no significant difference detected for stiffness or displacement between anterior and posterior struts although the trend was for posterior struts to be more stiff. There was no difference detected in any measure when comparing proximal and distal struts. The range of strengths found for the struts in three-point bending was 1281.3 to 4148.6 N.

In the torsion group, significant differences were found in peak torque at failure and stiffness when comparing anterior and posterior struts. [Figure 2] No difference was determined for displacement or energy absorbed prior to failure between anterior and posterior struts. The mean torque for posterior struts was 23.7 N-m in comparison with 20.0 N-m for anterior struts with p<0.04. Stiffness averaged 62.9 N-m/rad for posterior struts and 45.3 N-m/rad for anterior struts with p<0.01. The strength in torsion for these struts ranged from 11.8 to 38.3 N-m.

Dexa scan values of the femoral necks ranged from 0.79 to 1.13 gm/cm² for the bending femurs and from 0.80 to 1.15 gm/cm² for the torsion femurs. In evaluating strength of struts in relation to bone density of the femoral neck, no clear correlation was found for either bending or torsional specimens.

Discussion  There is a lack of standardization in many aspects of the procurement process that tissue banks currently use in preparation of allograft bone including site of strut harvest, strut dimensions, and age of donors for structural grafts. It is essential for clinicians to know and understand the mechanical properties of cortical struts since they are used for immediate structural support and stability in reconstructive surgery. This study evaluated the intrinsic strength of deep frozen cortical struts from alternative sites on the human femur and compared femurs from different skeletons. The data shows that biomechanical properties of strut grafts vary with anatomic site of harvest and demonstrate that the posterior diaphysis provides struts that are stronger in both three point bending and torsion than the anterior diaphysis. It is further evident that there is considerable variation in strength between struts of the same size from different donors in the population. This study has established strength parameters for cortical struts that will enable surgeons to optimize strut use in their surgical practice.

References

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