Stiffness of Subchondral Bone of Grafts and Defect Site in Osteochondral Repair Influences Stability of Repair

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As an intervention strategy for osteoarthritis (OA), osteochondral autograft/allograft transplantation (OATS) has received good clinical results with a 25% failure rate after long term follow up of 12 years. Age, size of defect, malalignment, and history of surgery are commonly correlated with failure of this intervention. Yet, although the procedure requires interaction of an osteochondral (OC) graft with a patient's debride defect area (host environment), important aspects of this interaction still need to be clearly identified and characterized. Here, we evaluate how changes in stiffness of the OC graft with respect to its host environment affect the dislodging of the graft.

Methods

Fourteen distal femurs were harvested from adult porcine legs (65-100 kg), stripped of muscles and ligaments and cut mid shaft. Eight of the samples were immersed in PBS and imaged with µCT at an isotropic voxel size of 82 µ. All samples were then wrapped in PBS soaked tissue and frozen (-80 °C) before OC graft harvest.

The µ-CT images were scaled to 0–255 greyscale. Cylinders (8mm diameter, 10mm high) of subchondral bone in region where OC grafts were to be harvested were generated using Simpleware ScanIP 7.0. BV/TV was determined for each condyle (n=16: 8 medial, 8 lateral). Samples were then ranked according to BV/TV values.

All samples were thawed and cuboids were cut from each condyle (~2 x 2 x 1 cm^3). OC grafts were extracted from center using 8.5 mm mosaicplasty chisel. Three groups were defined: <u>same-in-same</u> (n=12, from six non-imaged femurs): grafts were replaced in the cube they were harvested from in identical orientation. <u>Stiffer graft</u> (n = 8) and <u>stiffer host</u> (n=8) (from imaged femurs): Samples were paired using BV/TV rank to give the greatest and most consistent difference in stiffness between them by taking the top half and pairing them in consecutive order with those from bottom half. Grafts from each pair were switched and placed into corresponding cube, aligning to be flush with articulating surface. Each sample was then imaged using µCT, scaled and geometries of bone were derived as previously described. Finite Element (FE) models with a tetrahedral mesh were produced using geometry and underlying greyscale which were converted to Young's moduli values using a previously derived linear conversion factor. These models were imported into ABAQUS CAE 2017 and stiffness for each sample was determined through FE simulation.

Each cuboid sample was inverted, with articulating surface facing downward, and secured in an acrylic fixture with four screws. Push-out tests were conducted using an Instron 3365 equipped with a 50 N load cell. All samples were submerged in PBS at 37 C throughout testing and pushed out of host using a 5 mm indentor at a rate of 1 mm/min.

Key data from the force-displacement output were defined: Dislodging/Maximum Force: force required to begin graft movement and maximum; Initial Work/Extended Work: work required to move graft 1 and 2mm respectively. Each parameter was compared to the stiffness of the stiffer component.

Results

<u>Same-in-same</u>: There was a strong positive correlation between increase in stiffness and increase of force or work for: dislodging force (R^2 = 0.6547); max force (R^2 = 0.498); and extended work (R^2 =

0.6025) (Fig 1: A, B, & D). There was also a moderate positive correlation with initial work (R^2 = 0.2176, Fig 1C).

Stiffer Graft & Stiffer Host: For each pairing, the sample with the stiffer host had a greater dislodging force, max force and extended work value than its stiffer graft pair (Fig 1A, B, D-red squares vs. green triangles). However, the initial work values demonstrated no such trend.

Discussion & Conclusions

When the graft was replaced into same host, the strong positive correlation in force to dislodge the graft, maximum force and work required to move the graft 2mm (extended work) indicates that stiffness of the graft plays an important role in initial stability of implanted OC grafts. The stiffer the tissue, the harder it is to dislodge and keep moving out of the defect area.

More importantly, when there is a mismatch of stiffness between graft and defect area the graft's stability within the defect area is affected more severely. When the graft is stiffer, it is easier to dislodge and move whereas when the defect area is stiffer it becomes more difficult.

These findings indicate that un-matched stiffness of the OC grafts and debride defect area are one element which may be responsible for the failure of OATS surgical techniques and donor tissue could be imaged and stratified to provide appropriate allografts for different recipients.