James Dyson Foundation Undergraduate Bursary 2018/19
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Project Report
Surgical Microdrilling for Arthritis Treatment

Arthritis is a disease which results in damage to the cartilage covering the end of the bones in a joint. This causes pain and stiffness. In serious “end stage” cases where the disease has a significant impact on the patient’s quality of life, the usual treatment is arthroplasty (joint replacement). There is, however, a gap in current research for early stage treatment strategies before the disease develops this far. One such treatment option is microfracture which involves forming small holes through the subchondral bone (that is, the bone beneath the cartilage) with a needle. As a result of this surgery, the hole bleeds and a blood clot forms which is rich in stem cells and growth factors which help new cartilage to form. This replaces the cartilage damaged by arthritis.

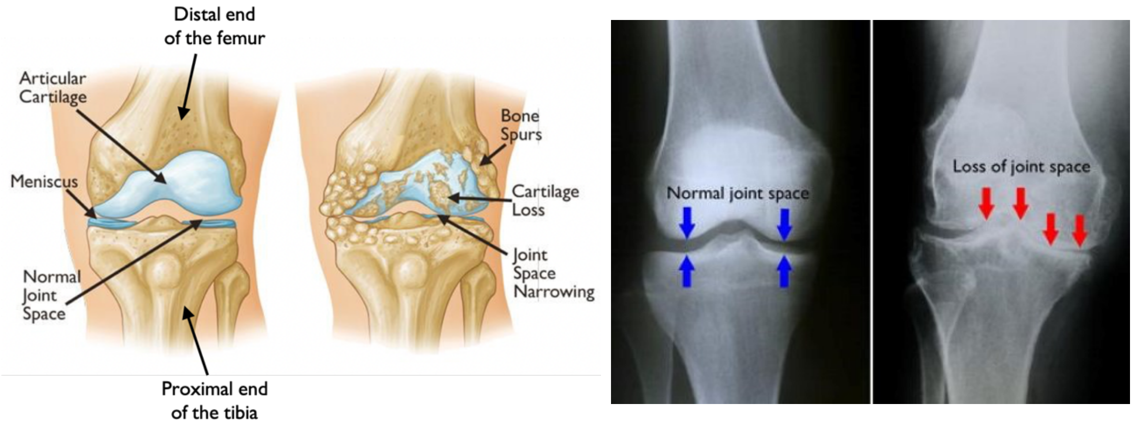

Figure 1 - Anatomy of the knee joint

Microdrilling has been investigated as an alternative to microfracture, where a drill is used to form the holes, rather than a needle. It has been suggested in the research that using a drill makes the holes more accurate in size and location than using a needle. It has also been suggested that these drilled holes are “cleaner”, with less debris remaining from the surgery – this helps new cartilage to form and is hence preferable to microfracture.

This project aimed to further this research by investigating the potential benefits of microdrilling over microfracture. Firstly, an experimental apparatus setup was designed which allowed for the first drilling research of its kind at Addenbrooke’s Hospital Department of Trauma and Orthopaedic Surgery. This provided the equipment setup for later experiments which compared the results of microfracture and microdrilling surgeries. The findings of this project were in agreement with other research that has been done. The depth of the drilled holes were, on average, much closer to the correct intended depth than when the holes were formed by hand using a needle.

Furthermore, we used two methods to compare the cleanness of holes formed by microdrilling with those of microfracture. Both of these methods analysed CT images of the holes, such as those in Figure 2 and 3 below.

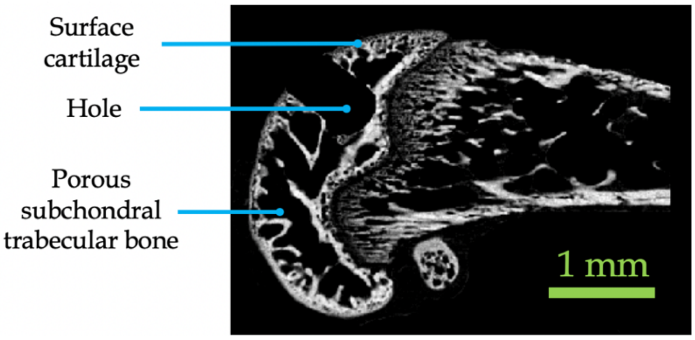

Figure 2 - CT scan of drilled hole at the end of the femur bone

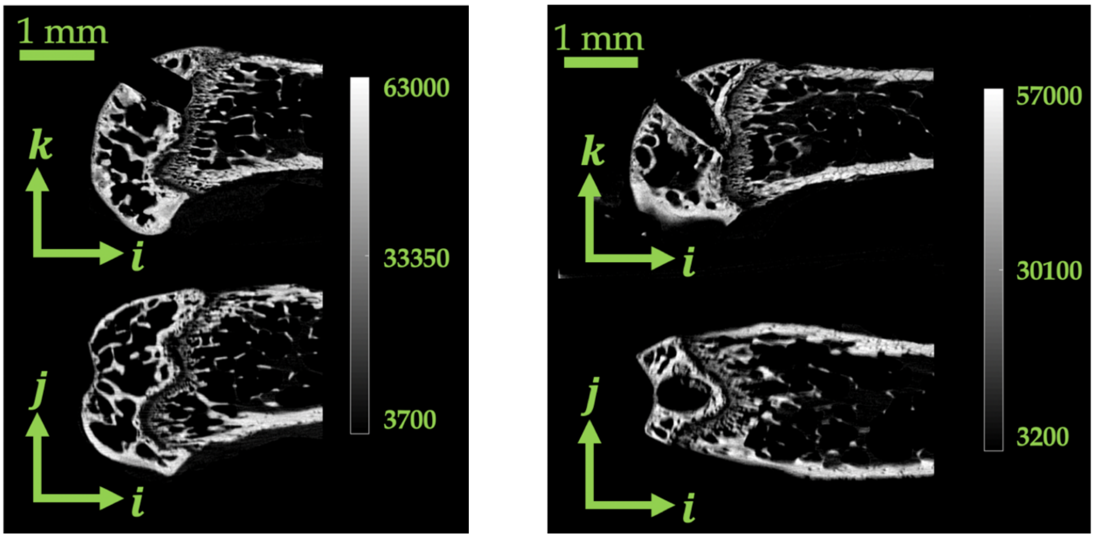

Figure 3 - CT scans of drilled hole (left) and needle hole (right)

By taking a “cut” across the diameter of the hole, we can plot the intensity of the pixels at the top and bottom of the hole (as in Figure 4 below).

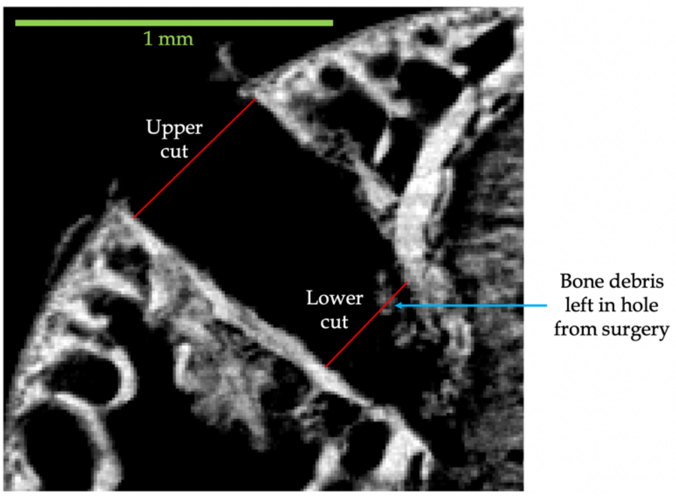

Figure 4 - Cross section of hole formed by needle with upper and lower cuts marked

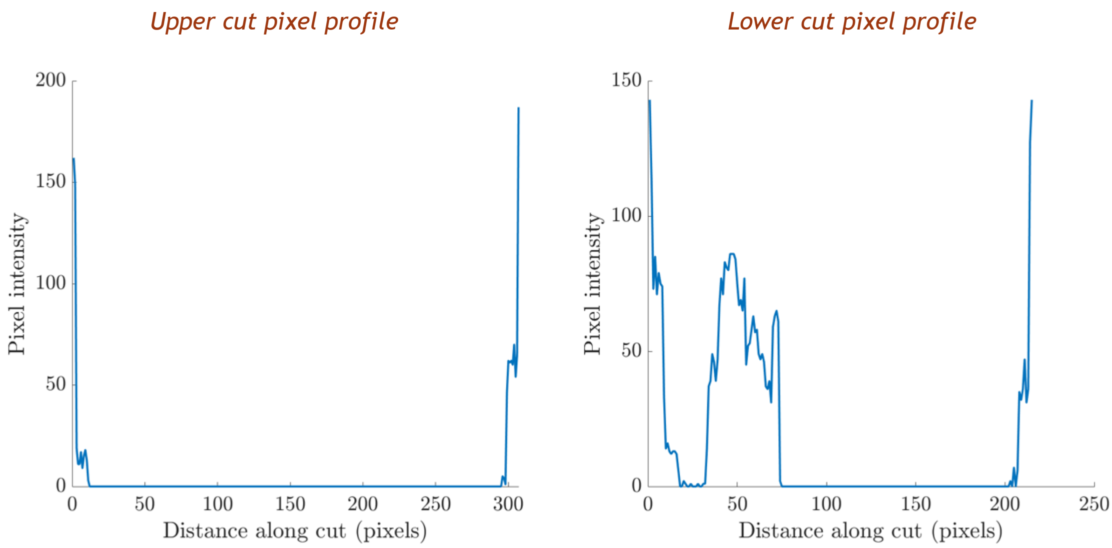

Figure 5 - Pixel intensity profiles along upper and lower cuts of hole

We can see from Figure 4 that the hole is not very clean; there is debris left over from the surgery in the bottom of the hole. This is common for needle (microfracture) holes but not for the drilled holes. This means that the pixel profile across the lower cut of the hole in Figure 5 (right) is not smooth.

The first method to measure cleanness was to see how smooth these lines were – smoother lines mean a cleaner hole with less debris, which is beneficial for new cartilage to form.

The second measure of cleanness was to see how similar the upper and lower diameters of the hole were. We can see from Figure 3 that the drilled holes have much straighter edges which means the upper and lower diameters were much more consistent than with the needle. This is beneficial for cartilage formation since it means there is easier access for blood marrow to form a clot, and hence make new cartilage.

To conclude, this project helped implement a new setup for drilling surgeries to be used at Addenbrooke's Hospital, which will be very useful for future research. We also helped prove the higher accuracy and precision of drilling over microfracture. It is hoped that this research will eventually be used to inform human surgeries in the future.