The use of biodegradable fixation devices in the treatment of osteochondritis dissecans and osteochondral fractures
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The Meniscus Arrow® or metal screw for treatment of Osteochondritis dissecans? In Vitro comparison of their effectiveness.

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ABSTRACT

Three draw bench tests in axial direction were conducted to examine the pull out forces in predrilled human condylar bone of one single Meniscus Arrow, one single metal screw and three Meniscus Arrows in one bone block, the Arrows being inserted using the standard hand instruments. Bone blocks with three Meniscus Arrows were tested additionally in tangential direction, imitating shear forces. All observed values were within the range of 1 standard error (SE) or higher and exceeded the values in meniscal tissue, as reported in the literature. These are much higher than the shear force during a single movement in the human knee. Most metallic devices, used for fixation of the fragments in the treatment of osteochondritis dissecans must be removed in a second operation. Left in place, as with Herbert screws, they can disturb future imaging and damage the opposite cartilage of the tibia plateau. Staples, left in place, can break. Finally, some metals evoke allergic reactions and, at least in animals, are potent carcinogens. Although fusion of osteochondritis dissecans fragments in their original locations, fixed with non compressive biodegradable pins, has been reported, these tests show the hold of compressive meniscus Arrows in bone to contribute to a better result than non-compressive pins. Other biodegradable devices are also available for this application. However, one advantage is that using meniscus Arrows, already available in the hospital for mending ruptured menisci, saves the costs of investing in other sets of instruments and devices. Another advantage is the smaller diameter of the meniscus Arrows than that of other biodegradable devices, resulting in less damage to the fragments.
INTRODUCTION

Several different non metallic devices have been used over the last 5 decades for fragment fixation in the treatment of Osteochondritis Dissecans, like bone pegs or cartilage - bone cylinders or metallic devices like pins, staples or screws in all sort of designs. For several reasons, most metallic devices have to be removed by means of a second operation. Left in place, they cause damage to the opposite cartilage surface of the tibia. Left in place, but imbedded under the cartilage surface, they can disturb future imaging like CT or MRI or, gradually protruding, they cause cartilage damage after all. Chromium, nickel and cobalt are also potent carcinogens in animals. This stimulated the research for biodegradable devices that, once inserted, do not have to be removed after consolidation of the fragment. Three biodegradable polymers; polydioxanon, polyglycolic acid and polylactic acid and their co-polymers, combinations or blends, are used for this purpose. However, both synovitis and sterile inflammatory sinus formation are reported when using polyglycolic acid and polylactic acid devices.

Although good results with only biodegradable pins as fixation devices have been reported, stable fixation with compression screws contributes to a better healing of the reinserted fragment, especially in adults, probably because it neutralizes both shear and disrupting forces. The disadvantage of pins is that no substantial compressive hold can be applied.

Meniscus Arrows® (M.A.’s, Bionix Implants Ltd Tampere, Finland), have been in use for several years ago and are to mend ruptures in the vascularised part of the meniscus. They consist of a biodegradable polylactic acid copolymer, have a smaller diameter (1.1 mm) than the smallest biodegradable screws (2.0 mm) or nails (1.5 mm; Smart Nail®, Bionix Implants Ltd Tampere, Finland) and can be inserted arthroscopically. Since they are already available in the hospital, their use obviates the purchase of further sets of instruments. For these reasons, they could become the preferable fixation devices for treatment of osteochondritis dissecans if they could provide sufficient stable hold in bone. The aim of this study, with a view to the application as fixation devices for the treatment of osteochondritis dissecans, was to test the hold in bone of the Arrows and compare this to the hold of screws with a diameter of 2 mm (Figure 1).

Figure 1: The 2 devices tested:
on top the A.O. screw with a diameter of 2 mm and a length of 15 mm
below the Meniscus Arrow® with a length of 16 mm
(see for color image: page 141)
MATERIALS AND METHODS

Fresh frozen and thawed human condyles were clamped in an Instron 1195 draw bench materials testing device. The load cell measured 1000N maximum, with a scale set at 0 – 200N for the Arrows and at 0 – 500 for the screws, with a time scale of 0 – 600 sec. The extraction speed was 5 mm / min. A drill with a diameter of 1.0 mm was used to create the holes, using a template measuring 20 x 20mm (Figure 2). The Arrows were carefully inserted with a small hammer using the standard hand instruments.

![Figure 2: Standardizing the drill holes, using a template](image)

Three times a single Arrow with a length of 16 mm was pulled out of the bone in an axial direction (Figures 3,4).

Twice a single Arrow after extraction as described above was re-inserted in the original holes, to test the pull out force of the damaged Arrow.

Three bone blocks were prepared. The blocks were 3 mm thick. Each bone block was fixed with 3 new Arrows on its original location and pulled out of the bone in an axial direction (Figure 5). Three times this was performed with new blocks and Arrows in a direction parallel to the joint surface, thus applying a shear force on the devices (Figures 6,7). As an additional test, in one case the bone block, with still macroscopically intact Arrows, was refixed and subsequently pulled off again in the same direction (Ars 11).

Finally, 3 metal screws (Synthes, Switzerland) with a diameter of 2 mm and a length of 15 mm were, successively, pulled out of the bone in the same way as the single Arrow.
Figure 3: One Meniscus Arrow®, put through a hole in a metal loop, inserted in the condyle, to be pulled out.
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Figure 5: One bone block, fixed with 3 Meniscus Arrows®, with 3 metal loops between block and condylar bone, to be pulled off.

Figure 6: The shear force testing. One bone block, fixed with 3 Meniscus Arrows®, with 3 metal loops between block and condylar bone, to be pulled off.
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RESULTS

The results are presented in Table 1; the Standard Error formula was used to evaluate the results. The extraction force of a single Arrow ranged between 59N and 78N, with an average of 68N. The average extraction force of the bone block, fixed with 3 Arrows ranged for the axial direction between 108N and 148N, with an average of 122N. In tangential direction the respective values were 115N and 128N, with an average of 121N. The axial extraction of the single screws resulted in values between 162N and 334N, with an average of 232N. Axial extraction of 2 of the 3 bone blocks after reinsertion in the previous holes of the 3 Arrows, apparently minimally damaged, produced values between 44N and 55N. After the same procedure with one bone block in tangential direction 102N was noted. The intermittent tensioning and retensioning of the system causes the sawtooth like pattern in Figures 4 and 7. When the Arrow shifts upwards the system unloads itself again. This repeats several times (Figures 4, 7)

DISCUSSION

No findings have yet been published regarding the application of the Arrow in bone. During its 8 years of extensive clinical use only occasional synovitis has been reported after insertion of Arrows for meniscal repair. Several reports have been published regarding the pull-out force of Arrows out of menisci. The mean value of 68N in our tests, exceeds the value reported in literature (53N, 44N and 57N). The values in our series are within the range of ±1 standard error or even higher (table 1). Although the pull-out force, as would be expected, was lower after reinsertion due to
deformation of the barbs, the Arrows still showed a considerable hold in the bone (mean value 50N). The contact surfaces of the motionless joint normally keep a replaced fragment in place by the compressive force arising in the joint due to the ligaments – and muscle action and body weight – as long as it stays in contact with both joint surfaces. If the load is varying during movements or unloading the limb, dislocating micro movements can inhibit the fusion of the fragment when non-compressing pins are used. This could explain the variability in the results when pins are used as fixation devices\(^\text{1,11,13,22}\) and indicates that fixation with compression or stable hold is preferable.\(^\text{2,11,13,19}\)

Biodegradable screws or nails produce larger holes in the fragment having a considerably larger diameter than 1.1mm. They will dissolve slowly\(^4\), due to their larger volume and the characteristics of the biodegradable material, which can lead to erosion on the opposite cartilage of the tibia plateau.\(^\text{1,16,21}\) Furthermore, the quantity of the implanted material in relation to the degradation characteristics of the material may be a factor influencing the clinical manifestation of the foreign body reaction.\(^\text{4,27}\) Shear forces are extremely low in a knee joint; friction coefficients range from 0.005 to 0.023.\(^\text{1,12,14}\) During walking the maximum load on the knee is four times the bodyweight.\(^\text{2,4}\) An estimate of the shear force acting on the fragment during walking can therefore be made as follows. The shear force is equal to the product of the friction coefficient and the maximum compressive load arising in the joint, (= 4 x body weight). Thus for an individual with a body weight of 80 kg the shear force is between 16 and 74 N.\(^\text{1,12,14,24}\)

The shear force of over 100N, measured in our tests of the bone blocks, fixed with three Arrows is much higher than required to dislocate the fragment in one cycle of movement of the human knee in the loaded situation. However, weight bearing, moving and walking impose repetitive strains on the fragment. These strains are not tested here, but should be taken into account in clinical application.

The fragile heads of the Arrows are positioned sufficiently far below the cartilage surface to reduce the risk of damaging the opposite joint surface while moving the joint after consolidation but before degradation of the Arrows (Figure 8). The barbs are the structures of the Arrows mainly responsible for the grip in the tissue. The free space of the shaft between the head of the Arrow and the first barb (figure 1) measures 6mm. This implicates that the thickness of the bony part of the fragment should

| Table 1 |
|-------------------|---|---|---|
| Measurements | 1 | 2 | 3 |
| Single Arrow | 59 | 68 | 78 |
| Bone block (3 Arrows), after reinsertion | 55 | 44 | - |
| Bone block (3 Arrows) | 110 | 148 | 108 |
| Single screw | 162 | 200 | 334 |
| Shear force tests | 115 | 120 | 128 |
| Shear force tests after reinsertion | 102 | - | - |
not exceed 5mm to ensure that all the barbs are at least 1 mm in the recipient bone tunnel. Clinical use of the procedure described above began after completing this biomechanical study.

CONCLUSION

The meniscus Arrows have sufficient initial hold in bone to be used as fixation devices in the treatment of osteochondritis dissecans disease. In the clinical setting prompt reinsertion in the femur condyle can be considered, if meniscus Arrows, already advanced through the fragment in the recipient bony bed, are mistakenly extracted from the condyle during the operation procedure. Because of the repetitive strain on the fixation devices in the clinical situation, temporary immobilisation should be considered to induce the first impulse to consolidation.

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