Quality of scaffold fixation in a human cadaver knee model

Introduction: Cartilage regeneration is moving towards the implementation of one stage procedures and the use of 3D-seeded scaffolds. This is a novel aspect of the surgical technique which requires further evaluation. Comparison of various scaffold fixation techniques has previously been described. However, that study did not include the more sophisticated arthroscopic implantation techniques for 3D-matrices.

The aim of this study is to compare four potential 3D-scaffold fixation techniques in a human cadaver knee model under loaded continuous passive motion.

Materials and Methods: Twenty human cadaver knees were used for this study. A 2 cm³ ellipsoid cartilage defect was created in the weight bearing portion of each medial and lateral femur condyle. Four fixation techniques (Figure 1), fibrin glue (Tissucol®, Baxter), transosseous fixation², biodegradable pin¹ fixation (SmartNail®, ConMed Linvatec) and continuous scaffold sutures (Vicryl®6/0, Ethicon), were randomly assigned to either the medial or lateral femoral condyle to implant a custom-printed porous PEGT/PBT 1000/70/30 scaffold. Following this, the knees were closed in layers and subjected to a loaded (35 N) continuous passive motion protocol in a vertical orientation. After 60 and 150 cycles the knees were opened and the implantation sites photographed for evaluation of the fixation techniques. Evaluation was performed using a modified scoring system focusing on area coverage, outline detachment and scaffold integrity. In addition, an endpoint fixation test was performed after 150 cycles, by using a pulley block system.

Differences in quality of the scaffold fixation techniques, per scoring item, were analyzed for statistical significance by a non-parametric Kruskal-Wallis test followed by a multiple comparison test and Bonferroni correction.

Results: Compared to fibrin glue and biodegradable pin fixation, the transosseous and cartilage suture fixation techniques were very time consuming. Evaluation after 60 and 150 cycles revealed no differences between medial and lateral implantation (data not shown). After 60 cycles, 3 fibrin glue, 2 biodegradable pin fixation and 1 transosseous fixation out of 10 scaffolds were completely detached, whereas scaffolds fixed by cartilage sutures remained stable after 60 and subsequent 150 cycles. If total detachment occurred during the motion cycles, full thickness fissures were observed at the fixation sites for the biodegradable pin and transosseous fixation techniques. Individual evaluation of the different fixation techniques revealed marginal differences for area coverage between the 4 different fixation techniques after both 60 and 150 cycles (Figure 2). Folding of the scaffold at the outline was regularly noticed for the biodegradable pin fixation, whereas the transosseous technique often showed failure of 1 or 2 transosseous sutures. These events mainly determined the outline detachment score for these two techniques. Cartilage sutures seem to provide a good outline attachment after all motion cycles as compared to the other three fixation techniques (Figure 2). The fibrin glue technique scored superior for scaffold integrity compared to transosseous (p<0.05) and cartilage sutures (p=0.01). During application of transosseous, biodegradable pin or cartilage suture fixation, minor scaffold damage was found leading to further disorganization during loaded motion (Figure 2). Endpoint fixation was highest for the cartilage sutures whereas the fibrin glue technique showed a very weak final fixation strength (p=0.01). A comparison of the actual fixation, tested by endpoint fixation, is shown in Figure 3.

Discussion and conclusion: In the present study, four different fixation techniques for a custom-printed PEGT/PBT 1000/70/30 scaffold were compared in human cadaver knee joints in a loaded continuous passive motion protocol. The fibrin glue technique provided excellent protection of scaffold integrity and, if not detached, a good area coverage. However, end point fixation was limited using fibrin glue as a sole fixation method. The biodegradable pin¹ and transosseous suture fixation² are new techniques that can easily be applied during arthroscopy, but the most important problem with these techniques is the scaffold damage created during implantation as outlined by our integrity scores after 60 and 150 cycles. The main limiting factors for successful fixation with these techniques depend on the scaffold properties. Failure of the scaffold at the implantation sites immediately results in failure of the technique. Cartilage sutures already proved to be very efficient for the fixation of collagen fleece assisted autologous chondrocyte implantation. For our scaffold the sutures provided firm endpoint fixation, good area coverage and outline attachment. On the other hand the technique is very time consuming and affects scaffold integrity, initiating further deterioration during motion. This study showed that the quality of 3D matrix fixation is a combination of scaffold properties and mechanical stability of the fixation technique applied. Studies improving scaffold properties devoting special attention to the effect of fixation technique on the scaffold integrity will result in an excellent scaffold fixation for future clinical application.

References:
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