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Katsuji Shimizu

and

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Foreword

Basic research will bring about significant advances in the knowledge, diagnosis, and treatment of musculoskeletal disorders. The purposes of the Combined Meeting of the Orthopaedic Research Societies are to promote, support, develop and encourage research in orthopaedic surgery, musculoskeletal diseases, musculoskeletal injuries and disciplines related thereto.

This issue is based on papers presented at 7th Combined Meeting of the Orthopaedic Research Societies(CORS), which was held at Kyoto International Conference Center, Kyoto, Japan, from October 16 to 20, 2010. We thank most sincerely the prestigious faculty and the participants who brought their data and experience, and who prepared these chapters for publication. Thanks are also due to the Science Council of Japan who is the co-host of this meeting, to our colleagues of nine societies including Japan, Australia/New Zealand, Canada, China, Europe, Korea, Taiwan, UK and USA for their support and advice in planning the meeting.

We hope that the discussions in Kyoto will help us all in planning the directions we should be taking in our future research and in patient care.

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March, 2011

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6th Meeting of the European Federation of National Associations of Orthopaedic Sports Traumatology – EFOST

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Improved Chondrogenic Differentiation of Bone Marrow-Derived Mesenchymal Stromal Cells in a Spongiform Collagenous Scaffold

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Summary

Mesenchymal stromal cells (MSC) are progenitor cells that regenerate mesenchymal tissues. They can be isolated without major obstacles from adult bone marrow, expanded and differentiated *in vitro*, albeit with variable success. We therefore developed an improved method for chondrogenic differentiation of MSC utilizing a chondroitin sulfate-augmented bilayered scaffold specifically approved for autologous chondrocyte implantation in the knee. We report that chondrogenic differentiation of adult bone marrow-derived MSC in this scaffold yielded cells that expressed high levels of type II collagen, even in absence of chondrogenic cytokines, and amplified after addition of TGF-ß. We conclude that this scaffold is an interesting tool to further develop MSC-based cellular therapies for cartilage regeneration.

Introduction

Cartilage has a limited capacity for healing or regeneration. Therefore cell-based therapies were established utilising mature chondrocytes isolated from remote sites of the affected joint (1). However, the availability of suitable autologous chondrocytes is limited. Therefore mesenchymal stromal cells (MSC) were considered to serve for cartilage repair (2, 3). The potential of MSC to differentiate *in vitro* in chondrocytes has been demonstrated (4-7). But MSC undergoing chondrogenic differentiation *in vitro* may display an unfavourable phenotype characterized by an elevated expression of type X collagen, MMP-13, and alkaline phosphatase (8).

To overcome this problems different types scaffolds were introduced for tissue engineering of cartilage (9). A new construct of a collagen type I-based scaffold with a honeycomb-like structure generated by interconnecting pores, enriched by chondroitin sulfate and seeded with chondrocytes is routinely used for ACI (10). We therefore investigated the chondrogenic differentiation potential of MSC in this clinically established scaffold.

Material and Methods

Isolation of human MSC and cell culture

Bone marrow aspirates (n=28, age 45 to 83 years) were obtained from the BGU Center for Traumatology, Tuebingen after approval by the ethics committee of the University of Tuebingen. MSC were prepared, characterized and differentiated as described recently (11-13).

Analysis of gene expression

RNA was extracted from cells (RNeasy Kit, Qiagen) and cDNA was generated (RT for PCR Kit; Clontech) to enumerate gene expression by quantitative RT-PCR (qRT-PCR, LightCycler, Roche) utilizing commercially available primer pairs (SearchLC). The PCRs were evaluated as described (14), and mean values, standard deviations and p values were computed (Excel, GraphPad , ANOVA tests).

Results

Chondrogenic differentiation of MSC was induced by chondrogenic induction medium enriched with TGF-ß in cells seeded in the three-dimensional (=3D) collagenous spongiform scaffold and compared to MSC after chondrogenic differentiation in the same differentiation medium but in culture flasks (Fig. 1). Cells differentiated in the spongiform scaffold revealed a 10^5-fold higher expression of type II collagen ($p<0.05$) compared with cells differentiated in flasks (=2D), but with the same level of expression of type I collagen and IL-1ß. Transcripts encoding IL-6 ($p<0.01$) or MMP-1 ($p<0.01$) were significantly lower in the spongiform scaffold, whereas transcripts encoding MMP-3 were elevated to some extent (Fig. 1).

Next we analyzed the effect of seeding MSC in the scaffold in absence of chondrogenic stimuli and investigated the gene expression patterns of such cells in 3D versus 2D cultures (Fig. 2). In 3D, the expression of type II collagen was elevated

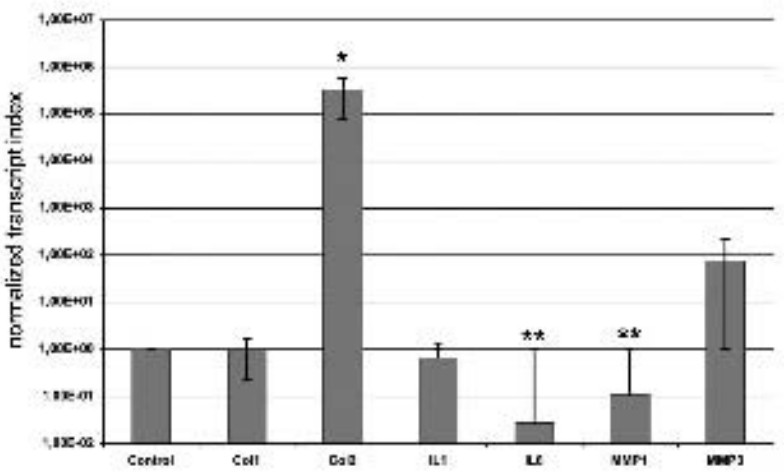

Figure 1: Gene expression in MSC after chondrogenic differentiation in spongiform scaffolds (3D) compared to MSC chondrogenically differentiated in culture flasks (2D).
MSCs were seeded into the 3D spongiform scaffold and incubated in chondrogenic differentiation medium. MSC seeded in cell culture flasks (2D) and incubated in chondrogenic differentiation medium served as controls (n=4 each). The expression of type II collagen was 105-fold improved in MSC differentiated in the 3D culture compared to the cells chondrogenically differentiated in cell culture flasks ($p<0.02$). The expression type I collagen or IL-1 did not differ after chondrogenic differentiation in 3D versus 2D culture, but IL-6 and MMP-1 were reduced significantly ($p<0.01$), and MMP-3 elevated to some extent. MSC prior differentiation served as controls (normalized transcript index = 1).

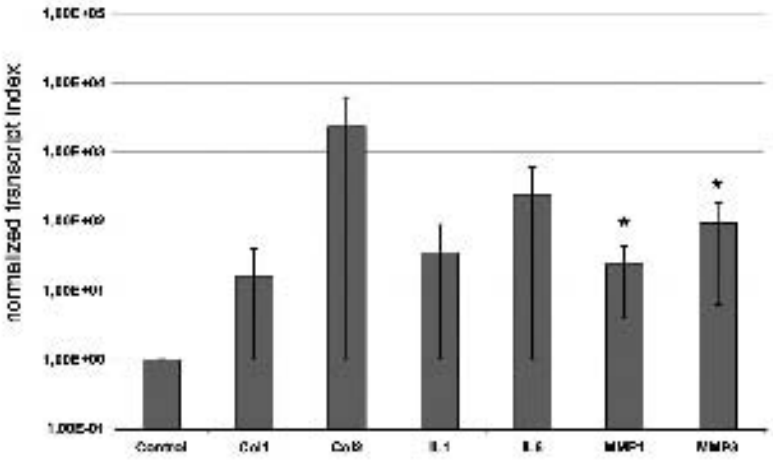

Figure 2: Analysis of gene expression in MSC in the spongiform scaffold versus cells in flasks w/o addition of chondrogenic factors MSCs were seeded into the spongiform scaffold or in flasks in expansion medium (n=4 each). After 3 weeks of inoculation, the expression of marker genes was investigated. The expression of type II collagen is augmented to a variable degree in MSC in the sponge as compared to MSC incubated in flasks. The expression of collagen type I, IL-1ß, and IL-6 are induced to a lesser degree, but MMP-1 and MMP-3 are elevated significantly ($p<0.01$). Founding MSC served as control (normalized transcript index = 1)

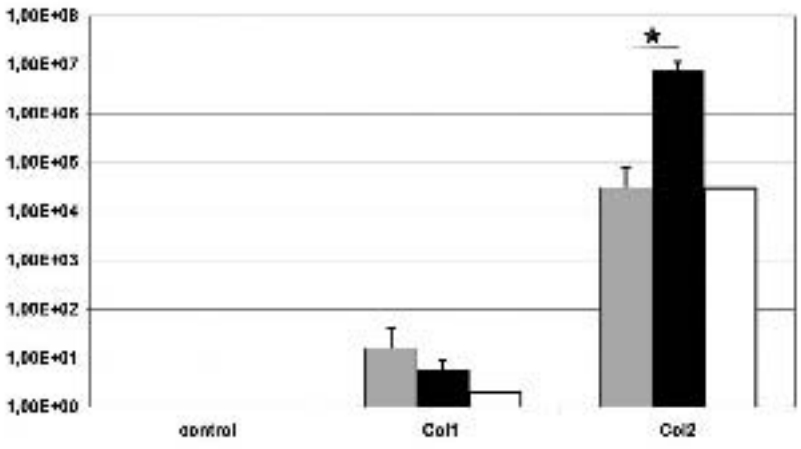

Figure 3: Expression analysis of different markers in chondrogenically differentiated MSCs
MSCs were seeded into the spongiform scaffold (grey bars, n=3) or micromasses (black bars, n=3) and incubated for 3 weeks in chondrogenic differentiation medium. Cells in alginate beads served as standard (white bars, n=1). Expression of type I and type II collagens was investigated by qRT-PCR. Expression of type II collagen was elevated more that 3x104-fold (spongiform scaffold), 7x106-fold (micromasses), and 3x104-fold (alginate) in comparison to cells prior to differentiation, and in micromasses type II collagen mRNA is significantly higher compared to cells in the scaffold ($p<0.031$), with no significant differences in the expression of mRNA encoding type I collagen. MSC prior to differentiation served as controls (normalized transcript index = 1).

approximately 10^3-fold compared to cells cultured in flasks (2D, Fig.2). This suggested that this spongiform scaffold facilitated an elevated expression of type II collagen in absence of soluble chondrogenic factors such as TGF-ß. The expression of type I collagen, IL-1ß, IL-6, MMP-1, and MMP-3 were elevated in 3D culture as well, but to a lower extent compared to type II collagen. The differences in induction of the MMPs reached statistical significance ($p<0.05$, Fig. 2).

For chondrogenic differentiation of MSC, micromass cultures or alginate beads are generally utilized as standard techniques. We therefore explored the expression of type I and type II collagen in MSC chondrogenically differentiated in the spongiform scaffold (n=3), in micromasses (n=3), and in alginate beads (=1) in comparison to MSC prior to differentiation. MSC in the spongiform scaffold, micromasses or alginate beads expressed 10^4 to 10^7- more of type II collagen in comparison to the controls (=1; Fig. 3). In micromasses significantly more type II collagen was observed compared to cells in the spongiform scaffold or alginate beads ($p<0.031$). Compared to controls, expression of type I collagen was elevated in the 3D cultures to some extent (Fig. 3) was not significantly different in the tree culture systems.

Conclusions

We investigated a porous scaffold generated from type I collagen as a carrier for MSC and tested if this material may facilitate chondrogenic differentiation of human MSC. Chondrogenic differentiation of human MSC in the 3D scaffold yielded a si-

gnificantly higher expression of type II collagen compared to MSC undergoing the chondrogenic differentiation in flasks. The induction of chondrogenic marker genes in 2D culture is very weak. For this reason, chondrogenic differentiation of human MSC is routinely performed in 3D systems such as various micromass cultures (5, 12, 15), alginate beads (16, 17), other hydrogels or polar carriers (18, 19).

Our spongiform scaffold appeared to generate a chondrogenic stimulus on MSC even in the absence of soluble chondrogenic stimuli (TGF-ß, dexamethasone, ascorbic acid). In normal expansion medium, the expression of type II collagen mRNA was approximately 1000-fold higher in 3D cultures compared to MSC in flasks (2D). We hypothesize that the closed compartment of the scaffold enabled autocrine stimulation of the cells by preventing a rapid diffusion of such factors into the distant culture medium. This notion is supported by the finding that addition of BMP-2 to chondrocytes enhanced expression of type II collagen significantly in 3D culture systems (20). Although the induction of type II collagen in micromasses was significantly higher compared to cells in alginate or spongiform scaffold, the latter construct is a preferred material for tissue engineering, as it is already approved for clinical use, whereas micromasses and alginate beads have not been established as constructs to treat cartilage defects.

References

1. Brittberg, M., Peterson, L., Sjouml,gren-Jansson, E., Tallheden, T., and Lindahl, A. Articular Cartilage Engineering with Autologous Chondrocyte Transplantation: A Review of Recent Developments. *J Bone Joint Surg Am* 85, 109, 2003.
2. Li, W.-J., Tuli, R., Okafor, C., Derfoul, A., Danielson, K.G., Hall, D.J.,Tuan, R.S. A three-dimensional nanofibrous scaffold for cartilage tissue engineering using human mesenchymal stem cells. *Biomaterials* 26, 599, 2005.
3. Mauck, R.L., Yuan, X., Tuan, R.S. Chondrogenic differentiation and functional maturation of bovine mesenchymal stem cells in long-term agarose culture. *Osteoarthr Cart*14, 179, 2006.
4. Pittenger, M.F., Mackay, A.M., Beck, S.C., Jaiswal, R.K., Douglas, R., Mosca, J.D., Moorman, M.A., Simonetti, D.W., Craig, S., Marshak, D.R. Multilineage potential of adult human mesenchymal stem cells. *Science* 284, 143 1999.
5. Mackay, A.M., Beck, S.C., Murphy, J.M., Barry, F.P., Chichester, C.O., Pittenger, M.F. Chondrogenic Differentiation of Cultured Human Mesenchymal Stem Cells from Marrow. *Tissue Engin* 4, 415, 1998.
6. Awad, H.A., Quinn Wickham, M., Leddy, H.A., Gimble, J.M., Guilak, F. Chondrogenic differentiation of adipose-derived adult stem cells in agarose, alginate, and gelatin scaffolds. *Biomaterials* 25, 3211, 2004.
7. Kavalkovich, K.W., Boynton, R.E., Murphy, J.M., Barry, F. Chondrigenic differentiation of human mesenchymal stem cells within an alginat layer culture system. *In Vitro Cell Develop Biol* 38, 457, 2009.
8. Fackson, M., Dorothy, S., Peter, R., John, A. Limitations of using aggrecan and type X collagen as markers of chondrogenesis in mesenchymal stem cell differentiation. *J Orthop Res* 24, 1791, 2006.
9. Welsch, G.H., Mamisch, T.C., Zak, L., Blanke, M., Olk, A., Marlovits, S., Trattnig, S. Evaluation of cartilage repair tissue after matrix-associated autologous chondrocyte transplantation using a hyaluronic-based or a collagen-based scaffold with morphological MOCART scoring and biochemical T2 mapping: preliminary results. *Am J Sports Med* 38, 934 2010.

10. Marlovits, S., Aldrian, B., Tichy, C., Albrecht, C., Nürnberger, S. Biomaterialien für die autologe Knorpelzelltransplantation. *Orthopäde* 38, 1045, 2009.
11. Felka, T., Schäfer, R., deZwart, P., Aicher, W.K. Animal serum- free differentiation of human mesenchymal stem cells. *Cytotherapy* 12, 143 2010.
12. Felka, T., Schäfer, R., Schewe, B., Benz, K., Aicher, W.K. Hypoxia reduces the inhibitpry effect of IL-1beta on chondrogenic differentiation of FCS-free expanded MSC. *Osteoarthr Cart* 17, 1368 2009.
13. Dominici, M., Le Blanc, K., Mueller, I., Slaper-Cortenbach, I., Marini, F., Krause, D., Deans, R., Keating, A., Prockop, D.,Horwitz, E. Minimal criteria for defining multipotent mesenchymal stromal cells. The International Society for Cellular Therapy position statement. *Cytotherapy* 8, 315, 2006.
14. Rasmussen, R., Morrison, T., Herrmann, M., Wittwer, C. Quantitative PCR by continuous fluorescence monitoring of a double strand dna specific binding dye. *Biochemica* 2, 8 1998.
15. Johnstone, B., Hering, T.M., Caplan, A.I., Goldberg, V.M., Yoo, J.U. In vitro chondrogenesis of bone marrow-derived mesenchymal progenitor cells. *Exp Cell Res* 238, 265, 1998.
16. Yang, I.H., Kim, S.H., Kim, Y.H., Sun, H.J., Kim, S.J., Lee, J.W. Comparison of phenotypic characterization between alginate beads and pellet culture systems as chondrogenic differentiation models for human mesenchymal stem cells. *Yonse Med J* 45, 891 2004.
17. Mehlhorn, A.T., Schmal, H., Kaiser, S., Lepski, G., Finkenzeller, G., Stark, G.B., Südkamp, N.P. Mesenchymal Stem Cells Maintain TGF-ß-Mediated Chondrogenic Phenotype in Alginate Bead Culture. *Tissue Engin* 12, 1393, 2006.
18. Noth, U., Rackwitz, L., Heymer, A., Weber, M., Baumann, B., Steinert, A., Schutze, N., Jakob, F., Eulert, J. Chondrogenic differentiation of human mesenchymal stem cells in collagen type I hydrogels. *J Biomed Mater Res* A 83, 626, 2007.
19. Cho, J.H., Kim, S.-H., Park, K.D., Jung, M.C., Yang, W.I., Han, S.W., Noh, J.Y., Lee, J.W.J.W. Chondrogenic differentiation of human mesenchymal stem cells using a thermosensitive poly(N-isopropylacrylamide) and water-soluble chitosan copolymer. *Biomaterials* 25, 5743, 2004.
20. Grunder, T., Gaissmaier, C., Fritz, J., Stoop, R., Hortschansky, P., Mollenhauer, J., Aicher, W.K. Bone morphogenetic protein (BMP)-2 enhances the expression of type II collagen and aggrecan in chondrocytes embedded in alginate beads. *Osteoarthr Cart* 12, 559, 2004.

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Long term follow -up of cervical hydroxyapatite spacer

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No support was available for this study. IRB approval from AGH, Pittsburgh PA: RC-1611

Summary

This report provides long-term follow-up on a dense form of hydroxyapatite used as a bone graft substitute, as an intervertebral spacer for cervical disc disease. It was shaped to avoid stress concentrations and did not fracture. Extrusion was noted but resolved with improved contouring.

Introduction

The anterior cervical discectomy and fusion with the gold standard of an autologous graft[1, 2] has the most reliable and quite satisfactory results, but is accompanied by a significant incidence of chronic pain at the separate bone graft harvest site, as well as other complications[3]. Allograft has been used to avoid this morbidity but with an increased risk of fracture[4], subsidence, delayed healing[5], late fracture[6] and even allogenic concerns[7]. Alternatives have been considered[8], and among these ceramics, particularly Hydroxyapatite (HA) with well-established biocompatibility, as it is native to bone. This strong material contributes to the structural strength of bone but as a material it is quite brittle. *In vivo*[9, 10] studies established the feasibility of HA, particularly good maintenance of disc height but also reported problems, specifically of extrusion and fracture.

Reported complications of clinical studies include extrusion[11] and radiolucent clear zones and a fracture risk[12], including cord compression by retropulsed fragments. Using an anterior plate with Pro Osteon 200 compared to autograft resulted in a fracture rate of 89% for HA compared to autograft of 11%[13]. An anterior plate may allay some concerns, as a strong form of HA was reported without extrusion or fracture using a plate[14, 15], as well as enclosing HA in a cage [16], but introducing other morbidities and expense. Unfortunately fractures seemed to be almost accepted, recently reported in a strong form of HA (65% HA with 35% TCP) with a plate but still a fracture rate of 25%[17]. A technique using a dense form of HA without a plate was presented[18] as a technique with no fractures in initial follow up, the long-term is reported here.

Materials and methods

A prospective, IRB approved study of HA as a custom implant, was initiated when the index patient had an excellent result with HA. He had a prior allograft fusion subsided into kyphosis and had not returned to work after 18 years until the revision surgery. The technique[18] was by taking a dense block of 96% pure hydroxyapatite, and intraoperatively shaping the implant with a Midas Rex Diamond wheel (WH-1). Aware of the reports of fracture and particularly neurological concerns, the contouring during surgery emphasized matching the implant to the posterior inferior lip of the superior vertebrae to prevent fracture near the canal. The overall intent was to shape the implant to the anatomy of the disc space, as a congruent shape would reduce stress concentrations and maximize appositional area of contact. The HA was gas sterilized with ethylene oxide to prevent heat sensitization, the leading edge tapered to about 4 mm, and maximum body of the implant) height 7 mm, guided by the patient's x-rays.

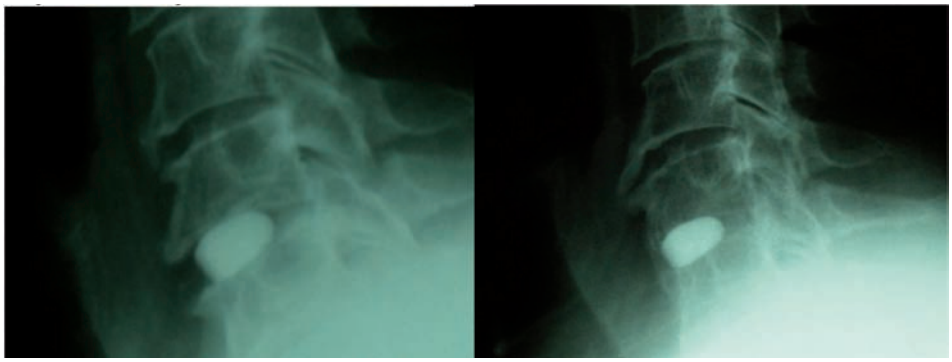
Unfortunately, the initial effort emphasized the posterior shape and sought to gain disc height, but leaving the anterior surface flat to mate with a custom impactor, with a non metallic end which had been designed to ease insertion. Despite early encouraging results, migration and three extrusions occurred in close temporal proximity. One of these occurred after prolonged emesis, another after a fall, but a third occurred without incident, interrupting the study after 16 cases and prompting a redesign of the implant.

Subsequent implants, figure 1, were modified to approximate both the anterior and posterior contours of the intervertebral disc space, which was more in conformity with the stated goals. This was for stability, (as a thumb tack on its head rather than point comes back to its original position when displaced) maximum contact or appositional area, and minimizing stress concentrations. This resulted in the second series of 16 patients which are presented here, along with the "initial design", the first series of 16; in this entire series, no fractures occurred.

Patients in this consecutive series, who were clinically recommended to have an anterior cervical discectomy and fusion, were offered autograft, allograft, or hydroxyapatite. This prospective study was not randomized, unfortunately, only 4 patients selected autograft and one selected allograft during the study. This unselected series had challenging cases, 9 patients had prior surgery: 2 single level which had failed with allograft, 4 failed to fuse a segment adjacent to prior fusion, and 3 had multiple levels allograft procedures with one failed to fuse.

A custom distractor was used with pins in the vertebrae above and below the operated level. The exposed bony endplate was lightly burred[19] (which reportedly increased loss of disc height to 1.9mm and decrease in lordosis from 4.9^0 to 3.1^0) for consistency with allograft and autograft where it is to stimulate osteogenesis, but the dense HA was not expected to have ingrowth, at least not in this implant without porosity. Blood loss was customarily less than measurable, estimated at 15 - 30 cc; all patients were observed overnight and discharged the following day.

Post operatively, a Philadelphia collar was advised full time for 6 weeks. Patient's were followed in the office at 3 and 6 weeks, thereafter as clinically indicated and usually allowed to return to work in 2-3 months, when able or employed. Follow-up was to contact the patient at 2 years for follow-up interview and exam, all were



Captions: Figure 1A: 6 weeks post op; 1B: 7 years post op

available then. The long term at 8 to 10 years was by sending a letter, followed by a telephone call, for interview and offering examination and X-rays when possible. Of those contacted at the long term, 56% were willing to provide follow up results, 35% were lost to follow up or declined to participate and 9% were deceased.

Results:

This study include 32 patients who had an HA implant, operated between 1993 and 1995, for radiculopathy alone in 30 and also myelopathy in 2. The average age was 47 years, 18 were male, 14 female. Patients had flexion - extension lateral x-rays and anterior- posterior movement more than 2 mm was considered an indication for an anterior cervical plate. In the entire series 23 had surgery without internal fixation, 21 at a single level and 2 at two levels. Of the 23 primary procedures (no previous cervical surgery), 17 were done at a single level, 5 at two levels, and one was at three levels. The study included 5 revisions, for problems with the spacer: 2 of the 3 patients with some migration were revised, and the other was clinically excellent and thus not interested. The 3 extrusions were each revised with the initial implant retained and an anterior plate. Also 2 patients went on to have an additional microdiscectomy at an adjacent level without complaint regarding the hydroxyapatite spacer.

Review of patients at 2 years revealed disc height increase of 0.8 mm which was maintained at 2 years, the cervical lordosis at the affected level increased 2.5° after surgery and remained at 2.2° at 2 years. An Odom type scale[20] was used to classify clinical results: no restrictions, no medication as excellent; some pain, no limitations, only OTC medication good; able to do most things, prn medication fair, and either revision or regular prescription medication, activity limited as poor. The initial study had revisions, by definition poor, but all patients had restoration of reflexes and resolution of radiculopathy and myelopathy after their final procedure, so the clinical results for the final design, second series of 16 were 94% good or excellent (1 fair), and the entire series were 75% good or excellent.

While these results in the second series are consistent with literature and satisfactory, particularly in an unselected series with prior failures, there was no donor site morbidity and no fractures. Extrusions were resolved satisfactorily with anterior contouring.

Discussion

This HA feasibility study was limited in numbers as a custom implant, but sought to return to basic biomechanical principles to improve, particularly with regard to fractures of the implant.

The principle problems reported of hydroxyapatite have been extrusion and fracture. The initial part of this study confirms the extrusion problem. Attempting to recess compromised by efforts to maximize the disc height and present a flat surface for my custom impactor. The more fully congruent shape had its maximum implant height more congruent with the disc space, allowing increase in disc height, and the implant was more easily recessed, solving the extrusion problem.

Further, the endplates were preserved, the strongest part of the vertebral body which hence should be respected to reduce subsidence, preserving the bony endplate prevented subsidence or lucencies around the implants. A study of four failed cases[21] revealed lucencies in all, fractures in 2 and subsidence in another. A rectangular form of HA, with 40% to 45% porosity, requiring resection of the end plates was considered satisfactory[14] with loss of disc height of 1.6 mm and loss of lordosis of 2.3^0 and 4 fractured implants. Other reports of "wide decompression" felt average subsidence of 1.6 mm, none over 3 mm, and 4 fractured implants (11%) was acceptable[22].

This study is limited by failure to randomize, small numbers as a custom device, and unselected patients. However, it is an important contribution as no fractures occurred by respecting fundamental biomechanical principles. An optimal design would respect these biomechanical principles by matching the anatomy, thus reducing stress concentrations, providing stability and maximizing appositional area of contact. This approach allowed preservation of the bony endplate and provides restoration of disc height, restores segmental lordosis, and minimizes subsidence.

Bibliography

1. Robinson RA, Smith GW. Anterolateral disc removal and interbody fusion for cervical disc syndrome. *Johns Hopkins Hosp Bull* 1955;96:223-4.
2. Smith GW, Robinson RA. The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. JBJS 1958; 40-A (3): 607-624.
3. Arrington ED, Smith WJ, Chambers HG, et al. Complications of iliac crest bone graft harvesting. *Clin Orthop Relat Res* 1996;329:300-9
4. Whitecloud TS, LaRocca H. Fibular strut graft in reconstructive surgery of the cervical spine. Spine 1976; 1(1): 33-43.
5. Zdeblick TA, Ducker TB. The Use of Freeze dried Allograft Bone for Anterior Cervical Fusions. Spine 1991; 16(7): 726-729.
6. Bright RW, Burchardt H. The biomechanical properties of preserved bone grafts, In: Osteochondral allografts, Biology, Banking, and Clinical Applications, Friedlander GE, Mankin HJ, Sell KW, eds. Boston: Little, Brown & Company, 1983; 241-246.
7. Horowitz MC, Friedlander GE. Introduction to Specific T-Cell Responsiveness to Allogenic Bone. JBJS 1991; 73A(8): 1157-1168.
8. Chau, A M T, Mobbs, RJ. Bone graft substitutes in anterior cervical discectomy and fusion. Eur Spine J. 2009 April; 18(4): 449–464.
9. Cook SD, Dalton JE, Tan EH, et al. In vivo evaluation of anterior cervical fusions with hydroxylapatite graft material. *Spine* 1994;19:1856-66.

10. Zdeblick TA, Cooke ME, Kunz DM, Wilson D, McCabe RP. Anterior Cervical Discectomy and Fusion using a Porous Bone Graft Substitute. Spine 1994; 19(20):2348-2357.
11. Kim P, Wakai S, Matsuo S, et al (1998) Bisegmental cervical interbody fusion using hydroxyapatite implants:. J Neurosurg 88:21–27
12. Ito M, Abumi K, Shono Y, et al. Complications related to hydroxyapatite vertebral spacer in anterior cervical spine surgery. *Spine* 2002;27:428-31.
13. McConnell JR, Freeman BJ, et al. A prospective randomized comparison of coralline hydroxyapatite with autograft in cervical interbody fusion. Spine. 2003 Feb 15;28(4):317-23.
14. Kim, SC, Kang, SW, et al. Clinical and Radiological Outcomes of Anterior Cervical Interbody Fusion Using Hydroxyapatite Spacer J Korean Neurosurg Soc 46 : 300-304, 2009
15. Thalgott JS, Fritts K, Giuffre JM, et al. Anterior interbody fusion of the cervical spine with coralline hydroxyapatite. *Spine* 1999;24:1295-9.
16. Dai LY, Jiang LS. Anterior cervical fusion with interbody cage containing beta-tricalcium phosphate augmented with plate fixation: *Eur Spine J* 2008;17:698-705.
17. Falavigna,A,Righesso, O, Volquind, D, Telas, A R Anterior cervical interbody fusion with hydroxyapatite graft.. Spine Vol 34 #25 page 2769-2774, 2009
18. Foster MR. The use of hydroxyapatite for anterior cervical fusion. J Orthop Techniques 1994; 2(1): 7-13.
19. Emery SE, Bolesta MJ, Banks MA, Jones PK. Robinson Anterior Cervical Fusion, Comparison of the Standard and Modified Techniques. Spine 1994; 19(6): 660-663.
20. Odom GL, Finney W, Woodhall B. Cervical disc lesions. JAMA 1958;166:223-8.
21. Xie Y, Chopin D, Hardouin P, et al. Clinical, radiological and histological study of the failure of cervical interbody fusions with bone substitutes. *Eur Spine J* 2006;15:1196-203.
22. Suetsuna,F , etal Anterior cervical fusion using porous hydroxyapatite ceramics for cervical disc herniation: a two-year follow-up. The Spine Journal 1(5) p. 348-357, Sept/Oct 2001

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Verification of a joint simulator for total hip dislocation using an industrial robot

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Summary

Despite considerable improvements of total hip replacements (THR) dislocation remains a serious complication. As *in vivo* measurements of the dislocation process are not applicable, we are developing a novel mechatronic hardware-in-the-loop (HiL) hip joint simulator based on an industrial robot as physical test setup. The purpose of this work was to verify the functionality of the physical test setup compared to a previous mechanical test device regarding resisting moments. Thus, the dislocation process including impingement, subluxation and final dislocation of one relevant manoeuvre was simulated for a modular THR system. As a result, the HiL hip joint simulator showed considerable improvements concerning measuring sensitivity, reproducibility and accuracy of the measured resisting moment in comparison to the mechanical test device.

Introduction

Dislocation of total hip replacements (THR) remains a serious complication after total hip arthroplasty. There are multiple factors related to joint instability and dislocation including soft tissue condition as well as implant positioning and design [1]. However, *in vivo* measurements of the dislocation process are not feasible due to ethical considerations. Thus, a novel mechatronic hardware-in-the-loop (HiL) hip joint simulator [2, 3] is implemented which connects a physical test setup with a computer model in order to analyse these influencing factors of total hip dislocation. The objective of this work was the verification of the functionality of the physical test setup in comparison to a mechanical test device [4]. Performing one dislocation-associated movement of a modular THR system the measured resisting moments were analysed with respect to range of motion, impingement, and point of dislocation.

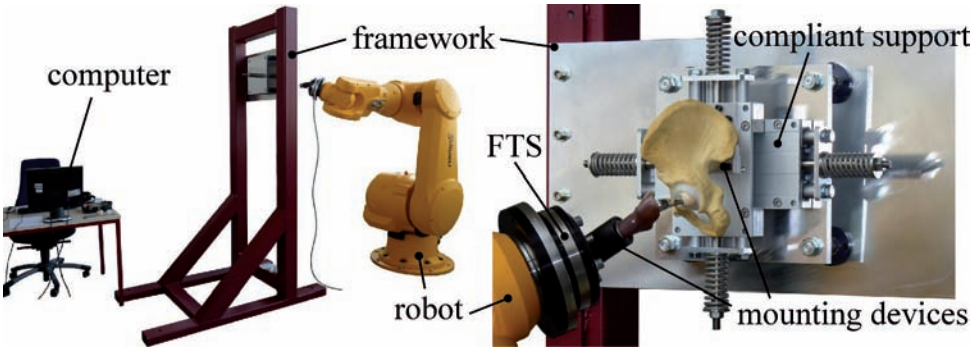

Fig. 1: Physical test setup of the HiL hip joint simulator.

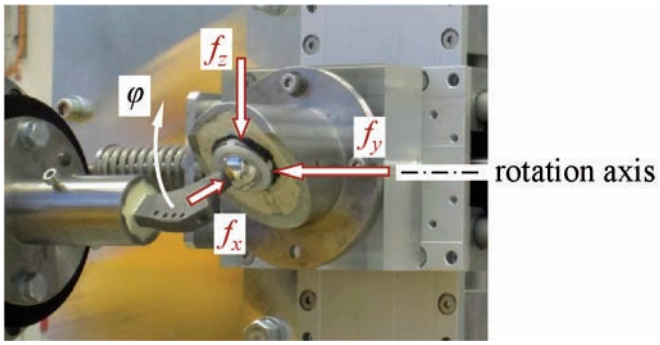

Fig. 2: Simulation of posterior dislocation. The femoral stem is rotated (angle ϕ) around a fixed rotation axis while loaded by the robot with forces f_x, f_y and f_z.

Materials and Methods

The physical test setup of the HiL hip joint simulator is composed of an industrial robot (TX 200, Staeubli Tec-Systems GmbH, Bayreuth, Germany) and a compliant support mounted on a framework. The robot is equipped with a 6D force-torque sensor (FTS, ATI Industrial Automation, Apex, NC, USA) measuring current loads on the attached joint component (Fig. 1).

In the present study, a modular THR system (Alloclassic®, Zimmer, Winterthur, Switzerland) with a acetabular cup (Alloclassic® CSF, size 52 mm) and an uncemented femoral stem (Alloclassic® SL, size 5) with a 12/14 taper were used. The stem was matched with a cobalt-chromium head with a diameter of 28 mm. The spherical head articulated with the corresponding insert, a standard ultra-high-molecular-weight polyethylene (UHMW-PE) insert (Sulene®) with an internal diameter of 28 mm. Both components were embedded into mounting devices. The acetabular cup was fixed on the compliant support, the femoral stem at the endeffector. The acetabular cup was placed with 45° inclination and 0° anteversion, respectively. Stem axis and rotational axis of the endeffector were aligned.

According to Kummer et al. [5] one relevant dislocation-associated manoeuvre

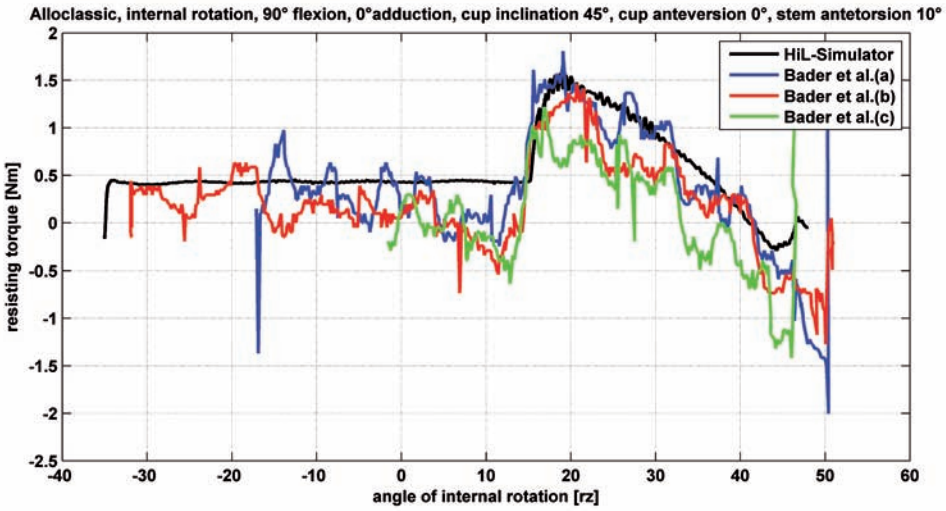

Fig. 3: Resisting moment over rotation angle for posterior dislocation process for a modular THR system in comparison to data provided by Bader et al. [4]. Cup orientation was 45° inclination and 0° anteversion.

were examined for verification (Fig. 2). Thus, the same test procedure according to Bader et al. [4] was reproduced to simulate the process of impingement, subluxation and final dislocation. The manoeuvre was maximum internal (and external) rotation at 90° flexion and 0° adduction in accordance with an increased risk of posterior dislocation in low sitting position. During rotation the femoral stem was constantly loaded by the robot with given forces f_x = 15 N, f_y = 427.5 N and f_z = 270 N. The experimental test was carried out at room temperature (25 °C) and under dry conditions. Corresponding resisting moment was continuously measured by the FTS attached to the endeffector of the robot.

Results

The manoeuvre was carried out until full dislocation was achieved (Fig. 3). At first, a constant resisting moment caused by friction between the joint components was measured. The event of impingement of the stem at the liner could be recognized by a clear increase of the resisting moment. During subluxation the resisting moment decreased until joint dislocation occurred at the insert.

Conclusions

The physical test setup of the HiL hip joint simulator could be verified with respect to the dislocation process for a modular THR system. The result corresponded to the test data derived from Bader et al. [4], whereas considerable improvements could be identified with respect to measuring sensitivity, reproducibility and accuracy. Currently, a biomechanical multi body model of the lower extremity is implemented closing the loop for a HiL simulation. Therefore, the complex dislocation mechanism

can be evaluated taking into account the impact of adjacent muscle, ligament and capsule structures.

Acknowledgements

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References

1. ROBBINS, G.M., MASRI, B.A., GARBUZ, D.S., GREIDANUS, N., DUNCAN, C.P., Treatment of hip instability, Orthop Clin North Am 32 (4), 593-610, 2001.
2. KAEHLER M., WOERNLE C., BADER R., Hardware-in-the-Loop Simulation of Constraint Elements in Mechanical Systems. In: KECSKEMÉTHY A., MUELLER A. (Eds.), Computational Kinematics, Berlin, Springer, pp. 159-166, 2009.
3. WOERNLE C., KAEHLER M., RACHHOLZ R., HERRMANN S., ZIERATH J., SOUFFRANT R., BADER R., Robot-Based HiL Test of Joint Endoprostheses. In: LENARCIC J., STANISIC M. (Eds.), Advances in Robot Kinematics: Motion in Man and Machine, Berlin, Springer, pp. 521-528, 2010.
4. BADER, R., SCHOLZ, R., STEINHAUSER, E., BUSCH, R., MITTELMEIER, W., Method for the evaluation of factors influencing the dislocation stability of total hip endoprostheses, Biomed Tech 49 (5), 137-144, 2004.
5. KUMMER, F.J., SHAH, S., IYER, S., DICESARE, P.E., The effect of acetabular cup orientations on limiting hip rotation, J Arthroplasty 14 (4), 509-513, 1999.

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Surface roughness of retrieved zirconia heads and polyethylene wear after cemented THA

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Summary

Studies of polyethylene wear used for a zirconia head in vivo have given conflicting results. We hypothesized the linear wear rates for an oxidized zirconia head would be lower than those published for a cobalt-chrome head. In addition, we analyzed femoral heads retrieved at revision surgery with regard to surface roughness. Between 1994 and 1999, 46 hips were implanted cemented primary THA used for a zirconia head. At a mean of 12 years follow-up (range 10–15 years), 3 revisions were needed. Polyethylene wear was measured radiologically. Surface roughness of femoral heads including those retrieved at revision surgery was analyzed with use of a digital microscope, Surfcom, and X-ray diffraction. Zirconia heads articulating with a contemporary polyethylene produced less radiographic evidence of polyethylene wear than did cobalt-chromium heads in the literature. An increase of surface roughness in retrieved zirconia caused by a phase transformation was noted.

Introduction

Studies of polyethylene wear used for a zirconia head in vivo have given conflicting results[1-3]. We hypothesized the linear wear rates for an oxidized zirconia head would be lower than those published for a cobalt-chrome head. In addition, we analyzed femoral heads retrieved at revision surgery with regard to surface roughness.

Materials and methods

Between 1994 and 1999, 46 hips were implanted cemented primary THA (MX-1, Mizuho, Tokyo) used for a zirconia head (Diameter, 26 mm; Nihon Tokushu Tougyo, Nagoya). At a mean of 12 years follow-up (range, 10–15 years), 3 revisions were needed. Polyethylene wear was measured radiologically by determining the migration of the center of the femoral head relative to the centre of the cup, based on the

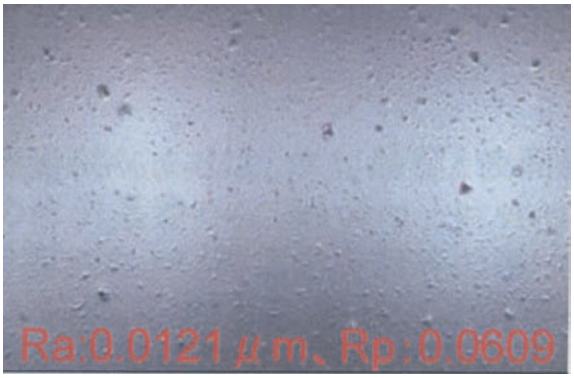

Figure 1 Digital microscope findings of a zirconia head implanted for 15 years

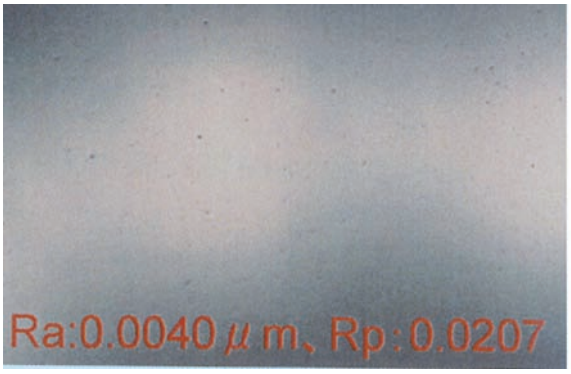

Figure 2 Digital microscope findings of a non-implanted zirconia head

computer-aided technique. Surface roughness of femoral heads including those retrieved at revision surgery was analyzed with use of a digital microscope (VH-50000, Keyence), Surfcom (Tokyo Seimitsu), and X-ray diffraction.

Results

Mean linear wear par year was 0.113 mm (n=25, SD 0.105 mm, range 0.017 - 0.38 mm). Surface roughness (Rp) of 3 retrieved zirconia heads was 0.0515 micro-m, 0.0568 micro-m, and 0.0609 micro-m, compared with 0.0207 micro-m in a non-implanted zirconia head; the transformation rate of the tetragonal to the monoclinic crystal was 28%, 35%, and 40%, respectively. Digital microscopic findings were shown in Figure 1 and Figure 2.

Conclusions

This study suggested that zirconia heads articulating with a contemporary pol-

Table 1 Linear penetration after THA

Study	Femoral head materials	Head diameter (mm)	Number of hips	Linear penetration Mean (range) (mm/year)
Charnley et al. (1975)	Stainless-steel	22	72	0.15 (0-0.6)
Isaac et al. (1992)	Stainless-steel	22	87	0.21 (0-0.6)
Kabo et al. (1993)	Cobalt-chrome	28	23	0.23
Hernandez et al. (1994)	Titanium	28	134	0.22 (0-1.41)
Healy et al. (2002)	Cobalt-chrome	32	53	0.17 (0.04-1.4)
This study (2010)	Zirconia	26	25	0.11 (0.02-0.38)

yethylene produced less radiographic evidence of polyethylene wear than did cobalt-chromium heads in the literature[4-8] (Table 1). An increase of surface roughness in retrieved zirconia caused by a phase transformation was noted.

References

1. Hernigou P, Bahrami T. Zirconia and alumina ceramics in comparison with stainless-steel heads. Polyethylene wear after a minimum ten-year follow-up. J Bone Joint Surg Br. 85:504-509, 2003.
2. Kawate K, Ohmura T, Kawahara I, Tamai K, Ueha T, Takemura K. Differences in highly cross-linked polyethylene wear between zirconia and cobalt-chromium femoral heads in Japanese patients: a prospective, randomized study. J Arthroplasty. 24:1221-1224, 2009.
3. Liang B, Kawanabe K, Ise K, Iida H, Nakamura T. Polyethylene wear against alumina and zirconia heads in cemented total hip arthroplasty. J Arthroplasty. 22:251-257, 2007.
4. Charnley J, Halley DK. Rate of wear in total hip replacement. Clin Orthop Relat Res. 112:170-179, 1975.
5. Isaac GH, Wroblewski BM, Atkinson JR, Dowson D. A tribological study of retrieved hip prostheses. Clin Orthop Relat Res. 276:115-125, 1992.
6. Kabo JM, Gebhard JS, Loren G, Amstutz HC. In vivo wear of polyethylene acetabular components. J Bone Joint Surg Br. 75:254-258, 1993.
7. Hernandez JR, Keating EM, Faris PM, Meding JB, Ritter MA. Polyethylene wear in uncemented acetabular components. J Bone Joint Surg Br. 76:263-266, 1994.

8. Healy WL, Casey DJ, Iorio R, Appleby D. Evaluation of the porous-coated anatomic hip at 12 years. J Arthroplasty. 17:856-863, 2002.

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Effectiveness of Pain Measurement by Electric Phenomenon

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Abstract

Pain is associated with a fall of resistance to Galvanic current. Skin impedance is readily measured and in this study the relationship between change of pain and skin impedance was evaluated. A significant fall in skin impedance was noted when the patients with the chronic pain and the low back pain were done the hyperthermia of hot pack and the xylocaine intramuscular injection. Changes of skin impedance is a very useful objective method of evaluation of pain-associated somatic change.

Introduction

Pain is associated with a fall of resistance to Galvanic current. Skin impedance is readily measured and in this study the relationship between change of pain and skin impedance was evaluated. A significant fall in skin impedance was noted when the patients with the chronic pain and the low back pain were done the hyperthermia of hot pack and the xylocaine intramuscular injection. Changes of skin impedance is a very useful objective method of evaluation of pain-associated somatic change.

Purpose

The purpose of this study is to examine whether it is possible to evaluate of the pain by the measurement of the change in the skin impedance.

Subjects

- Chronic pain outpatients: 40 (male16, female24)
- Mean age: 62.2±8.3y.o

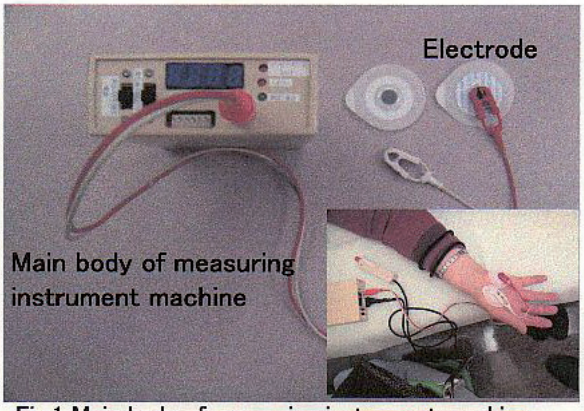

Fig.1 Main body of measuring instrument machine and electrode

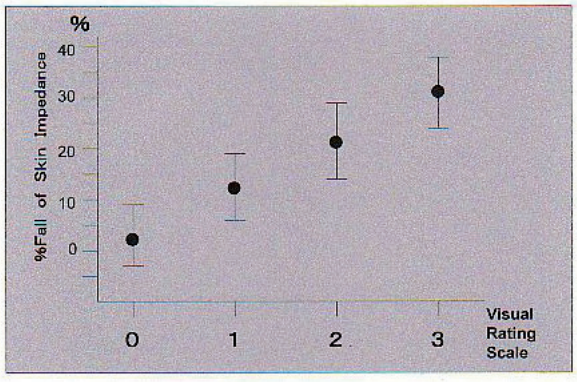

Fig.2 Subjective pain and %fall of skin impedance

- Average period of going to hospital regularly: 13±4.2m
- All cases have no organic disease but slight deformity at vertebral body and knee joints by X-P and CT

Methods

The skin impedance obtained from the electrodes applied to the hand was measured, and it made comparative study of the value before and after the pain treatment. (Fig.1) The patients with the chronic pain and the low back pain were done the hyperthermia of hot pack and the xylocaine intramuscular injection, and visual rating scale(VRS) , giving a score of 3 for severe and almost unbearable pain, 2 for moderate but endurable pain, 1 for mild but distracting pain and 0 for no pain was compared additionally before and after treatment as sight scale, and compute % fall of skin impedance.

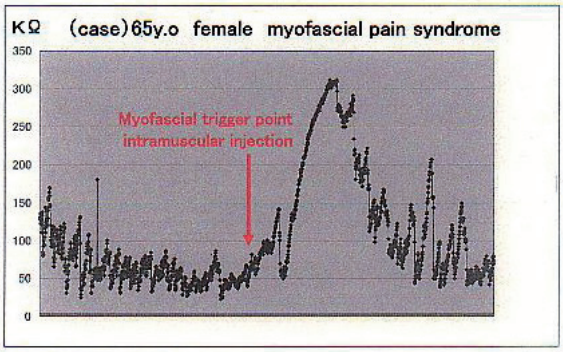

Fig.3 Change of skin impedance by intramuscular injection

Results

For the patients with the chronic pain and the low back pain, the difference was admitted in the individual value that was able to be put in the resting state,(Fig.2) and the change was seen in response to the state of their posture. Impedance decreased with the exacerbation of the pain, and it has increased with the improvement of the pain sensation.

The larger the improvement of the pain sensation was, the smaller increases of impedance when the low back pain was improved by the effect of the intramuscular injection.(Fig.3)

There was no change in impedance in case of the patients by the intramuscular injection of physiological salt solution though their sight scales were improved.

Discussion

The pain is a subjective phenomenon, and it is changeable. The objective evaluation is difficult because there are extremely a lot of troubles that cause the pain. The improvement of the pain and the change in the skin impedance were in the correlation. It was suggested that a quantitative evaluation of the pain sensation was possible though it was thought the change of the pain took place through the autonomic nerve system.

Conclusion

The possibility of quantitatively appreciation of the pain by the change of the skin impedance value was suggested. We hope to examine the change in the pain sensation exactly in the future and to examine the assessment that can do by 24 hours measurements.

References

1. Riley LH Jr, et al: Uses of the electrical skin resistance method in the study of patients with neck and upper extremity pain. Johns Hopkins Med J 137:69-74,1975

2. Drummond PDC: The mechanism of facial sweating and cutaneous vascular response to painful stimulation of the eye. Pain 115:1417-1428,1992
3. Wang GH: The Galvanic skin reflex. A view of old and recent works from a physiologic point of view.. Part one. Am J Phys Med 36:295-320,1957
4. Wang GH: The Galvanic skin reflex. A view of old and recent works from a physiologic point of view.. Part two. Am J Phys Med 37:35-57,1958
5. National Institutes of Health. NIH Consensus Statement. Bioelectrical impedance analysis in body composition measurement. Nutrition 12:1-35,1996

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Entrapment of The Suprascapular Nerve by A Ganglion of The Spinoglenoid Notch: The SLAP Lesion As A Reason For Ganglion of The Spinoglenoid Notch

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Abstract

Purpose: Spinoglenoid notch ganglion cyst may be a probable cause of suprascapular nerve entrapment syndrome. Developmental causes of the ganglion cyst have been still under debates, but some have insisted that one of the causes is superior labrum anterior and posterior (SLAP) lesion by the one-way valve mechanism. The authors performed arthroscopic cyst drainage and SLAP repair as a treatment for suprascapular nerve entrapment syndrome caused by ganglion cyst of the spinoglenoid notch and evaluated the results.

Methods: From August 2000 to March 2007, 15 cases of suprascapular nerve entrapment syndrome caused by ganglion cyst of the spinoglenoid notch were reviewed. Follow-up MRIs and EMGs were performed, and the clinical results were evaluated using Rowe's and Zarins' Constant score.

Results: Rowe's and Zarins' score improved by 92 points at postoperative from preoperative record of 65 points. On MRI taken at the final follow-up, in exception to one case in which no additional symptoms were shown, the ganglion cysts either completely disappeared or decreased in size. On EMG, it was found that all the patients except one had remission of neurogenic lesion.

Conclusion: In the case where suprascapular nerve entrapment syndrome caused by ganglion cyst of spinoglenoid notch is suspected, SLAP lesion may also be ac-

companying as the probable cause of the pre-mentioned ganglion cyst. Thus, while conducting preoperative MRI or intraoperative arthroscopy, a careful analysis of possible damages in capsulolabral complex of glenohumeral joint is necessary, and for treatment, decompression of the ganglion cyst along with SLAP repair, needs to be implemented.

Keywords: Suprascapular nerve entrapment, Spinoglenoid notch ganglion, SLAP

Introduction

Suprascapular nerve entraptment syndrome is relatively rare and is similar to the lesions found in cervical and shoulder regions. It can arise for various reasons including repetitive and extreme shoulder motion, anatomical variants of the scapular notch, and morphologic characteristics of the notch. In a rare case, it can be caused by direct compression of lipoma or ganglion cyst[1-3]. The glenolabral cyst can cause pain, and atrophy of supraspinatus and infraspinatus muscles by compressing the suprascapular nerve. Various approaches including aspiration[4], arthroscopic decompression[5], and open excision[6] have been suggested as the therapeutic options.

Some authors have described that ganglion cyst of the spinoglenoidal notch is related to repetitive overhead activities and one-way valve mechanism that is related to labral tear caused by trauma[2,7]. However, others have explained lesions of the capsulolabral complex and ganglion cysts to have separate pathologies and have stated that concurrence of these two diseases is just coincident. We hypothesized that one-way valve mechanism due to superior labrum anterior and posterior (SLAP) is an initial cause of these cysts; thus, in this study, patients, who were diagnosed with suprascapular nerve entraptment syndrome, underwent arthroscopy and were checked for any concurrent SLAP lesions. If the concurrent lesion was confirmed, the cyst was arthroscopically decompressed, and SLAP repair was done.

Materials and Methods

Between August 2000 and March 2007 fifteen patients underwent surgical treatment for ganglion cysts at the spinoglenoid notch. The average age was 38.3±8.7 years old (range: 28 – 52 years old) at the time of surgery. There were 12 (80%) men and 3 (20%) women.

In 11 cases (73.3%), the dominant shoulder was affected, and in 4 other cases (26.6%) the non-dominant side was affected. As for the patients' vocations, 8 cases were workers (53.3 %), 3 cases were athletes (20%), 2 cases were camera men (13.3%), and 2 cases were housewives (13.3%). Average period from the display of symptoms until the time of surgery was 4.2±1.7 years (range: 6 months to 7 years), while average follow-up period was 28±7.4 months (range: 24 to 48 months). No previous histories of other shoulder symptoms or instabilities before the operation were found in any patients. Other pathologies such as cervical spine degeneration, herniated disc, central nervous lesion, and rotator cuff lesion were ruled out. If a patient had weakness with or without pain of the involved shoulder, atrophy of supraspinatus and infraspinatus muscles, discomfort in posterolateral and lateral part, or tenderness and weakness around the spinoglenoid notch, then suprascapular nerve entrapment syndrome was suspected. All patients had preoperative magnetic resonance imaging

(MRI) and electromyography (EMG) studies that led to the diagnosis of compression of the suprascapular nerve by a cystic formation at the spinoglenoid notch. This study was approved by our institute's ethical review board, and informed consents were obtained from all patients.

Operative technique and rehabilitation

Arthroscopic surgery was performed by a shoulder specialist (K.D.S.), 2 residents, and a professional nurse. After an examination under general anesthesia, the patient was placed in a semi-sitting beach-chair position. A standard posterior portal was established, and diagnostic arthroscopy was performed. Anterosuperior and anteroinferior portals were created when necessary. In the case of a SLAP lesion, the lesion was lifted, and the probe easily passed underneath the labrum into the spinoglenoid notch. The SLAP lesion was mobilized either from anterior or posterior. Entrance to the cyst was widened using a tissue elevator, and the ganglion cyst was drained into the joint by manual pressure applied onto the infraspinatus fossa. Suretac (Acufex, Mansfield, MA) was used to suture the labral lesions. Separated labrum was accordingly placed in order to be restored to its original anatomical location. If both SLAP and bankart lesions were present, then the SLAP lesion was sutured first. Depending on the size of the lesion and its posterior or anterior extension, from one to three anchors were inserted. After the SLAP repair, the shoulder was immobilized for 3 weeks in an abduction pillow of 20° abduction, with isometric and passive anterior flexion exercises starting on the postoperative day 1. Patients started progressive extension exercise at 2 weeks after the surgery. After 3 weeks, active assisted exercises were initiated. After 4 weeks, the pillow was removed, and the patients began full range motion. After 6 weeks, therabands and dumbbells were used to strengthen the muscle. Resistant muscle reinforcing exercises were initiated after 12 weeks. Return to regular sports activity was allowed 6 months after the surgery.

Evaluation methods

During the follow ups, Rowe's and Zarins' evaluation method[10] was used to analyze shoulder function. It is consisted with four subscales: (1) function, (2) pain, (3) stability, and (4) range of motion of the shoulder. Scores were allocated for each of the function; 50 was given to function, 10 to existence of pain, 30 to stability, and 10 to range of motion. Scores of over 90 was classified as excellent, 70 to 89 as good, 40 to 69 as fair, and less than 40 as poor. All the patients were evaluated before the surgery, 6 and 12 weeks after the surgery, and at the latest post operative follow-up by clinical evaluation methods. The instability of shoulder was evaluated under general anesthesia. Grade 1 was designated to those whose humeral head was incompletely dislocated from the glenoid rim. If there was dislocation from the glenoid rim with the capability of spontaneous reduction, then it was defined as grade 2. If the dislocation could not be reduced spontaneously, then it was considered as grade 3[11-12]. In the final follow up, MRI and EMG studies were carried out to research recurrence of the disease after the surgery. EMG studies were performed by neurologists at Wonju Christian hospital. A radiologist, who specializes in musculoskeletal system, provided readings of the MRI results. The significance of differences between

preoperative and postoperative values was tested by the paired *t* test with SPSS (SPSS for Windows Release 11.0; SPSS, Chicago, Illinois). Value of $P<0.05$ was considered statistically significant.

Results

Clinical Results

Rowe's and Zarins' evaluation score was used to analyze 15 cases showing suprascapular nerve entrapment syndrome caused by ganglion cyst of the spinoglenoid notch. The preoperative score was 65±6.8 (44-80) points. After an average follow-up period of 28±7.4 (24-28) months, the mean postoperative score had improved significantly to 92±6.7 (70-100) points. Excellent outcomes were found in 8 cases (50%), good in 6 cases (40%), and fair in 1 case (6%). Of the 15 cases that underwent arthroscopic decompression and SLAP repair, 93.3% of the patients showed results that were better than good. At the final follow up, no patients suffered from pain although, in 2 cases, patients (13.3%) still had minor tenderness. In all cases, forward flexion and external rotation force were improved, but 2 cases (13.3%) did not show full recovery. In addition, 12 cases (85.7%) out of 14 cases that had visible atrophy of infraspinatus muscle in the infraspinatus fossa before the surgery showed full reversal of the condition, but the other 2 cases (14.2%) did not show any improvements. In exception to 2 cases (14.2%) that did not show improvement in muscle atrophy, all patients were able to return to their previous vocations and to continue their sports activities.

MRI and EMG results

Preoperative MRI showed ganglion cysts in all patients. Follow up MRI revealed no recurrences in 13 patients (86.6%), and recurrence or persistence of the cyst was found in 2 cases (13.3%). In one of these two cases, the remaining cystic mass was small, and it did not lead to nerve entrapment syndrome. As for the other case, preoperative MRI did not show any SLAP lesion. Diagnostic arthroscopy was performed, and arthroscopy did not reveal any SLAP lesion either. The patient underwent open excision. Level of pain the patient complained increased after 8 months of a pain-free interval and, for that reason, follow-up MRI was ordered. Follow-up MRI discovered recurrence of the ganglion cyst, and the patient underwent reoperation. During the reoperation, we found SLAP lesion through arthroscopy, and we performed both arthroscopic drainage over the cyst and SLAP repair. At the final follow up, the patient had a good result. Preoperative EMG found that 10 cases (66.6%) had abnormalities in the suprascapular nerve, 4 cases (26.6%) only in the inferior branch of the suprascapular nerve, and 1 case (6.6%) normal. On follow-up EMG, all the patients except 2 (13.3%) showed remission of the neurogenic lesions.

Accompanying lesion

Preoperative MRI showed type II SLAP lesions as accompanying lesions in 10 cases (66.6%), and via arthroscopy, it presented type II SLAP lesions in 12 cases (80%) and

type V SLAP lesions in 3 cases (20%)[13-14]. For all patients, who underwent arthroscopic treatment, instability was tested under general anesthesia. Only 3 cases (20%) were found to be grade 1, and other 12 cases (80%) did not show any instability. On arthroscopy, type V SLAP lesions were found in all 3 cases that were classified as grade 1.

Discussion

The suprascapular nerve starts in the superior trunk of the brachial plexus, where the fourth, fifth and sixth cervical nerve roots are gathered, passes between trapezius muscle and under the belly of omohyoid muscle, and runs through the supraglenoid notch under the superior transverse ligament. Then, it distributes two motor branches to supraspinatus muscle, while it distributes sensory fibers in the coracoclavicular and coracohumeral ligaments, the AC joint, and the subacromial bursa. Subsequently, it goes through the spinoglenoid notch, and distributes two motor branches in the infraspinatus muscle and sensory branch in posterior aspect of the glenohumeral joint capsule[3]. Therefore, the possible sites that supracaspus nerve compression can occur are thought to be spinoglenoid and supralenoid notches. Lesions at the supraglenoid notch are caused by anatomical variants of the notch itself and the superior transverse ligament[15-17]. Suprascapular nerve compression that occurs in the spinoglenoid notch can be triggered by entrapment of the nerve underneath the spinoglenoid ligament. Some authors have described that the nerves are damaged by anatomy of the spinoglenoid notch and repetitive overhead activities [18-19]. The other reason that is believed to cause the nerve compression is compressing effect of a mass such as ganglion cyst in the spinoglenoid notch[20-21]. In this study, patients had suprascapular nerve compression due to ganglion cyst in the spinoglenoid notch. The theory of one-way valve mechanism, which states that ganglion cyst in the spinoglenoid notch is formed by myxoid degeneration of soft tissues around joints[22], instability of the glenohumeral joint, or leakage of joint fluid and synovial tissue due to the tear of the capsulolabral complex, has been proposed, but it still remains controversial. Thompson et al[9] have suggested that there is no relationship between ganglion cyst and intraarticular lesion of the shoulder joint while Ogino et al[3] and Ticker et al[24] have stated that ganglion cyst originates in fibers of the posterior glenohumeral joint capsule but is difficult to prove its communication with the joint. Ganzhorn et al[25] has insisted that ganglion cyst is connected to the shoulder joint, and Kessler et al[26] has reported five cases where patients with ganglion cysts were associated with SLAP lesions which he based his assertion of the SLAP as the cause of the cyst. Piatt et al[27] has reported concurrence of SLAP lesion and ganglion cyst as 89%, and our study demonstrated higher prevalence than previous studies as SLAP lesion (12 type II, 3 type V SLAP lesions) was discovered in all cases (100%). While ultrasonography used as a diagnostic tool normally focuses on determining pathology of the cyst and MRI is a good method to check the tear of the capsulolabral complex, Magee[28] has stated that the sensitivity of conventional MRI for labral tear is only 83-84%; instead, MR arthrography (MRA) has a higher sensitivity of 95-98%. In this study, preoperative MRI found SLAP lesion in two thirds of all study subjects, but missed making the diagnosis of the concurrent lesion for the rest of the third. If suprascapular nerve entrapment due to ganglion cyst is suspected, then it is important to have preoperative MRA performed to check concurrence of SLAP lesion. Furthermore, in the cases where arthroscopy cannot

confirm the SLAP lesion, leading to the assumption that the cyst does not contact the capsule, Kessler et al[26] asserts that the assumption may not necessarily be true, and that it may be a misdiagnosis by microeffusion or one-way valve mechanism during the arthroscopy; therefore, Kessler et al[26] highly emphasizes the importance of MRA to verify a connection between the cyst and labral tear. In our study, preoperative MRI and first arthroscopy did not detect the SLAP lesion in 1 case; thus, open excision was proceeded. However, symptoms recurred, and on MRI conducted 8 months after the surgery, the patient showed recurrence of the ganglion cyst. On second arthroscopy, type II SLAP lesion was observed, the cyst was drained, and the SLAP lesion was repaired. After the second surgery, the patient resolved with a good result. In this case, there were possibilities that the authors may have looked over during the first surgery. In cases with recurrent ganglion cyst, MR arthrography needs to be done before the surgery to probe any accompanying lesions in detail during arthroscopy. In their research to find a prevalence of acute shoulder dislocation's accompanying lesion, Antonio et al [29] have reported a specificity of MRA as 96.6%, which signifies the importance of conducting MRA for detection of the ganglion cyst's accompanying lesion. In this study, instabilities of the joint under general anesthesia were tested during the surgery. In 3 cases that accompanied type V SLAP lesions, instability of grade 1 was found, and none of the cases suffered from symptoms of instability or microinstability, or dislocations before the surgery. Generally, bankart lesion has not been considered as the essential lesion of anterior shoulder joint dislocation. However, tear in the capsulolabral complex does not always denote that all the patients react with positive results in instability test. Also, there are no related symptoms associated with the instability. Many authors have suggested about several treatment methods to the ganglion cyst in the spinoglenoid notch[2,6,9,10]. Cummins et al[1] have suggested that a conservative management of suprascapular nerve entrapment due to ganglion cyst showed inferior results than suprascapular nerve injury due to other causes, that surgeons should not delay an option of surgical treatment and thus underlined the importance of operative treatment. For surgical methods, aspiration using ultrasound or computed tomography, open excision, arthroscopic evaluation and open excision, or arthroscopic decompression is available. Aspiration is effective in decreasing the size of ganglion cyst, but this cannot evaulate intra-articular lesions and has a higher possibility of relapse[1]. Neviaser et al[30] and Ogino et al[3] have reported good results with open excisions only, while Cummins et al[1] and Fehrman et al[2] have suggested correction of intra-articular lesion through arthroscopic evaluation before open excision may be imperative in improving final results. Piatt et al[27] have also said there is higher satisfaction, when both treatment of SLAP and cyst excision are conducted at the same time. Lichtenberg et al[7] have insisted to close the one valve mechanism, because the existence of SLAP leads to form ganglion cyst by the mechanism. In this study, when SLAP lesion was assumed as the cause of ganglion cyst and was subsequently repaired, it had a better than good results in 93.3% of study population at the final follow-up. Moreover, on follow-up MRI, all the cases except 1 ganglion cyst disappeared or decreased in size, and no more symptoms were noted. Also, in exception to 2 cases, this study found remission of neurogenic lesions on follow-up EMG. Although any possibilities of cyst's spontaneous disappearance without any treatments should still be regarded, patients with symptoms more than 6 months before the surgery improved soon after the surgery, and, if there is a significant change

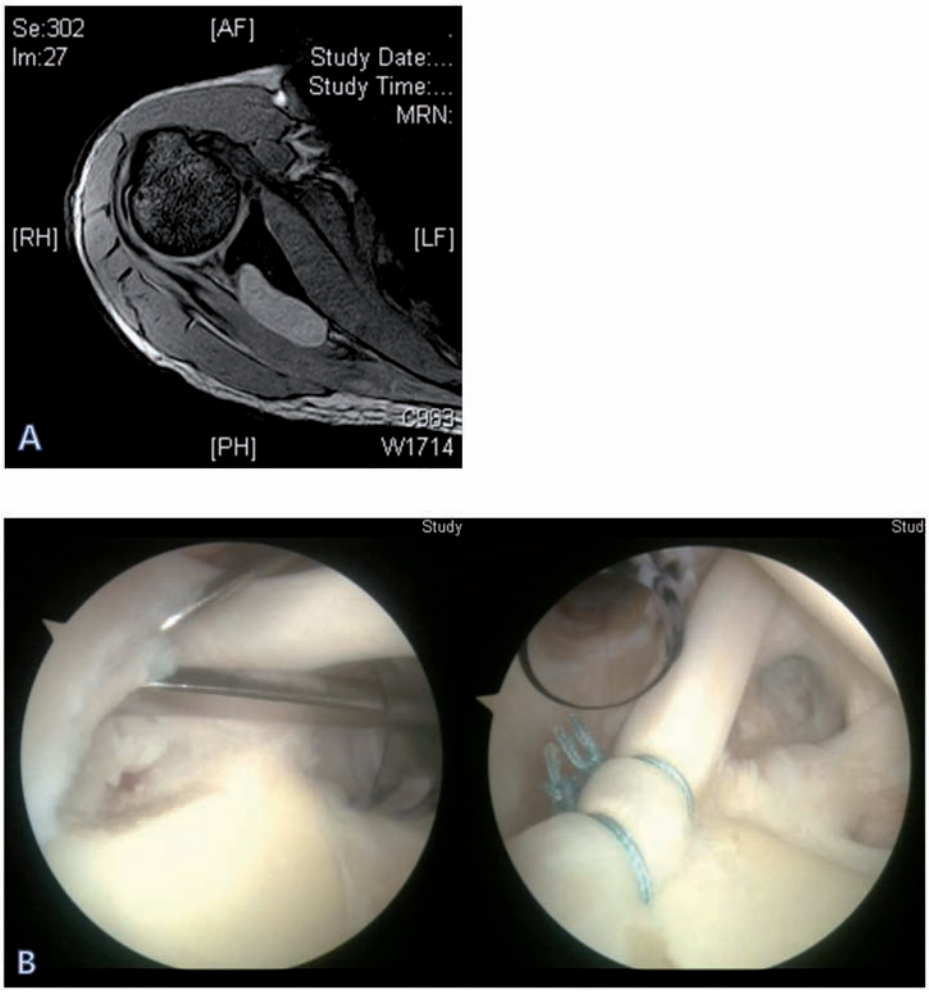

Fig. 1 A. MRI T2WI shows ganglion cyst formation at the spinoglenoid notch. B. After ganglion cyst decompression (B-1), arthroscopic SLAP repair is performed (B-2).

in the results of MRI and EMG at the final follow up, it is considered worthwhile to focus on one way valve mechanism as the cause factor of ganglion cyst in the spinoglenoid notch, and it is essential to repair SLAP lesion, which is the pathway of cyst formation. <-run on sentence plz help me

Conclusion

In cases that are suspicious of suprascapular nerve entrapment syndrome due to ganglion cyst at the spinoglenoid notch, SLAP can be accompanied due to the development of the ganglion cyst. Thus, on preoperative MRI and arthroscopy during the

surgery, it requires a careful analysis of damages in the capsulolabral complex, and it is necessary to conduct both decompression of the ganglion cyst and SLAP repair as a conventional treatement plan.

References

1. Cummins CA, Messer TM, Nuber GW. Suprascapular nerve entrapment. J Bone Joint Surg Am. 2000;82:415-24.
2. Fehrman DA, Orwin JF, Jennings RM. Suprascapular nerve entrapment by ganglion cysts: a report of six cases with arthroscopic findings and review of the literature. Arthroscopy. 1995;11:727-34.
3. Ogino T, Minami A, Kato H, Hara R, Suzuki K. Entrapment neuropathy of the suprascapular nerve by a ganglion. A report of three cases. J Bone Joint Surg Am. 1991;73:141-7.
4. Leitschuh PH, Bone CM, Bouska WM. Magnetic resonance imaging diagnosis, sonographically directed percutaneous aspiration, and arthroscopic treatment of a painful shoulder ganglion cyst associated with a SLAP lesion. Arthroscopy. 1999;15:85-7.
5. Iannotti JP, Ramsey ML. Arthroscopic decompression of a ganglion cyst causing suprascapular nerve compression. Arthroscopy. 1996;12:739-45.
6. Hirayama T, Takemitsu Y. Compression of the suprascapular nerve by a ganglion at the suprascapular notch. Clin Orthop Relat Res. 1981:95-6.
7. Lichtenberg S, Magosch P, Habermeyer P. Compression of the suprascapular nerve by a ganglion cyst of the spinoglenoid notch: the arthroscopic solution. Knee Surg Sports Traumatol Arthrosc. 2004;12:72-9.
8. Antoniadis G, Richter HP, Rath S, Braun V, Moese G. Suprascapular nerve entrapment: experience with 28 cases. J Neurosurg. 1996;85:1020-5.
9. Thompson RC, Jr., Schneider W, Kennedy T. Entrapment neuropathy of the inferior branch of the suprascapular nerve by ganglia. Clin Orthop Relat Res. 1982:185-7.
10. Rowe CR, Zarins B. Recurrent transient subluxation of the shoulder. J Bone Joint Surg Am. 1981;63:863-72.
11. Cofield RH, Irving JF. Evaluation and classification of shoulder instability. With special reference to examination under anesthesia. Clin Orthop Relat Res. 1987:32-43.
12. Molina V, Pouliart N, Gagey O. Quantitation of ligament laxity in anterior shoulder instability: an experimental cadaver model. Surg Radiol Anat. 2004;26:349-54.
13. Maffet MW, Gartsman GM, Moseley B. Superior labrum-biceps tendon complex lesions of the shoulder. Am J Sports Med. 1995;23:93-8.
14. Snyder SJ, Karzel RP, Del Pizzo W, Ferkel RD, Friedman MJ. SLAP lesions of the shoulder. Arthroscopy. 1990;6:274-9.
15. Cohen SB, Dines DM, Moorman CT. Familial calcification of the superior transverse scapular ligament causing neuropathy. Clin Orthop Relat Res. 1997:131-5.
16. Cummins CA, Anderson K, Bowen M, Nuber G, Roth SI. Anatomy and histological characteristics of the spinoglenoid ligament. J Bone Joint Surg Am. 1998;80:1622-5.
17. Edelson JG. Bony bridges and other variations of the suprascapular notch. J Bone Joint Surg Br. 1995;77:505-6.
18. Jackson DL, Farrage J, Hynninen BC, Caborn DN. Suprascapular neuropathy in athletes: case reports. Clin J Sport Med. 1995;5:134-6; discussion 6-7.
19. Kukowski B. Suprascapular nerve lesion as an occupational neuropathy in a semiprofessional dancer. Arch Phys Med Rehabil. 1993;74:768-9.
20. Fritz RC, Helms CA, Steinbach LS, Genant HK. Suprascapular nerve entrapment: evaluation with MR imaging. Radiology. 1992;182:437-44.

21. Sjoden GO, Movin T, Guntner P, Ingelman-Sundberg H. Spinoglenoid bone cyst causing suprascapular nerve compression. J Shoulder Elbow Surg. 1996;5:147-9.
22. Soren A. Pathogenesis and treatment of ganglion. Clin Orthop Relat Res. 1966;48:173-9.
23. Dietz SO, Lichtenberg S, Habermeyer P. Non-traumatic shoulder instability in an athletic patient with a periglenoidal cyst and a glenoid labral tear. Acta Orthop Belg. 2003;69:373-6.
24. Ticker JB, Djurasovic M, Strauch RJ, et al. The incidence of ganglion cysts and other variations in anatomy along the course of the suprascapular nerve. J Shoulder Elbow Surg. 1998;7:472-8.
25. Ganzhorn RW, Hocker JT, Horowitz M, Switzer HE. Suprascapular-nerve entrapment. J Bone Joint Surg Am. 1981;63:492-4.
26. Kessler MA, Stoffel K, Oswald A, Stutz G, Gaechter A. The SLAP lesion as a reason for glenolabral cysts: a report of five cases and review of the literature. Arch Orthop Trauma Surg. 2007;127:287-92.
27. Piatt BE, Hawkins RJ, Fritz RC, Ho CP, Wolf E, Schickendantz M. Clinical evaluation and treatment of spinoglenoid notch ganglion cysts. J Shoulder Elbow Surg. 2002;11:600-4.
28. Magee T. 3-T MRI of the shoulder: is MR arthrography necessary? AJR Am J Roentgenol. 2009;192:86-92.
29. Antonio GE, Griffith JF, Yu AB, Yung PS, Chan KM, Ahuja AT. First-time shoulder dislocation: High prevalence of labral injury and age-related differences revealed by MR arthrography. J Magn Reson Imaging. 2007;26:983-91.
30. Neviaser TJ, Ain BR, Neviaser RJ. Suprascapular nerve denervation secondary to attenuation by a ganglionic cyst. J Bone Joint Surg Am. 1986;68:627-8.

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Next generation antibacterial HA coating – In vitro and in vivo study of osteoconductivity –

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[Summary]

Bacterial infection related to orthopaedic implants is a significant complication today. We developed the novel Ag containing HA (Ag-HA) coating technology. In this study, osteocoductivity of the Ag-HA coating was evaluated in vitro and in vivo. HA powder containing 3 or 50wt % of silver oxide (Ag_2O) was thermal-sprayed on Ti specimens. In vitro study was performed based on ISO23317. For in vivo evaluation, each specimen was inserted into tibial bone of rats and cut off at 4 weeks after surgery, and then histological evaluation was done. The results showed good osteoconduction around the 3% Ag-HA coating. However, the 50% Ag-HA coating showed less new bone formation. The Ag-HA coating is assumed to show the antibacterial activity and the osteocoductivity when the controlled amount of Ag_2O was added.

[Introduction]

Surgical site infection related to orthopedic implants replacement is a serious complication that often leads to an increase in complicated revision arthroplasty. A way to possibly reduce such incidences of implant-surgery-related infections is using antibacterial materials on the surface of the implant itself, as in the case of cementless implants. We focused attention on silver (Ag), because it has a broad antibacterial spectrum and strong antimicrobial activity. However, it is reported that Ag disturbs the bone formation because of its toxicity, and application of antibacterial property of Ag for intraosseous portion of implants has been limited. In order to overcome this problem we aimed at developing the novel thermal spraying technology for Ag-HA coating with antibacterial activity and have been reporting the releasing properties of Ag ions, antibacterial activity, inhabitation activity of bacterial attachment, cytotoxicity and so on[1-3]. In this study, osteoconductivity of the Ag-HA coating was evaluated in vitro and in vivo.

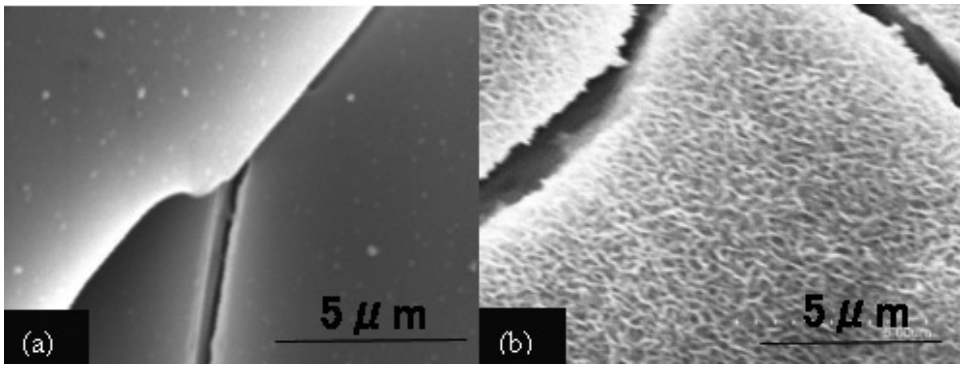

Fig.1 SEM Image of the surface of Ag-HA coating before SBF immersion (a) and after SBF immersion (b)

[Materials and Methods]

HA powder containing 3 or 50wt % of silver oxide (Ag_2O) was sprayed on the surfaces of titanium specimens by the thermal spraying method. The HA coated specimens without Ag were used as the control. In vitro study was performed based on ISO23317. After soaking in simulated body fluid (SBF) for 24 h, each specimen was analyzed by SEM and X-ray diffraction (XRD). On the other hand, the intraosseous implant evaluation was done. Each specimen (20 mm in length and 1 mm in diameter) was inserted into tibial bone of rats. The specimens were cut off from the rat's tibia with tibial bone at 4 weeks after surgery. After staining with toluidine blue, the condition of new bone formation was evaluated using optical microscope and the affinity indexes (percentage of the bone formation and bone contact) were calculated. The animal experiment was approved by the Animal Research Ethics Committees of Saga University.

[Results]

As the Ag-HA coating showed fast HA-forming ability in SBF, the coating was assumed to have good osteoconductivity (Fig.1). In the histological evaluation of animal experiment, good osteoconduction as much as the control (HA coating without Ag) was observed around the 3% Ag-HA coating. However, the 50% Ag-HA coating showed less new bone formation than that of the control (Fig.2 and 3).

[Discussion]

Ag has been widely used for antibacterial treatment in over-the-counter household medicines and so on. Bacteria are quite susceptible to Ag ions; bactericidal activity has been reported at Ag concentrations as low as 35 ppb[4]. Ag has another advantage over antibiotics. Although the incidence of antibiotic-resistant bacteria is a serious problem, Ag-resistant bacteria are not easily formed, and no such resistant bacterial strain is yet known. Recently, the clinical study of Ag-coated megaendoprostheses has been performed in Germany and good clinical results have started to be repor-

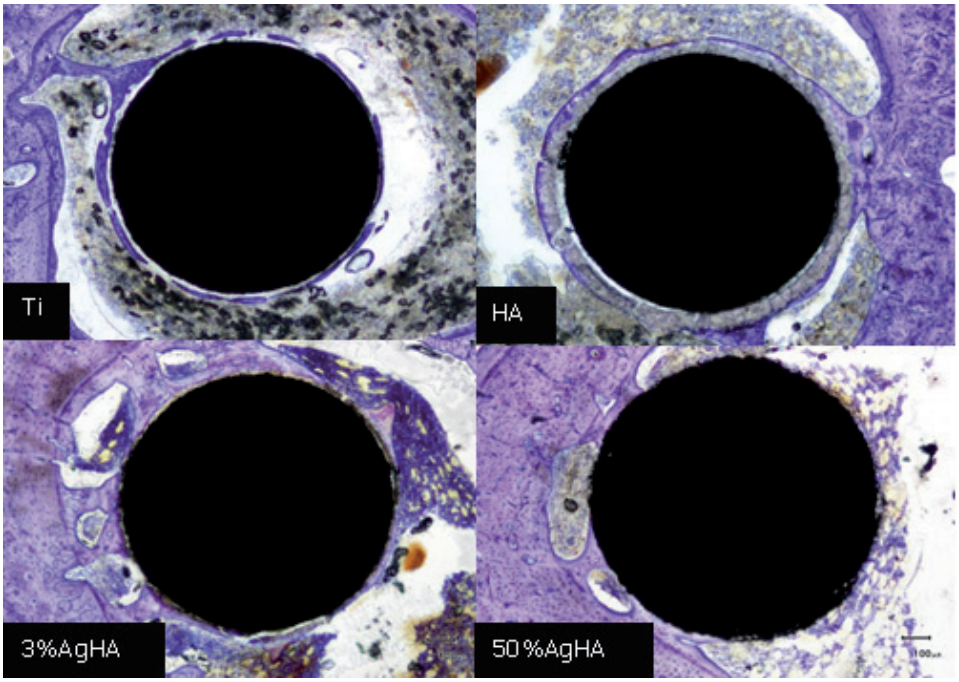

Fig.2 Histological images of the interface between bone and specimens after 4 weeks implantation.

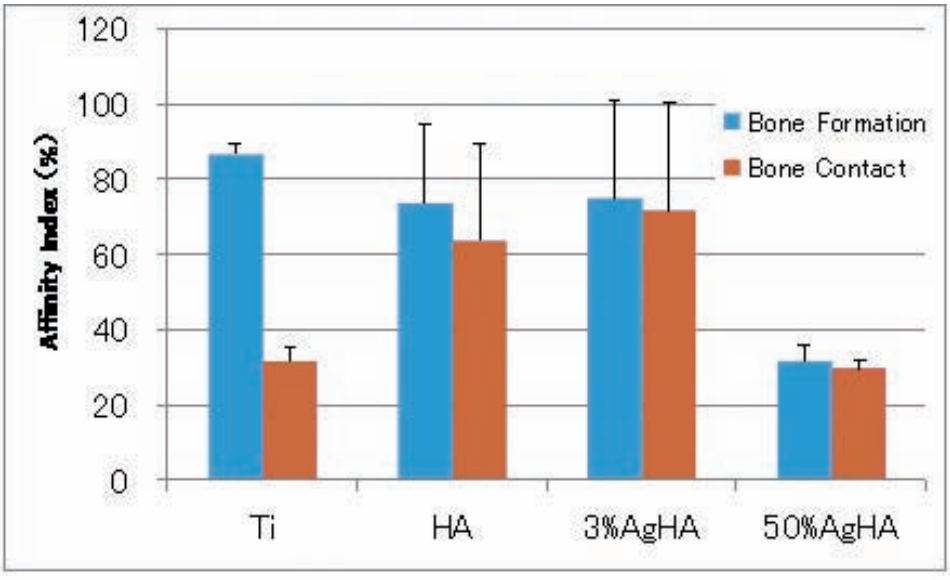

Fig.3 Affinity indexes

ted[5]. However, because of inhibition for bone formation by the toxicity of Ag ions, Ag coating for the intraosseous region is still under considering[6]. In this study, good osteoconduction was observed around the 3% Ag-HA coating. However, in the case of 50% Ag-HA coating, new bone formation was partially inhibited. Therefore, the Ag-HA coating is assumed to show the antibacterial activity and the osteoconductivity at the same time when the controlled amount of Ag_2O was added. The coating will be able to be applied for the intraosseous portion of implants and expected to reduce the incidence of implant-associated infections, especially osteomyelitis.

[References]

(1) NODA I et al. J Biomed Mater Res, 89, 456-465, 2009.
(2) ANDO Y et al. Mater Sci and Engi C, 30(1), 175-180, 2010.
(3) SHIMAZAKI T et al. J Biomed Mater Res, 92(2), 386-389, 2010
(4) CHAMBERS CW et al. J Am Water Works Assoc, 208–216, 1962
(5) AHRENS H et al. Abstract of the EBJIS, Sep. 17-19, 2009.
(6) HARDES J et al. Abstract of ISOLS/MSTS, Sep. 23-26, 2009.

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Evaluation of a femoral stem with an intertrochanteric plate

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Summary

Various type of collars have been used for the proximal fixation of femoral stems. The clinical results were, however, insufficient because of the unbalanced stress distribution on bone tissues. Especially, the position just below a collar was received high pressure which was irregularly concentrated. On the other hand, the intertrochanteric plate, which is added under a collar, can disperse the pressure on bone like as a washer under a screw. In the present study, stress distribution of a stem was directly measured under the loading test using a model bone. It was shown as the result that an intertrochanteric plate largely lowered the maximum stress than a collar. The result was verified by the FE analysis under the similar conditions of the measurements.

1. Introduction

To prevent loosening during the long-term use of femoral stems, stems with a plate or collar for mechanical fixation have been developed (Sakai et al., 2006). The advantage of femoral stems with a collar is force transmission in the proximal area, but their appropriate contact with bone is difficult to achieve. There is a possibility that this problem can be overcome using an intertrochanteric plate devised by Dr. Maezawa in 1968 (Figs. 1). Intertrochanteric plates are considered to have a role similar to that of washers, which, as well as screws, are industrial products. Therefore, in this study, to clarify the usefulness and effectiveness of an intertrochanteric plate (plate hereafter), we evaluated the following three items:(i) Pressure measurement was performed using stems with and those without a plate (collar stems), and the pressure distribution was compared between the two types of stem. (ii) Two finite element (FE) models with or without a plate were constructed, and the pressure immediately

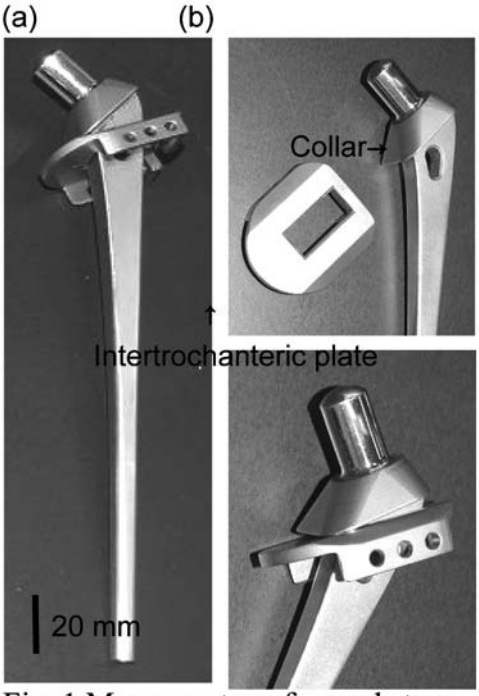

Fig. 1 Maezawa-type femoral stem. (a) Femoral stem with an intertrochanteric plate. (b) Enlarged image of the proximal area.

below the plate was compared between the two models by finite element analysis (FEA). (iii) Two FE models with a plate that is slightly movable or immovable were constructed, and the stress distribution and relative micromotion were compared between the two models by FEA.

Contact between bone and joint prostheses is difficult to interpret because the general contact theory cannot be applied to this contact. Therefore, in this study, pressure, stress, and micromotion were used as parameters for the evaluation of fixation, and the plate and its function were evaluated employing two approaches, i.e., measurement and analysis. To contribute to the development of stems in the future, the effects of the plate, which has become infrequently used in clinical practice, were re-evaluated.

2. Methods

As materials, Maezawa-type femoral stems (Japan Orthopaedic Instruments, Inc., Japan) with a collar and plate as first-generation stems were selected. As controls for evaluation items (i) and (ii), stems after removing the plate were regarded as the collar type and used. As controls for the evaluation item (iii), the plate was fixed at

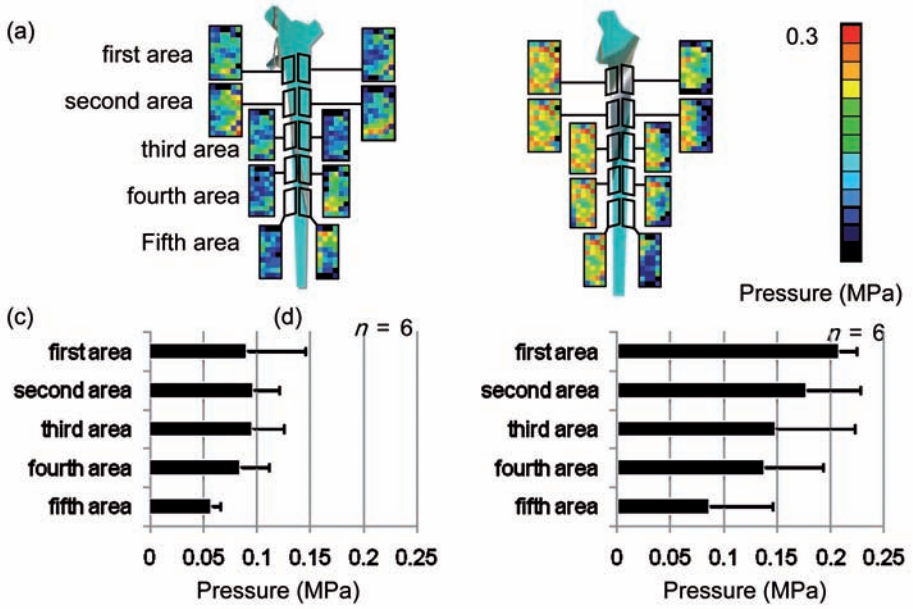

Fig. 2 Pressure distributions measured by tactile sensors. (a) Antero-medial side of the femoral stem with a plate. (b) Antero-medial side of the femoral stem without a plate. (c) Average of six artificial femur pressures at medial side of the femoral stem with a plate. (d) Average of six artificial femur pressures at medial side of the stem without a plate.

the stem, and a model with a morphology similar to that of the Maezawa type but without mobility in the proximal area was constructed.

The measurement system consisted of a computer for measurement control, I-SCAN (NITTA co., Japan), PCI interface board, tactile sensor sheet, and sensor connector. An artificial femur (SAWBONES, Pacific Research Laboratories, Inc., WA, USA) was dug so that the shape of the medullary cavity could become that of the external surface of the stem. A tactile sensor sheet was applied between the artificial femur and stem, which was placed in the loading tester. To simulate the abductor muscle force, acrylic resin was applied so that it would be pulled by the greater trochanter. Pressure distribution measurement was initiated a few seconds before loading, and 1 BW (650 N) was loaded on the femoral head for 10 seconds.

Stem models were constructed using 8-noded hexahedron isoparametric elements after correction of the external shape of existing femoral stems, and parts expected to be deformed were further divided into smaller subparts. As the characteristics of the material, the elastic modulus and Poisson's ratio were 110 GPa, and 0.29, respectively (Bühler et al., 1997). The elastic modulus for femur model was assumed to be 15.5 GPa for cortical and 1.00 GPa for cancellous bone, and Poisson's ratio was assumed to be 0.30 for cortical and 0.33 for cancellous bone (Burstein et al., 1976).

For the analysis system, Endeavor Pro-2000 (EPSON, Japan) was used as hardware and LS-DYNA Ver.950 (LSTC, CA, USA) as software. In evaluation item (ii), a constraint condition similar to that in measurement was reproduced; rotational displacement constraint in the y-axis direction was used. In evaluation item (iii), the

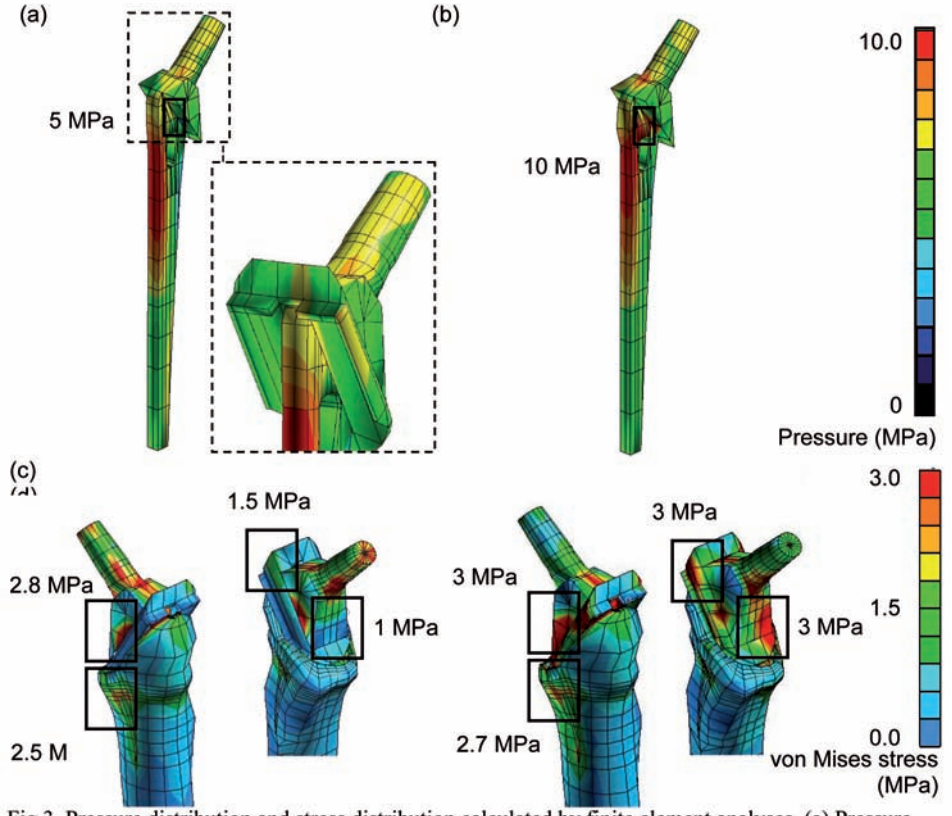

Fig.3 Pressure distribution and stress distribution calculated by finite element analyses. (a) Pressure distribution of femoral stems with a plate. (b) Pressure distribution of femoral stems without a plate. (c) Stress distribution of femoral stems with a plate. (d) Stress distribution of femoral stems without a plate.

distal end of the femur was constrained in all directions. In evaluation item (ii), a loading condition similar to that in the experiment was used; a step load (650 N) was applied to the proximal end of the stem for 10 seconds. As the abductor muscle force, a load of 520 N was pulled from the greater trochanter. In evaluation item (iii), the loading curve assumed a walking state was applied in 1,000 cycles for 1,000 seconds (Dennis et al., 2001). As the abductor muscle force, a step load (1,440 N) was pulled from the greater trochanter (Kotzer et al., 1991). Concerning the contact condition, the friction coefficient between the cortical bone and stem was assumed to be 0.3, considering slips among the stem, femur, and plate. In evaluation item (iii), the friction coefficient between the stem and plate was assumed to be 0.1.

3. Results

The pressure distribution in one of the six artificial femurs on the anterior and medial sides is shown in Figs. 2a, b. The pressure values with were higher than those

without a plate. The high-level pressure occurred in the proximal medial area without a plate. Figs. 2c, d shows the pressure distribution on the medial sides, revealing a significant difference between the presence and absence of a plate. The pressure in all areas was significantly higher without than with a plate. The high pressure was observed in the first and second areas on the medial side without a plate.

The maximum pressure immediately below the collar obtained by FEA was 5 MPa in stems with and 10 MPa in those without a plate (Figs. 3). The area showing low pressure was wider in stems with than in those without a plate. Stems without a plate showed a high pressure distribution. In models with a movable or fixed plate, the Von Mises stress distribution between the stem and bone changed in the proximal medial, lateral, anterior, and posterior areas but not in the distal area. Therefore, the two models were compared on the proximal medial, lateral, anterior, and posterior sides.

Table 1 shows micromotion of the stem and plate of models with a movable or fixed plate. Relative stem micromotion was lower in the model with a movable than in that with a fixed plate. The spatial micromotion of the plate was higher in the model with a movable than with a fixed plate.

4. Discussion

To avoid bone or stem destruction, it is optimal to decrease areas with a high pressure. In evaluation item (i), pressure measurement using six artificial femurs showed significantly lower pressures on the medial and anterior sides for stems with than for those without a plate. This may be due to the fact that the plate absorbed and dispersed the load on the femoral head. The pressure value is considered to be decreased by dispersing the pressure at the interface between the bone and artificial hip joint stem by the plate. In contrast, pressure is generated in the circumferential direction in the model without a plate due to stem settlement. The local pressure was considered to be exerted mainly in the inner frontal area. The high values in the first and second areas may be because the stem subsided due to the absence of a plate, resulting in contact between the bone and stem in these as tapered areas. In evaluation item (ii), pressure was used as a parameter to compare the results of the experiment in evaluation item (i) with the pressure distribution. The pressure distribution was not the same between the measurement and analysis, although they showed a similar tendency (high pressure in the proximal and low pressure in the distal area) was observed. A comparison of pressure immediately below the collar, which was the original purpose of evaluation item (ii), revealed no high pressure immediately below the collar with a plate because of sliding between metals but high pressure without a plate, probably because of the absence of this mechanism. Based on stem circumferential pressure values and pressure values immediately below the collar, stems with a plate may be more useful than collar-type stems without a plate. The degree of freedom of the stem increased using a plate, which may have been useful for favorable fixation. Therefore, plate micromotion was assessed as evaluation item (iii). No high-level stress was confirmed on the femur of the model with a movable plate, and stress on the femur of the model with a fixed plate was higher than on the stem of that with a movable plate. These results suggest that plate micromotion prevented excessive stress concentration. To evaluate the usefulness of plate micromotion,

Table 1 Relative and spatial micromotion of the movable plate stem and fixed-plate stem.

Micromotion (mm)	Relative micromotion	Spatial
	Stem	Plate
Movable plate	0.41	1.61
model	1.29	1.54

we considered that a repetitive rather than a step load was more appropriate, and a walking load was applied. In previous studies using a walking load, stress was often used as a parameter. Therefore, we used stress instead of pressure as a parameter. The stress values observed in this study were lower than the values that may cause bone or stem fracture, and were included in the range reported to provide fixation (Evans, 1969). Even when stress concentration inducing stem fracture occurs, stress values as expected to be lower in the model with a movable than in that with a fixed plate. Therefore, favorable fixation may be achieved by the addition of a plate to the stem. Since we speculated that the use of a plate decreases the shear stress of the stem and prevents subsidence, micromotion was calculated as evaluation item (iii). When the load does not increase, stress levels do not rise unless micromotion increases. The walking load in this analysis did not increase, although it was cyclic within a certain range. Therefore, the time-dependent increase in stress in the analysis of stress and micromotion was considered to be due to an increase in micromotion, and results consistent with this were obtained. We speculate that the model with a movable plate avoids loosening compared with that with a fixed plate based on low micromotion values of the former.

References

Sakai R. et al., Assessment of the fixation stiffness of some femoral stems of different designs. Clin. Biomech. 21, 370-378, 2006.

Burstein AH. et al., Aging of bone tissue: Mechanical properties. J. Bone Joint Surg. 58A, 82-86, 1976.

Bühler WD. et al., Three-Dimensional Primary Stability of Cementless Femoral Stems. Clin. Biomech. 12, 78-86, 1997.

Dennis AD. et al., “In vivo” determination of hip joint separation and the forces generated due to impact loading conditions. J. Biomech. 34, 623-629, 2001.

Kotzer GM. et al., Telemeterized in vivo hip joint force data: a report on two patients after total hip surgery. Journal of Orthopedics Research 9, 621-633, 1991.

Evans F.G., The mechanical properties of bone. Artif Limbs. 13, 37-48, 1969.

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Changes Over Time in Three-dimensional Kinematics during Deep Flexion Kneeling in Mobile-bearing Total Knee Arthroplasty

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Summary:

In 20 knees with a NexGen LPS-Flex mobile-bearing TKA during weight-bearing kneeling, an in vivo fluoroscopic analysis were performed. The averaged max. flexion angle was 131° at 12 M. The femoral condyles translated posteriorly from extension to 90° flexion, then more posteriorly to max. flexion at all intervals. Almost all rotation occurred at the surface between the tibial compo. and PE, whereas almost no rotation occurred at the surface between the PE and femoral compo. as knee flexed. From extension to max. flexion, the tibia rotated internally up to the averaged angle of 9°.

Introduction:

Achieving very deep flexion after total knee arthroplasty (TKA) is an important goal for patients from Japan, other countries in Asia, and the Middle East where lifestyle and religious or work activities demand sitting on the floor. Rotatingplatform mobile-bearing total knee arthroplasties (RP-TKA) were developed to provide congruent tibiofemoral articulations for anteroposterior stability and low contact stress, and rotational laxity to permit physiologic rotation in deeply flexed postures. Previous studies reported that the postoperative flexion after TKA changes over time and the improvement of flexion angle is achieved by three months to 3 years postoperatively. Improvements in flexion could possibly have an adverse effect on TKA kinematics. Few studies of mobile-bearing TKA, however, have so far compared the kinematics at different follow-up periods. The purpose of this study was to evaluate RP-TKA kinematics over time during weight-bearing flexion beyond 120°, which has not yet been reported.

Table 1 Average anterior-posterior translation of femoral condyles

Mean (range) (mm)

Follow-up time (months)	Medial condyle		Lateral condyle	
	90° flexion	max. flexion	90° flexion	max. flexion
3	2.7 (-3.1 to 7.5)	-3.8 (-12.5 to 6.3)	-0.3 (-4.5 to 6.2)	-6.2 (-14.0 to 0.5)
6	2.6 (-4.1 to 6.2)	-5.7 (-12.8 to 4.4)	-1.6 (-6.2 to 3.8)	-8.0 (-17.4 to 0.7)
12	1.6 (-4.0 to 9.2)	-4.7 (-10.8 to 3.8)	-2.7 (-16.8 to 3.5)	-11.6 †** (-28.5 to -3.3)

All mesurements calculated with regarded the values in straight-leg stance as "zero"
† $p<0.01$ versus the values at 3 months
** $p<0.05$ versus the values at 6 months

Materials and Methods:

A total of 20 knees in 20 consecutive patients (average age at surgery:77 years) underwent a mobilebearing TKA by the same surgeon with a measured resection technique. All patients were implanted with a posterior-stabilized RP-TKA prosthesis (NexGen LPS Flex Mobile, Zinmmer, Warsaw, Ind). During the operation, four tantalum beads with a diameter of 0.8 mm were inserted in predefined non-weightbearing areas of the polyethlene(PE) inserts using the Bead Injector (Tilly Medical Products AB, Lund, Sweden). All patients were followed up at 3, 6, and 12 months after surgery. At each interval true lateral radiographs were taken in three positions: weight-bearing stance in extension, kneeling at 90°; flexion, and kneeling at maximum flexion. These radiographs obtained were subsequently analyzed using a 3-D to 2-D model registration technique as previously described [1]. The lowest point on each condyle with respect to the tibial baseplate was determined, and the distance between this point and the AP center of the tibial baseplate was used to assess AP condylar translation (a negative value means posterior to the centerline of the baseplate). The axial rotations between the tibial baseplate, the PE insert, and the femoral component were calculated separately (a negative value means internal rotation). Statistical analyses were performed using nonparametric Freidman's tests to determine the differences at the three followup intervals and Wilcoxon Rank sum test to evaluate paired differences. Probabilities (P values) less than 0.05 were considered to be significant.

Results:

Knee flexion angle: The flexion angles in maximum flexion kneeling at 3, 6, and

Table 2 Average axial rotation angles

Mean (range) (degrees)

Follow-up time (months)	Tibia comp.to femoral comp.		Tibial comp. to PE insert		PE insert to femoral comp.	
	90° flexion	max. flexion	90° flexion	max. flexion	90° flexion	max. flexion
3	-3 (-13 to 10)	-4 (-13 to 7)	-3 (-9 to 8)	-3 (-11 to 6)	0 (-4 to 4)	0 (-6 to 5)
6	-6 (-12 to 4)	-4 (-14 to 2)	-5 (-13 to 2)	-4 (-14 to 2)	-1 (-6 to 3)	-1 (-6 to 4)
12	-5 (-14 to 7)	-9 †† ** (-18 to -2)	-4 (-11 to 7)	-6 † ** (-13 to 1)	-1 (-7 to 3)	-2 (-5 to 1)

All mesurements calculated with regarded the values in straight-leg stance as "zero"
† p<0.05, †† p<0.01 versus the values at 3 months
** p<0.05 versus the values at 6 months

12 months postoperatively were 122°, 129°, and 131° in maximum flexion kneeling, respectively. Those flexion angles at 6 and 12 months were higher than those at 3 months (p=0.0096 and 0.0040, respectively). Femoral condylar translation (Table 1): Significant differences were observed in the amount of posterior translation of the lateral condyle in the maximum flexion kneeling between 12 months and the two other intervals (p=0.0003 at 3 months and p=0.016 at 6 months). On the other hand, the amount of translation of the femoral medial condyles exhibited no differences over time. Axial rotation (Table 2): Almost all rotation occurred at the surface between the tibial baseplate and the insert, whereas almost no rotation occurred at the surface between the insert and the femoral component. There were significant differences in the amount of internal rotation angle between the tibial component with the PE insert and the PE insert with the femoral component at all intervals (p=0.0479 at 3 months, p=0.0008 at 6 months, and p=0.0479 at 12 months).

Discussion:

A number of researchers have analyzed the in vivo knee kinematics under several weight-bearing conditions using a variety of TKA designs, but there are few reports detailing axial rotation and insert motion in RP-TKA for flexion beyond 120°. The results in this sstudy demonstrate similar tibiofemoral kinematics for subjects with well-functioning posterior stabilized RP-TKA. These subjects averaged 131° knee flexion in maximum flexion kneeling at 12 months postoperatively, and consistent posterior femoral translation and tibial internal rotation from standing to deep kneeling. In addition, the overall trend was for the rotation of the PE insert to closely follow that of the femoral component with respect to the tibia. Our data complements previous reports, showing that condylar translations, tibial rotations and PE insert mobility change over at least the first postoperative year for knee flexion beyond

120°. Although the main limitation of the current study is the small number of knees, Our results might aid the development of a rationale for additional improvements in surgical techniques and prosthesis design, so that a closer-to-normal knee function over the entire range of flexion may be restored with TKA.

References:

Nakamura E, Banks SA, Tanaka A, Sei A, MizutaH. Three-Dimensional Tibiofemoral Kinematics During Deep Flexion Kneeling in a Mobile-Bearing Total Knee Arthroplasty.J Arthroplasty. 24:1120-42;009.

Footnote: The knee, in press, Azusa Tanaka, Eiichi Nakamura, Nobukazu Okamoto, S.A. Banks, Hiroshi Mizuta. Three-dimensional kinematics during deep-flexion kneeling in mobile-bearing total knee arthroplasty,2010,with permission from Elsevier.

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In vivo patch-clamp analysis of dopaminergic descending inhibitory pathway in the spinal dorsal horn

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Summary

In the present study, to elucidate the mechanisms of antinociception mediated by the dopaminergic descending pathway in the spinal cord, we investigated actions of dopamine (DA) on substantia gelatinosa (SG) neurons by in vivo whole-cell patch-clamp methods. This study showed that DA has both presynaptic and postsynaptic actions to inhibit synaptic transmission in SG neurons.

Introduction

It is well understood that DA has an action in the brain as a neurotransmitter and neuromodulator. However, little is known about the roles of DA in the spinal cord. The periventricular, posterior region (A11) of the hypothalamus is the principle source of descending dopaminergic pathways. Focal electrical stimulation in the region of the A11 area suppresses the nociceptive responses of neurons in the spinal dorsal horn[2)]. In addition, behavioral studies demonstrate that intrathecal administration of DA induced thermal antinociceptive effects through D2-like receptors when assessed by the tail flick test[1)]. These findings strongly suggest that the descending dopaminergic pathway plays an important role in the process of antinociception in the spinal cord. In the present study, to elucidate the mechanisms of antinociception mediated by the dopaminergic descending pathway in the spinal cord, we investigated actions of DA on spinal SG neurons by in vivo whole-cell patch-clamp methods.

Materials and Methods:

The methods used for the in vivo patch-clamp recording were similar to those described previously[4)]. Male Sprague-Dawley rats (5-7 weeks of age, 150-250 g) were

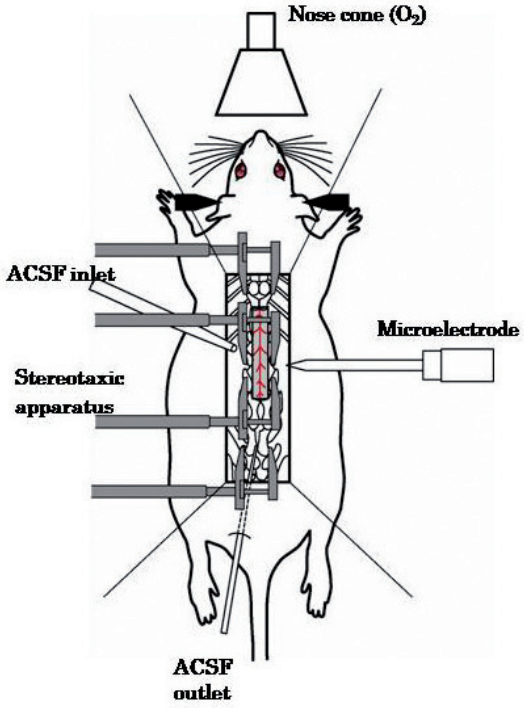

Fig. 1

anesthetized with urethane. The lumbar spinal cord was exposed at the level from L3 to L5 by a thoraco-lumbar laminectomy at the level from Th12 to L2, and the rat was placed in a stereotaxic apparatus (Fig. 1). Under a binocular microscope, the dura was cut and removed. Then the dorsal root that enters the spinal cord above the level of recording sites was gently shifted bilaterally so that a recording electrode could be advanced into the DH from the surface of the spinal cord. The pia-arachnoid membrane was removed using microforceps to make a window large enough to allow the patch electrode to enter the spinal cord. The surface of the spinal cord was irrigated with 95 % O_2 - 5 % CO_2-equilibrated Krebs solution. The electrode with a resistance of 8-12 MΩ was advanced at an angle of 30-45 degrees into the DH through the window in the pia-arachnoid membrane using a micromanipulator. A giga-ohm seal was then formed with DH neurons at a depth of 30-150 μm. Membrane potentials were held at -70 mV in voltage-clamp mode. After making a giga-ohm seal, the membrane patch was ruptured by a brief period of more negative pressure, thus resulting in a whole cell configuration. Drugs were dissolved in Krebs solution and applied by perfusion without any change in the perfusion rate or the temperature.

Results:

In the voltage-clamp mode (V_H = -70 mV), the application of DA induced outward

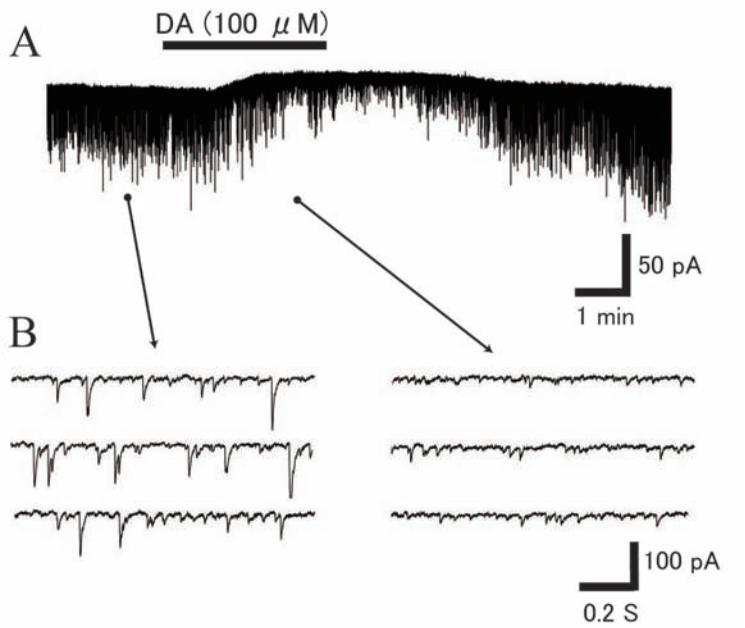

Fig. 2

currents in 70.8 % of DH neurons tested (n= 219). The average amplitude of the DA-induced outward currents was 19.5 ± 1.6 pA (n = 64) (Fig. 2A). Moreover, DA significantly suppressed the frequency and amplitude of glutamatergic spontaneous excitatory postsynaptic currents (EPSCs) (Fig. 2B). DA-induced outward currents are recorded in the presence of a Na^+ channel blocker, TTX (1 μM) or a non-NMDA receptor antagonist, CNQX (10 μM) (Fig. 3). DA also significantly decreases the frequency of miniature EPSCs in the presence of TTX. These results suggest that DA has both presynaptic and postsynaptic actions to inhibit synaptic transmission in DH neurons. DA-induced outward currents were significantly suppressed by GDP-β-S(2 mM) in the pipette solution (Fig. 4B) or perfusion of a non-selective K^+ channel blocker, Ba^{2+} (1 mM) (Fig. 4A). Moreover, the DA-induced outward currents were mimicked by a selective D2-like receptor agonist, quinpirole (100 μM) (Fig. 5A), but not by a D1-like receptor agonist, SKF 38393 (100 μM) (Fig. 5B). In addition, DA-induced outward current was attenuated by a selective D2-like receptor antagonist, sulpiride (30 μM) (Fig. 5C).

Conclusion:

These findings have indicated that DA-induced outward current is mediated by G-protein-activated K^+ channels through D2-likereceptors. Thus, the activation of dopaminergic descending pathway has antinociception effect via D2-like receptors on DH neurons in the spinal cord. Dopaminergic innervation of the spinal cord is largely derived from the brainstem. A previous study reported that there are no dopaminergic

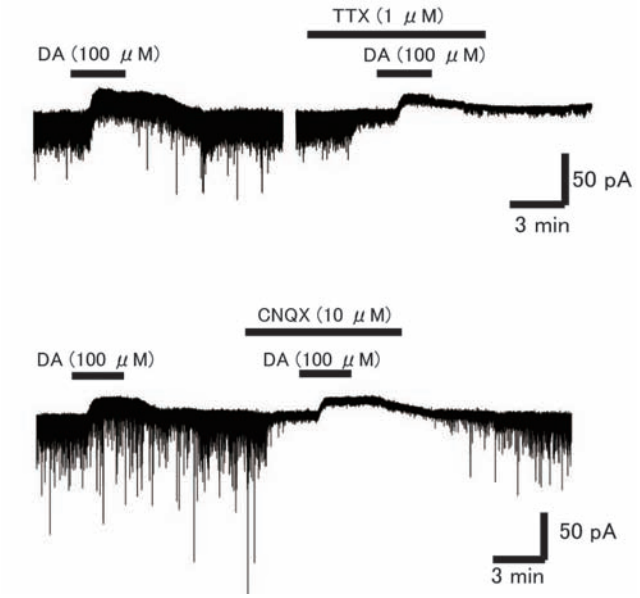
TTX (1 μM)
DA (100 μM)
DA (100 μM)
50 pA
3 min
CNQX (10 μM)
DA (100 μM)
DA (100 μM)
50 pA
3 min

Fig. 3

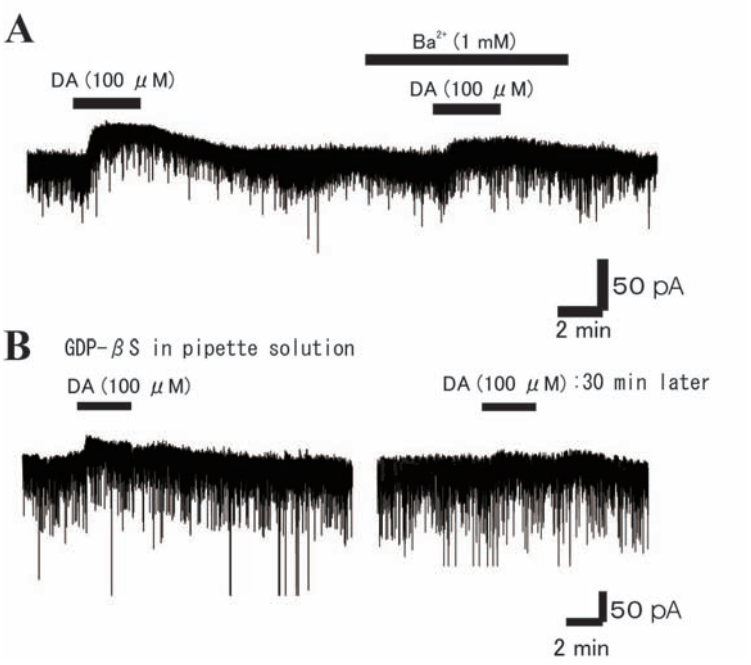
A
Ba2+ (1 mM)
DA (100 μM)
DA (100 μM)
50 pA
2 min
B
GDP-βS in pipette solution
DA (100 μM)
DA (100 μM) :30 min later
50 pA
2 min

Fig. 4

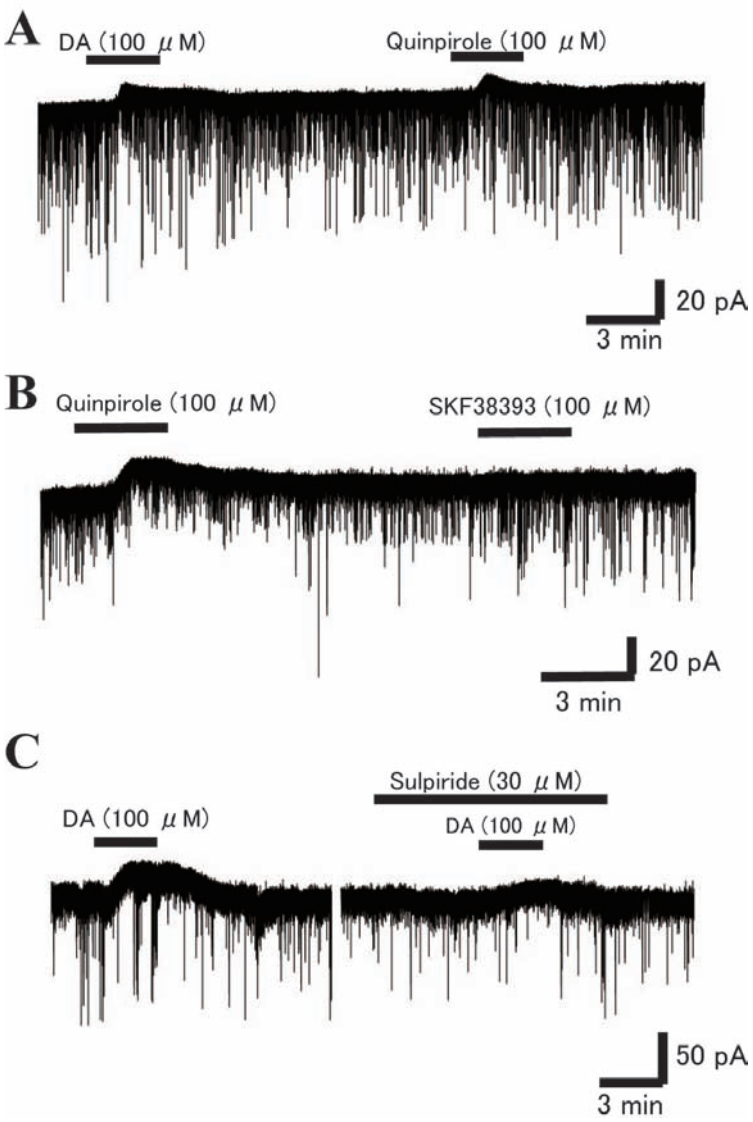

Fig. 5

cell bodies in the spinal cord and that only fibers and terminals are immunoreactive for DA[3]. Therefore, the potential origin of endogenous DA appears to be from dopaminergic neurons in the region of A11. Although dopaminergic descending inhibition mechanism has not been established yet, the present study has provided a cellular mechanism of the spinal DA-induced antinociception by patchclamp recording technique in vivo.

References:

[1] Barasi S, Duggal KN. The effect of local and systemic application of dopaminergic agents on tail flick latency in the rat. Eur J Pharmacol 117:287-294. 1985

[2] Fleetwood-Walker SM et al., Antinociceptive actions of descending dopaminergic tracts on cat and rat dorsal horn somatosensory neurones. J Physiol 399:335-348. 1988

[3] Holstege JC et al., Distribution of dopamine immunoreactivity in the rat, cat and monkey spinal cord. J Comp Neurol 376:631-652. 1996

[4] Sonohata et al., Actions of noradrenaline on substantia geltatinosa neurones in the rat spinal cord revealed by in vivopatchrecording. J Physiol 555(2):515-526. 2003

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Finite element analysis on the mechanical stability of 3D bone scaffolds depending on the pore geometry

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Summary

In the present paper we describe the influence of the pore geometry and subsequently the porosity on the structural stiffness of 3D bone scaffolds predicted with finite element analysis. Thirty-four finite element models were created with different porosities by varying the parameters for pore geometry. Adequate material properties, derived from experimental testing were used for the simulation. The calculations revealed a nonlinear correlation between structural stiffness and porosity. Furthermore, we found different values for the structural stiffness but with similar porosities of the numerical models. Therefore structural stiffness of bone scaffolds cannot be correlated only with porosity without concerning the strong dependence on the pore geometry.

Introduction

Treatment of large bone defects is a current challenge in orthopaedic surgery. The use of autologous material is still deemed to be the "Gold-standard" although there are several disadvantages for the patient [1,2]. Therefore synthetic scaffolds, e.g. based on calcium phosphate or titanium were developed to support bone regeneration. Besides biological aspects like biocompatibility the mechanical stability and high porosity with an interconnecting pore system having a suitable pore size are of great importance to enable bone and endothelial cell ingrowth. Especially rapid prototyping techniques like e.g. electron or laser beam melting offers the possibility to gain control about the architecture of the pore geometry and subsequent on the mechanical properties [3]. In order to analyze the influence of pore geometry on the structural stiffness of the 3D bone scaffolds we created thirty-four different numerical models for subsequent finite element analysis. Adequate material properties used for the numerical analysis were derived from experimental testing of titanium samples.

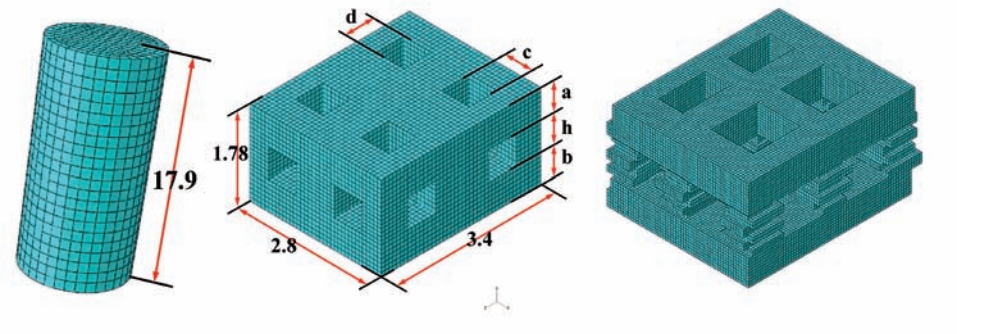

Figure 1: Numerical models used to determine the material properties (left), the porous cube to analyze various porosities depending on the values c, d and h (middle) and the model derived from SEM analysis. Values given in [mm].

Materials and Methods

In order to use an adequate material behaviour for the numerical analysis a cylindrical solid test sample (9 mm diameter, 17 mm height) was fabricated from titanium powder (Ti6Al4V) via selective electron beam melting (SEBM). Axial compression testing with a universal testing machine (Zwick Roell, Ulm, Germany) was performed up to a load of 95 kN. Load and displacement curves were recorded.

Subsequently, a numerical model with identical cylindrical shape was generated (Fig. 1, left) and displacements as performed on the experimental setup were applied. By modification of the material properties for both elastic and plastic parameters the numerical load and displacement curves could be adapted to the experimental values.

In a following step a second numerical model with an edge length of 2.8 x 3.4 mm and a height of 1.78 mm was created (Fig. 1, middle). Geometric dimensions were derived via SEM analysis and formed a small section of a porous scaffold with an overall porosity of approximately 63 %. Eight ideal rectangular cuts with various geometric dimensions in all three directions were placed in the cube to vary porosity in the range from zero (solid cube) to 80.2 % by variation of the parameters c, d and h. Porosity of the scaffold is defined as described in following equation:

$$\text{Porosity} = \left(1 - \frac{V_{scaffold}}{V_{cube}}\right) \cdot 100\% \text{Porosity} = \left(1 - \frac{V_{scaffold}}{V_{cube}}\right) \cdot 100\%$$

wherein $V_{scaffold}$ indicates the volume of the actual model and V_{cube} indicates the volume of the solid cube with constant value of 16.9 mm³. Furthermore, a numerical model was created considering the real, irregular pore structure of the scaffold derived from SEM data (Fig. 1, right).

Displacement of 0.3 mm in vertical direction was applied on the upper surface of the numerical models to simulate compression loading. Subsequently, the structural stiffness calculated from applied load and displacement of the models was analyzed. For all numerical models convergence testing was performed to avoid influences of the mesh density.

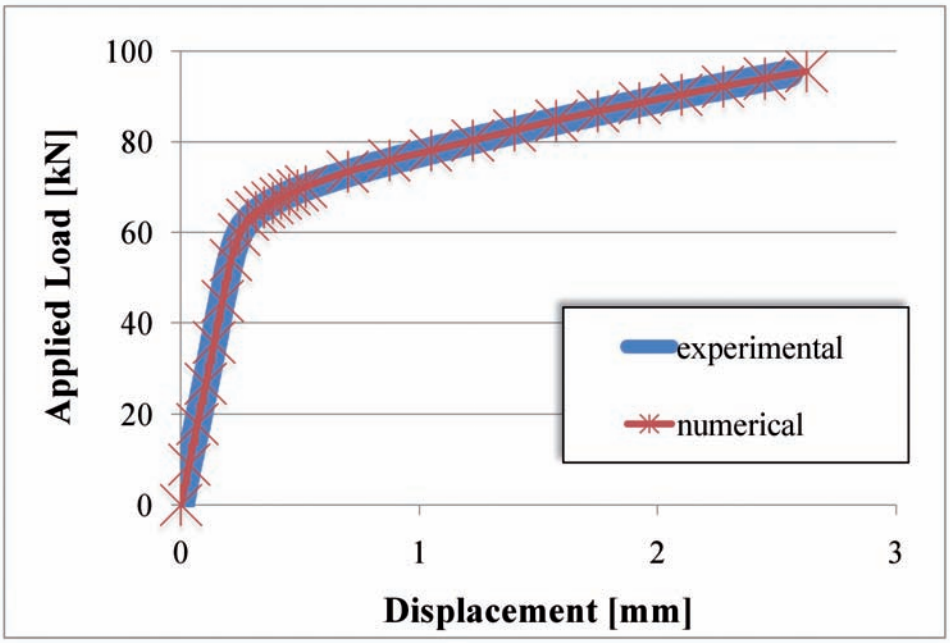

Figure 2: Load-displacement curves of the experimental testing (blue line) and the numerical analysis with adapted material properties (red line).

Results

The load displacement curves recorded from the experimental testing showed good correlation with the numerical analysis with a deviation less than 2% (Fig. 2).

The analysis of the influence of pore geometry showed a nonlinear correlation between decreasing structural stiffness and increasing porosity of the test samples. Structural stiffness was normalized to model with 600 µm pore size. The calculated correlation curve and coefficient of determination are shown in Fig. 3. Furthermore, modification of the pore size by the variables c and d exhibited a stronger effect on the structural stiffness than by variation of the strut height h at similar values of porosity.

The structural stiffness of the numerical model derived from SEM analysis was similar to those with ideal rectangular pores at similar values of porosity.

Conclusion

In the present study the material properties of 3D bone scaffolds based on Ti6Al4V were derived from experimental testing and implemented in numerical analyses with adequate accuracy. Our results demonstrate the strong influence of the porosity with a regular shape of the pores on the mechanical stability of the test samples. We could show that the structural stiffness did not decrease linearly with the porosity as reported in literature [4]. Furthermore, mechanical properties of the scaffold cannot

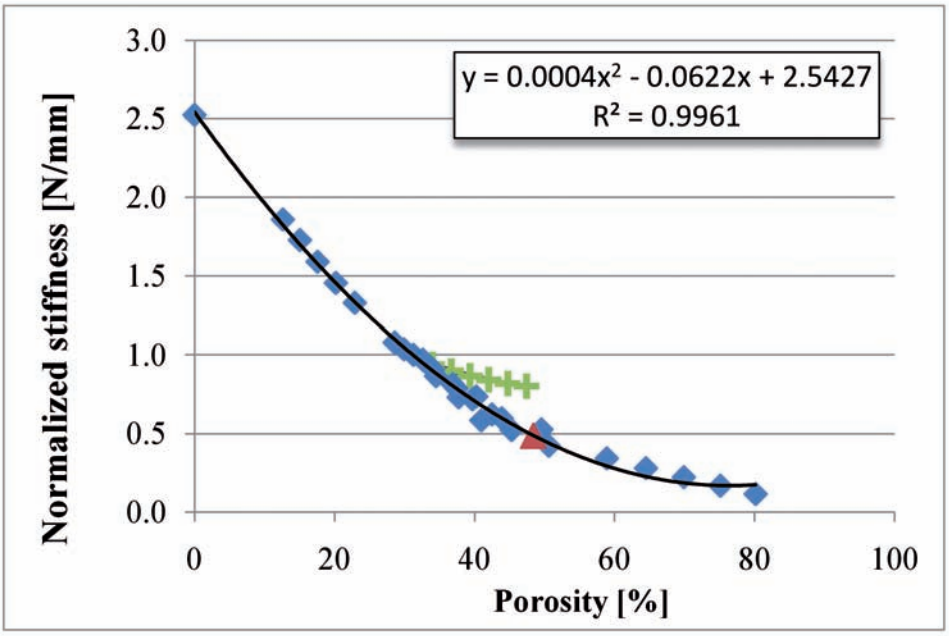

Figure 3: Influence of the porosity on the structural stiffness. Only few influence by variation of parameter h (green marks) in contrast to variation of parameter c and d in the range of porosities between 30 and 50 %. Structural stiffness of the irregular SEM-model (red mark).

be directly correlated with the porosity. Increasing the porosity by varying the strut height h did not decrease the structural stiffness as strong as it could be observed by varying the parameters c and d in the same range of porosity. Nevertheless, concerning the real irregular geometry of the pores the amount of areas with high stress within the scaffold during mechanical loading increased as reported [5], although only small deviation on the structural stiffness could be observed. The material behaviour determined seems to be suitable for further numerical and biomechanical studies using 3D bone scaffolds.

References

1. LAURIE SW, KABAN LB, MULLIKEN JB, MURRAY JE. Donor-site morbidity after harvesting rib and iliac bone. Plast Reconstr Surg. 73(6):933-8, 1984
2. YOUNGER EM, CHAPMAN MW. Morbidity at bone graft donor sites. J Orthop Trauma. 3(3):192-5, 1989
3. HEINL P, KOERNER C, SINGER RF. Selective Electron Beam Melting of Cellular Titanium: Mechanical Properties. Advanced Engineering Materials. 10(9):882-8, 2008
4. LIN L, TONG A, ZHANG H, HU Q, FANG M. The mechanical properties of bone tissue engineering scaffold fabricating via selective laser sintering. International Conference on Life System Modeling and Simulation. Shanghai: 146-152, 2007
5. CAHILL S, LOHFELD S, MCHUGH PE. Finite element predictions compared to experimental results for the effective modulus of bone tissue engineering scaffolds fabricated by selective laser sintering. J MATER SCI MATER MED. 20(6):1255-62, 2009

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Rotator cuff regeneration with bone marrow-derived mesenchymal stem cells in a rabbit model

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Introduction

Rotator cuff tears are among the most common injuries afflicting the shoulder, and clinical intervention is required. Rotator cuff injuries do not heal due to the complex anatomy and extended range of motion of the shoulder joint, as well as the relative weakening and hypovascularization of the cuff tendons post-injury[1]. The surgery to repair these tears is one of the most common procedures performed by orthopedic surgeons. Despite improvements in the understanding of these disease processes and advances in surgical treatment options, failure rates of rotator cuff repairs have ranged from 20 to 90%[2], depending on the patient age, tear size and chronicity, muscle atrophy and degeneration, tendon quality, repair technique, and the postoperative rehabilitation protocol[3].

In recent years, regeneration medicine is gaining attention, and tissue engineering[4] techniques have been introduced to various medical fields. We have previously described the successful results of tendon insertion regenerated by polyglycolic acid (PGA) sheets in a rabbit model. These results, however, had several weak points; regeneration of the fibrocartilaginous tendon insertion was slow, and the regenerated tissues primarily consisted of type III collagen[5].

Another promising method to use non-differentiated progenitor cells of musculoskeletal tissues to regenerate soft and hard tissues, as established by Caplan et al.[6], has utilized noncommitted progenitor cells from musculoskeletal tissues to regenerate both soft and hard tissues. These cells, termed mesenchymal stromal cells (MSCs), were isolated from a small volume of bone marrow aspirate and expanded in culture without undergoing differentiation to more advanced cell types.

The hypothesis of the present study was that an absorbable artificial scaffold with seeded MSCs could aid reconstruction of the fibrocartilaginous tendon-bone insertion, as well as enhance type I collagen production of the regenerated tendons *in vivo*. To test this hypothesis, we established a rabbit model of rotator cuff defects. Rabbits were treated with a PGA sheet embedded with seeded MSCs. We evaluated the histology of

the regenerated tendons, including the production of type I collagen, and determined the efficacy of MSCs in enhancing tendon-to-bone healing.

Materials and Methods

The PGA sheet were cut and doubled measuring 10×5×1 mm as a scaffold. Bone marrow-derived MSCs (bMSCs) were isolated from the tibia of 30 Japanese white rabbits under sterile conditions[7]. After culturing we seeded these collected cells onto each PGA scaffold by pipetting 100-μL aliquots of the cell suspension (1.0×10^6 cells). The cell-polymer complex was incubated at 37 degrees Celsius in a humidified chamber of 5% carbon dioxide overnight. The deficit of infraspinatus tendons of Japanese white rabbits were reconstructed with the PGA sheet (PGA group) (n=30), and that with cultured MSCs (MSC group) (n=30). They were sacrificed at 4, 8 and 16 weeks after operation. Continuous sections (5μm thick) were cut in the transverse plane in the middles of tendons, and stained with haematoxylin and eosin and Safranin-O for the histological characterization of tissue composition, and the histological findings were evaluated at both of tendon proper and the point of tendon insertion. Furthermore, type I and type III collagen in the reparative tissues was identified and examined immunohistochemically. In order to evaluate quantitatively, we utilized tendon maturing scoring system[8] consisted of six histological parameters including cellularity, fibrocytes vascularity, fiber diameter, cells parallel, fibers parallel, insertion histological pattern and collagen immunohistochemical findings. They were also evaluated biomechanically by measuring ultimate mechanical strengths and Young moduli at 4 and 16 weeks by a conventional tensile tester. Statistical analyses of the tendon maturing score and the mechanical properties were performed using 1-way analyses of variance and Fisher protected least significance post hoc test; a p value of <0.05 was considered to be statistically significant.

Results

At 4 weeks after operation, there were no histological findings and statistically significant tendon maturing scores in these two groups. At 8 weeks, although the PGA fibers ware remained yet and mild foreign body reactions were seen, fibrocartilage layer was found regularly in insertion in the PGA group (Figure 1A). On the other hand, in the MSC group not only the fibrocartilage layer but also the Sharpey's fibers were observed in insertion (Figure 1B). At 16 weeks after operation, in both group we found the four layer cartilage pillar pattern and the PGA fibers were completely disappeared. In immunohistochemical staining, more type I collagen (Figure 2A) could be found than type III (Figure 2B) at 16 weeks in the MSC group while more type III collagen (Figure 3A) could be found than type I (Figure 3B) in the PGA group. The tendon maturing score had a statistically significance at 8 and 16 weeks after operation between PGA and MSC group. The results of mechanical properties show that the regenerated tendons in the MSC group had adequate ultimate tensile strengths (3.70±0.27MPa) than the PGA group (2.11±0.90MPa) at 16 weeks after operation. There was no statistically significance about the Young's Moduli at 16 weeks (PGA 4.70±0.94, MSC 4.97±1.33). There was no statistically significance at 4 weeks after operation. All tendon-bone complexes failed at the point of tendon insertion.

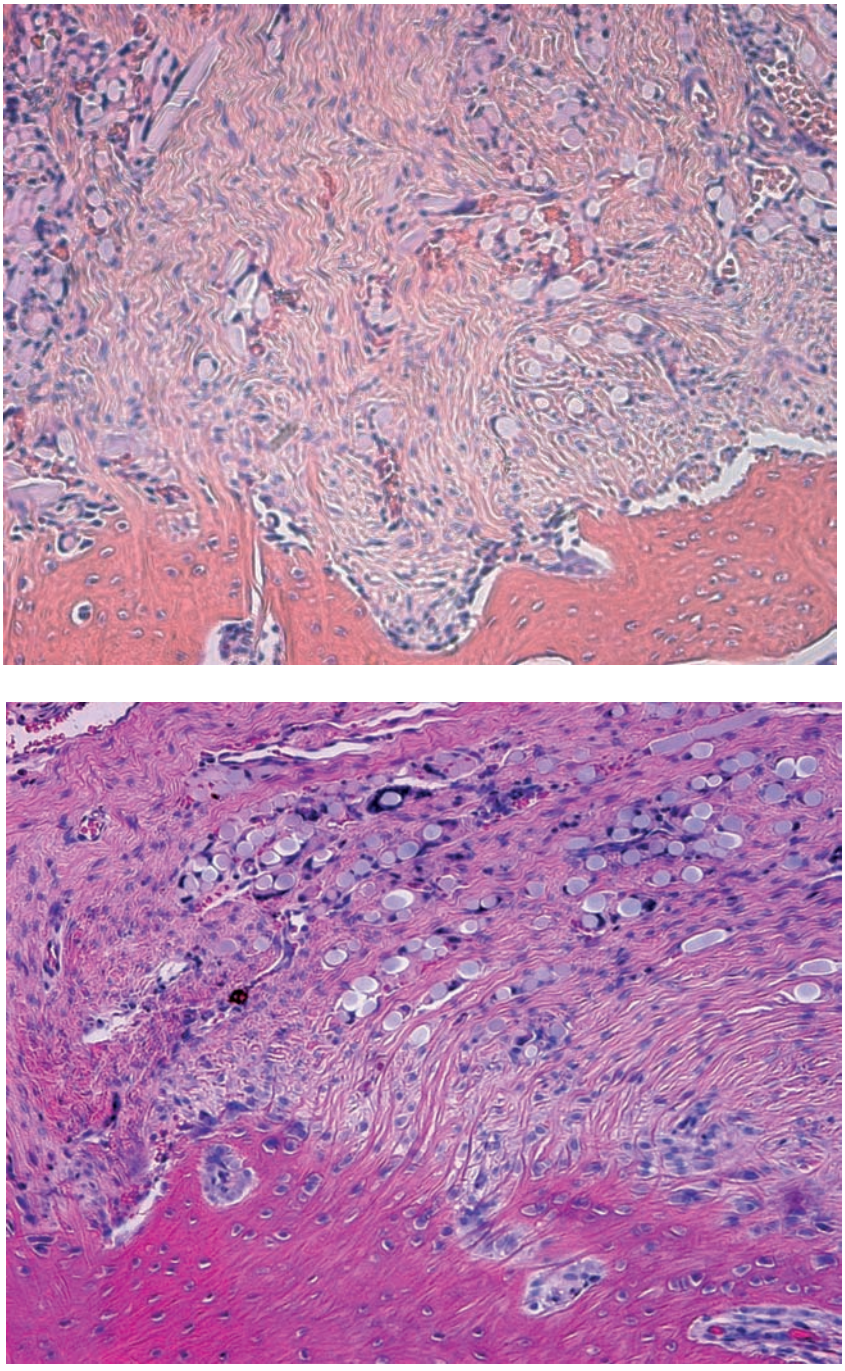

Figure 1 Photomicrographs of specimens at the PGA-bone interface 8 weeks after operation. A: in PGA group. B: in MSC group. (H-E stain. x200)

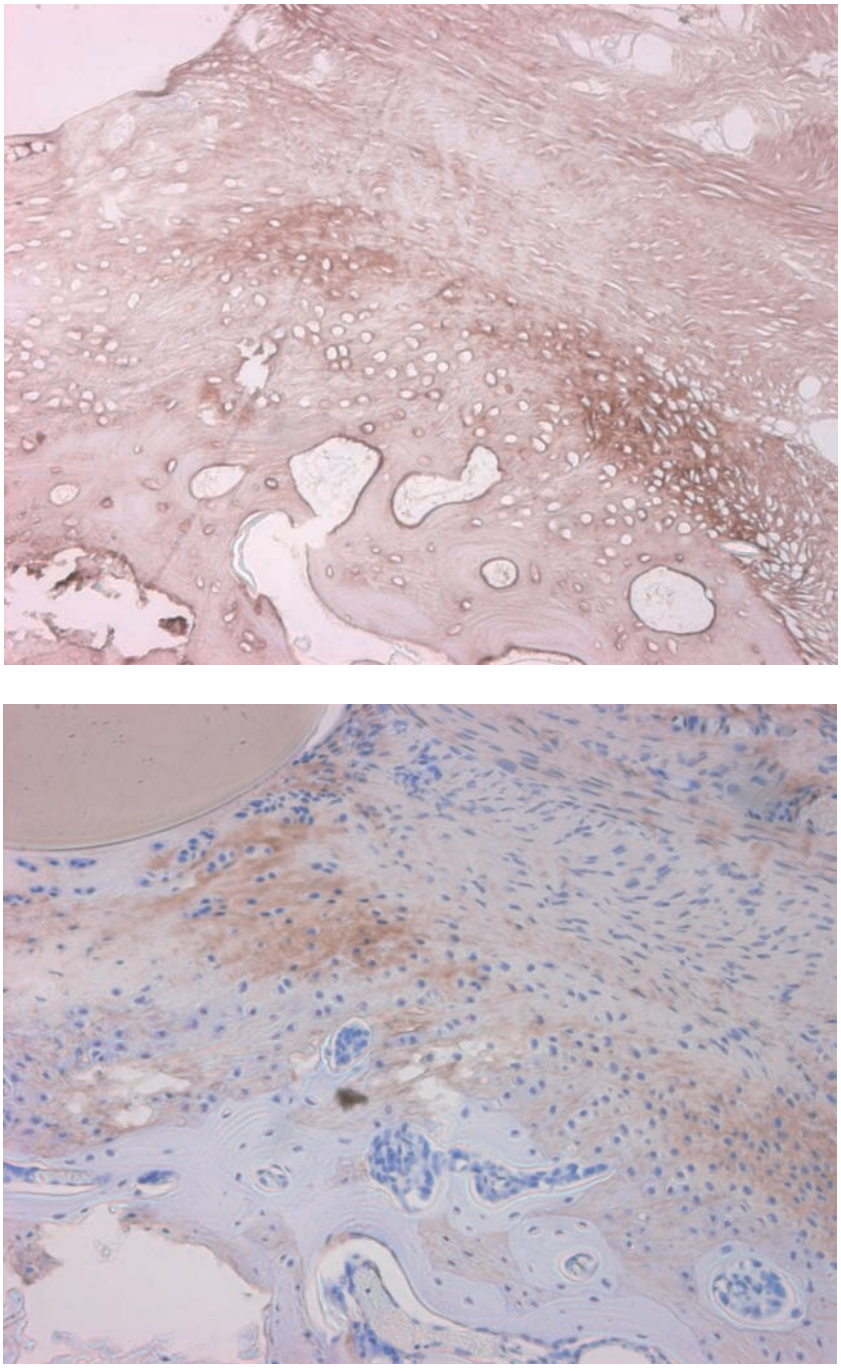

Figure 2 Photomicrographs of specimens at the PGA-bone interface in MSC group 16 weeks after operation. A: type I collagen. B: type III collagen. (immunohistochemical stain x200)

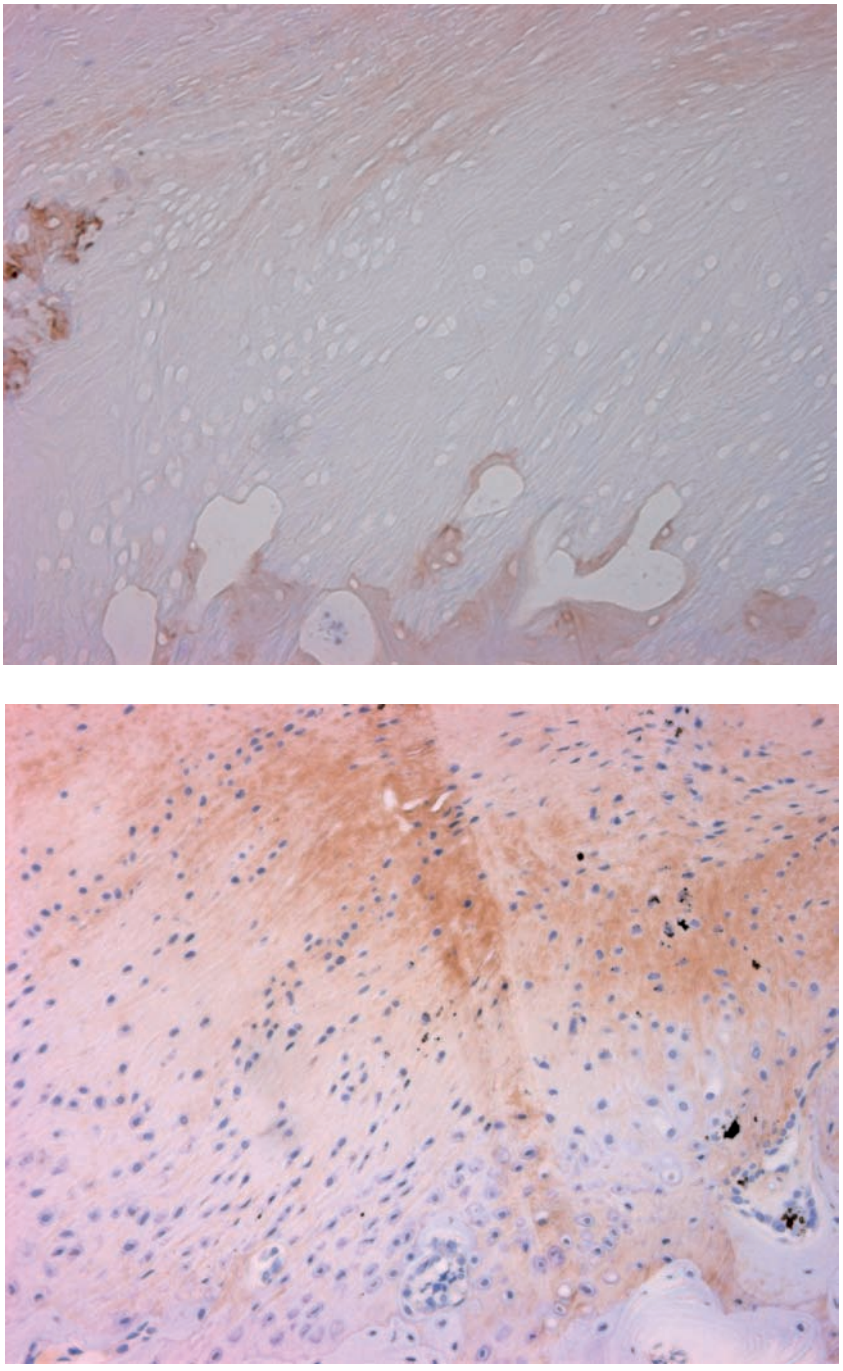

Figure 3 Photomicrographs of specimens at the PGA-bone interface in PGA group 16 weeks after operation. A: type I collagen. B: type III collagen. (immunohistochemical stain x200)

Conclusions

In the present study, we hypothesized that the application of bone marrow-derived MSCs would increase the amount of fibrocartilage formation and improve type I collagen-rich fiber organization at the insertion site, and obtain an ideal mechanical properties as a result. We were able to obtain successful results in regenerating the fibrocartilage layers, with many Sharpey's fibers at the tendon insertion sites at early time points and greatly increased type I collagen 16 weeks after surgery compared to the PGA group. Previous studies have shown that differentiation of bone marrow-derived MSCs can be adopted by the specific surrounding environment[9,10]. The delivery of high concentrations of undifferentiated MSCs to connective tissue defects has shown particular promise in animal studies for bone, cartilage, and tendon repair[7,11,12]. It is reasonable to expect that the bone marrow-derived MSCs can differentiate as well as promote the regeneration of bone, fibrocartilage-like tissue, and tendons under the specific environmental conditions of the tendon-bone interface.

The main component of extracellular matrices in ligaments and tendons is type I collagen. The mechanical properties of regenerated tissues, which predominantly consist of type III collagen, are likely to be inferior to those of the native tissues[13]. We confirmed that the relative proportion of dense type I collagen fibers against type III collagen seen in the MSC group led to enhanced the mechanical strength in regenerated tissues, although the mechanical properties of the regenerated tendon were inferior to the natural infraspinatus tendon regarding tensile strength and Young's modulus. The reason for dissociation between the abundance of type I collagen and the lower mechanical properties is unclear. The imbalance between type I collagen and other types of collagen may thus have caused this results because Silver et al. described that crosslinks are important in the mechanical coupling between collagen molecules[14]. Otherwise, the collagen fibril length in these regenerated tendons may be short. Silver et al. have suggested that both ultimate tensile strength and the elastic modulus are more dependent on fibril length than diameter[14]. Further research will thus be necessary to clarify these reasons.

In conclusion, bone marrow-derived MSCs had a good capacity to regenerate tendon-bone insertion including the production of type I collagen. However, the mechanical properties in the regenerated tendon were unsatisfactory because they were inferior to the normal tendon, despite the gradually increasing values at each time point. It is likely that this method will therefore be useful for the regeneration of a rotator cuff defect in clinical application.

References

1. Yamanaka K et al. The joint side tear of the rotator cuff. A followup study by arthrography. Clin Orthop Relat Res. 304,68-73,1994.
2. Gerber C et al. The results of repair of massive tears of the rotator cuff. J Bone Joint Surg Am,82,505-515,2000.
3. Cofield RH et al. Surgical repair of chronic rotator cuff tears. A prospective long-term study. J Bone Joint Surg Am. 83,71-7,2001.
4. Langer R et al. Tissue engineering. Science. 260,920-926,1993.
5. Yokoya S et al. Tendon-bone insertion repair and regeneration using poly-glycolic acid sheet in the rabbit rotator cuff injury model. Am J Sports Med. 36,1298-309,2008.

6. Caplan AI. Mesenchymal stem cells. J Orthop Res. 9,641-50,1991.
7. Awad HA et al. Autologous mesenchymal stem cell-mediated repair of tendon. Tissue Eng. 5,267-77,1999.
8. Watkins JP et al. Healing of surgically created defects in the equine superficial digital flexor tendon: Collagen-type transformation and tissue morphologic reorganization. Am J Vet Res. 46,2091-96,1985.
9. Jiang Y et al. Pluripotency of mesenchymal stem cells derived from adult marrow. Nature 418,41-49,2002.
10. Reyes M et al. Origin of endothelial progenitors in human postnatal bone marrow. J Clin Invest. 109,337-346,2002.
11. Richards M et al. Marrow-derived progenitor cell injections enhance new bone formation during distraction. J Orthop Relat Res. 17,900-8,1999.
12. Wakitani S et al. Mesenchymal cell-based repair of large, full-thickness defects of articular cartilage. J Bone Joint Surg Am. 76,579-592,1994.
13. Frank C. Medial collateral ligament healing: a multidisciplinary assessment in rabbits. Am J Sports Med. 11,379-389,1983.
14. Silver FH et al. Transition from viscous to elasticdependency of mechanical properties of self-assembled collagen fibers. Connect Tissue Res. 42,155-164,2000.

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Rationale of the original All-Inside Technique

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Summary

The success of Anterior Cruciate Ligament reconstruction depends on 3 major factors: biological, mechanical and rehabilitative. However more variables must be considered for ACL-R: graft choice, tunnel placement, graft tension and fixation, tunnel motion and graft healing.

Today it is not possible to create a normal ACL, not only because of intrinsic factors (anatomy, function, proprioception and structural properties) that influence the biological integration of the graft but also due to extrinsic factors regarding the patient and surgeon (skill, accuracy of the diagnosis, graft selection, surgical technique, fixation device and rehabilitation).

Traditional surgical techniques may improve the biomechanical properties of the graft but they cannot alone guarantee successful grafted tendon remodeling because graft remodeling depends on graft/bone interaction and graft/joint environment interaction.

Our all inside technique for ACL reconstruction offers a reliable and reproducible technique with the possibility to adapt the half tunnels to the graft length thereby reducing the bone loss.

Introduction

Anterior cruciate ligament (ACL) injury is a common problem, especially in athletes.

ACL reconstruction is today a common surgical procedure; the goal of ACL reconstruction (ACL-R) is to restore normal anterior knee stability.

The success of reconstruction depends on 3 major factors: biological, mechanical and rehabilitative. However more variables must be considered for ACL-R: graft choice, tunnel placement, graft tension and fixation, tunnel motion and graft healing.

The surgical outcome depends on the ability of the graft to reproduce the restraining action of the ACL and restore normal knee kinematics.

Figure 1

The aim of this paper is to describe the background and the rationale of using only one tendon in ACL-R.

Proprioceptive aspect makes ACL a real sensory organ through the hamstring reflex arch (Figure 1)

None of the methods and techniques proposed are able to improve the biological strategies on the graft but it is necessary to both improve surgical procedures and develop novel biological treatments.

For these reasons we developed a technique called "All-Inside" technique for ACL-R. It is a double half tunnel technique, one tibial and one femoral, manually drilled tunnels, in an in-out direction using a special instrument.

Today it is not possible to create a normal ACL, not only because of intrinsic factors (anatomy, function, proprioception and structural properties) that influence the biological integration of the graft but also due to extrinsic factors regarding the patient and surgeon (skill, accuracy of the diagnosis, graft selection, surgical technique, fixation device and rehabilitation).

ACL-R using hamstring tendons has recently received attention because of less donor site morbidity compared to when the patellar tendon is used. Many factors have contributed to extending use to the semitendinosus: loss of active knee flexion angle, lower internal tibial torque and muscle weakness and its effects on function and stability after sacrifice of hamstring tendons.

The semitendinosus tendon is needed to prevent excessive anterior tibial translation when the knee is near full extension.

Using Bone Patellar Tendon Bone can determine devastating complications even on the overall knee function: intraoperative and postoperative patellar fracture (incidence 0.23-2.3 %), neurological lesions, (Saphenus Nerve), anterior knee pain and difficulties in restoring the knee R.O.M.

Allograft harvested under sterile conditions (not irradiated or gas sterilized) induce immunological response with bone resorption and tunnel widening; irradiated they reduce structural properties

The ideal ACL-R should allow no damage to the proprioceptive system, be less invasive, preserve knee biomechanics, reduce ligamentisation time and bone loss, be

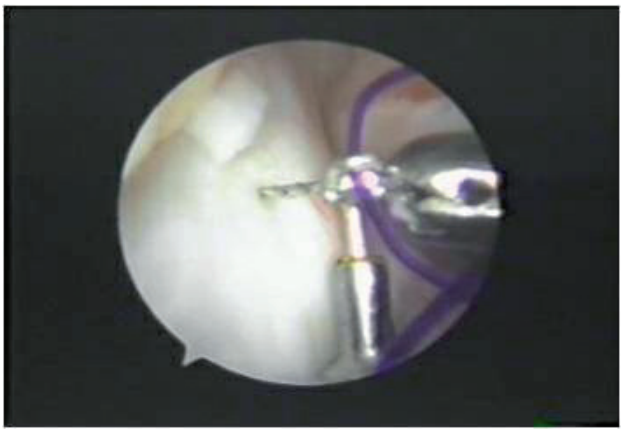


Figure 2

easy to perform, allow a fast recovery time for return to sport and/or work activities and offer good cosmetics.

Matherials and Methods

The advantages of the All-Inside Technique are that it uses only one tendon (Semitendinosus or Gracilis); needs a femoral half and tibial tunnel with the possibility of varying the length of the half -tunnel graft; no burning of the tunnel by drill; better tunnel healing; lower infection risk and less bleeding and limited esthetical damage.

The concept and the application of the All-Inside Technique are based on the most recent studies in biomechanics and tissue biology.

The biomechanical rationale is an in vivo study with the Strain Gauge Device (Dvrt) calibrated and surgically implanted (Figure 2) in the antero-medial band of the intact ACL. The long axis of the Dvrt was aligned with the fibres of the ACL.

The subject was asked to perform three types of movement: the peak of knee flexor muscle contractions occurred just before the peak of the ground reaction force which precedes ground impact.

This study demonstrates the protective role of the hamstrings towards the ACL with obvious rebounds in injury prevention, in post-surgical rehabilitation programs, in criteria to return to sport and in the technical choice of graft._

The background of All-Inside Technique is to preserve as much of the hamstrings tendon as possible during ACL-R with the biological rationale: graft remodelling.

Traditional surgical techniques may improve the biomechanical properties of the graft but they cannot alone guarantee successful grafted tendon remodeling because graft remodeling depends on graft/bone interaction and graft/joint environment interaction.

Graft/bone strategies are very important to ensure presence of biological bone morphogenetic proteins and sharpey like collagen fiber. This is the reason for manual

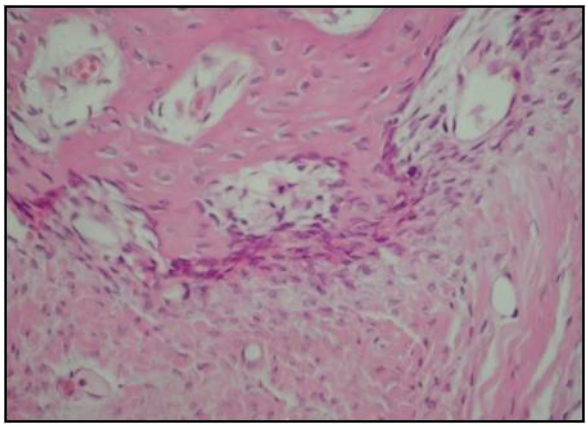


Figure 3

drilling which reduces the possibility of an inflammatory process with less necrosis preservating trabecular bone and determining better press-fit.

In the rabbit studies manual drilling of the tibial tunnel used in the all-inside technique caused less necrosis and enhanced greater osteoblastic activity (Figure 3).

Results

During the development of the technique for ACL-R much thought was dedicated to strategies which would enhance bone remodeling, bone-graft osteo-integration and bone sparing during tunnel drilling.

Manual drilling enhances these aspects.

Mechanical rationale for ACL-R using one hamstring is based on the absence of differences in clinical outcomes when using the ST alone versus the ST-Gr construct.

In biomechanical studies in vivo have shown that the internal rotation torque deficit is significantly higher in the ST-Gr group.

Does ACL-R with a Semitendinosus or Gracilis tendon alone using the All-Inside technique restore normal knee kinematics and in-situ force in the graft?

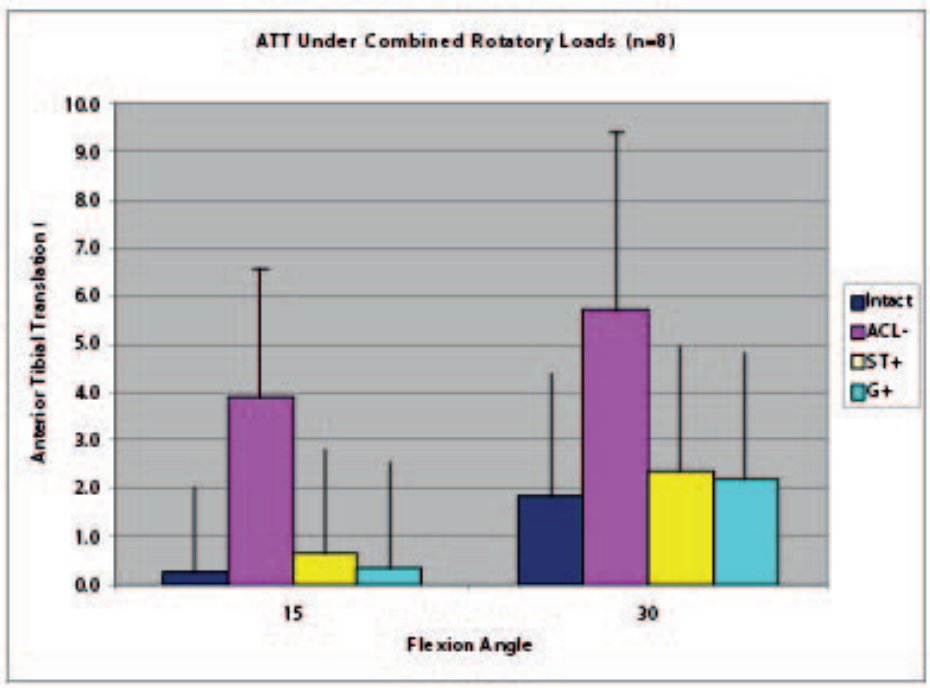
Our hypothesis is that ACL reconstructions with All-inside technique using either the semitendinosus or the gracilis tendon graft could restore the normal knee kinematics and the in situ force in the ACL similar to the intact knee

There would be no significant differences between reconstructions in terms of knee kinematics and in-situ forces in the graft.

Our aim was to determine whether the use of one hamstring tendon (semitendinosus or gracilis) graft in the All-inside technique for ACL-R could restore knee kinematics and the in situ force of the ACL to the level of an intact knee under applied loads simulating clinical exams using a robotic UFS testing System Robotic/ UFS Testing System.

The studies were conducted using10 human cadaveric knees in external loading conditions: anterior tibial load and combined rotator load.

Both autografts (semitendinosus or gracilis) restored knee kinematics to within 1.3



Graph 1

mm of those of the intact knee and the overall in-situ forces in the grafts were not significantly different to those of the intact ACL.

The kinematics of the reconstructed knee and in-situ forces of the St. and grafts were not different from each other in these loading conditions.

Only one hamstring tendon could be used as an autograft for ACL-R.

In conclusion the all-inside technique using one hamstring tendon can restore knee stability and *in-situ* force of the ACL under both anterior tibial and rotatory loads.

This could be an effective alternative to procedures which use both the semitendinosus and gracilis tendon. (Graph 1).

Surgical technique

Graft harvest. After an arthroscopic evaluation and treatment of possible associated lesions, the semitendinosus or the gracilis are harvested through a small incision (usually 1.5 cm) placed 2 cm medial to the tibial tubercle. The incision is made directly over the palpated tendons. The sartorius fascia is opened between the gracilis and semitendinosus. Using blunt dissection the semitendinosus tendon is freed from the bands that could cause a premature amputation of the tendon. The tendon is then released from its tibial insertion. Based on the length of the tendon it is triplicated or quadruplicated over a temporary suture loop and the size is measured.

Arthroscopy. Using a lateral infrapatellar portal and a standard antero-medial access chondral and meniscal lesions are treated if indicated. The notch is debrided and when it is possible we leave the ACL remnant as suggested by Georgoulis. A

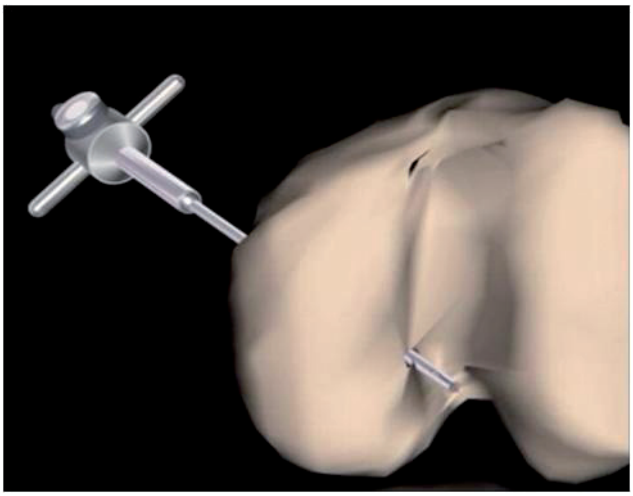


Figure 4

bony notchplasty is not routinely performed. A drill guide is then used in order to insert a tibial and femoral pin-guide. The introduction point of the tibial pin-guide is 2cm medial to the tibial tubercle with the knee flexed at 80 degrees. The angle of introduction is 20 degrees from the frontal plane and 45 from the tibial plateau. The femoral pin-guide is introduced out-in having the access 2 cm proximal and 1 cm anterior from the lateral femoral epicondyle. Angulation is 40 degrees lateral to the femoral axis and 45 degrees laterally. Following the pin-guide direction a femoral and tibial tunnel 4 mm wide is drilled out-in. In order to decide the endobutton loop length and prepare the graft, we do all measurements now: tibial and femoral hole length, intra-articular distance between the two holes and external femoral cortex-skin distance. After measuring the graft, it is finally harvested with an endobutton. Two polyester braided suture (number 5 and number 2) are passed trough the outside holes of the endobutton in order to pass the graft and flip the endobutton. A suture is placed on the graft to mark the femoral half tunnel length.

Manual drilling of half tunnels. Using a specific device (Figure 4) the tibial and femoral half tunnels are manually drilled. The device consists of a drill guide 4mm wide with length indicators (every 0.5 cm) and drill wings which can be turned out inside the joint (Figure 5). It is possible to choose between 4 different drill guides and wings ranging from 6mm to 9mm in diameter. The half tunnel is drilled manually in-out at a chosen length (25-30mm) according to the graft. To maintain the position and the direction on the external femoral cortex we fix a cannulated groove probe. In this way we will obtain a femoral and tibial half tunnel ranging from 25 to 30 mm in length. In an earlier study we found that manual drilling lead to considerably less heat necrosis in the drill holes compared to power drilling (Cerulli et al, unpublished data).

Graft introduction and fixation. The graft is introduced from the antero-medial portal. Two wires are passed, respectively, through the femoral and tibial tunnels in an out-in way and their respective loop is pulled out from the antero-medial portal. The

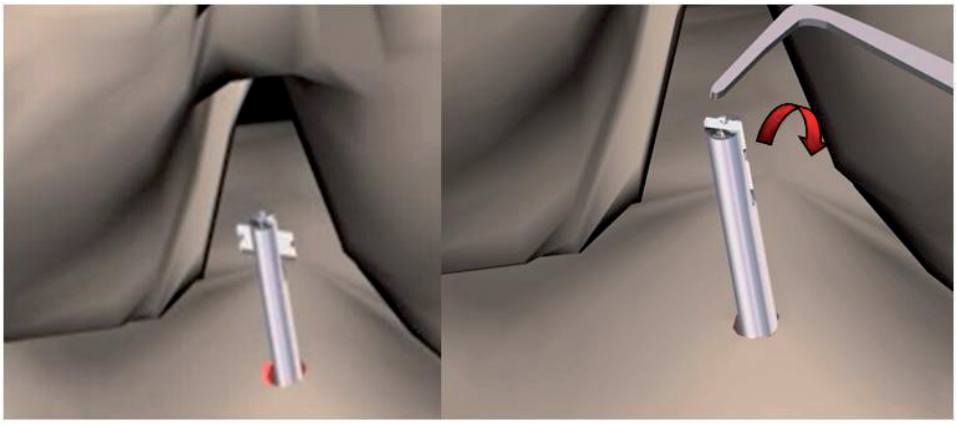


Figure 5

endobutton polyester braided sutures are passed through the loop of the femoral wire and then pulled out from the tunnel. The number 5 suture is then pulled to advance the endobutton through the tunnel. When the marking suture of the graft is inside the tunnel the number 2 braided suture is pulled to flip the endobutton device. The sutures at the tibial side of the graft are then passed through the loop of the tibial wire to insert the graft into the two half-tunnels. The graft is tensioned and tested with a probe. Tibial fixation is realized using the Cobra Ligament Fixation Device or tying the wires over a malleolar screw with a washer.

Conclusions

Our all inside technique for ACL reconstruction offers a reliable and reproducible technique with the possibility to adapt the half tunnels to the graft length thereby reducing the bone loss, allowing the use of one single tendon triplicated or quadruplicated and improving the quality of the contact area graft-bone. The manual drilling could be considered an important factor to improve bone-graft integration reducing the amount of necrosis provoked by the heat of the motorized drilling. However, before this technique can be generally recommended, we need to perform a prospective randomised study comparing our new technique with earlier standardized techniques.

References

1. Aglietti P, Buzzi R, D'Andria S: Patellofemoral problems after intraarticular anterior cruciate ligament reconstruction. Clin Orthop 288:195, 1993.
2. Bartlett R, Clatworthy M, Nguyen T. Graft selection in reconstruction of the anterior cruciate ligament. J Bone Joint Surg Br. 2001;83:625- 634.
3. Buss D, Warren R, Wickiewicz T: Arthroscopically assisted reconstruction of the anterior cruciate ligament with use of autogenous patellar-ligament grafts. J Bone Joint Surg Am 75:1346, 1993.
4. Georgoulis AD, Pappa L, Moebius U, Malamou-Mitsi V, Pappa S, Papageorgiou CO, Agnantis NJ, Soucacos PN. The presence of proprioceptive mechanoreceptors in the rem-

nants of the ruptured ACL as a possible source of re-innervation of the ACL autograft. Knee Surg Sports Traumatol Arthrosc. 2001 Nov; 9(6):364-8.

5. Winge S, Dunn P, Engstrom BK. Equal tension in all four strands of a semitendinosus graft with a low profile tibial fixation device (Cobra LFD). Knee Surg Sports Traumatol Arthrosc. 2006 Mar;14(3):287-90.
6. Howell S, Hull M: Aggressive rehabilitation using hamstring tendons. Am J Knee Surg 11:120, 1998.
7. Woo S, Hollis M, Adams D: Tensile properties of the human femur–anterior cruciate ligament–tibia complex. Am J Sports Med 19:217, 1991.
8. Dandy DJ. Historical overview of operations for anterior cruciate ligament rupture. Knee Surgery, Sports Traumatology, Arthroscopy 1996, 3(4):256–61.
9. Goradia V, Rochat M, Grana W: Tendon-to-bone healing of a semitendinosus tendon autograft used for ACL reconstruction in a sheep model. Am J Knee Surg 13:143, 2000.
10. Pinczewski L, Clingeleffer A, Otto D: Integration of hamstring tendon graft with bone in reconstruction of the anterior cruciate ligament. Arthroscopy 13:641, 1997.

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Arthroscopic treatment of recurrent anterior shoulder dislocations

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Introduction: Treatment of recurrent shoulder dislocation is a topic of considerable debate with surgeons obtaining equivocal results from both open and arthroscopic methods. We retrospectively evaluated the outcomes of arthroscopic repair for recurrent shoulder dislocations done in our center.

Methods: Twenty-four patients (19 males, 5 females; mean age 26.6 years; range 19-43 years) were treated by arthroscopic Bankart repair with suture anchors for post-traumatic recurrent anterior shoulder dislocations. Range of motion was measured pre and post-operatively and the patients were assessed using ROWE score for shoulder instability. The mean follow-up was 21.8 months.

Results: Functional results were excellent to good in 19 patients (79.1%) fair in 2 patients (8.4%) and poor in 3 patients (12.5%). The mean ROWE score was 80 (range of 35-95). There was a negligible loss of external rotation post-operatively but no cases of re-dislocation and no major complications.

Conclusion: Arthroscopic Bankart repair using suture anchors is a safe and reliable method of treating recurrent post-traumatic anterior shoulder dislocations.

Keywords: anterior shoulder dislocation, arthroscopic surgery, Bankart repair.

Introduction:

Orthopedic surgery is a field of constant evolution; similarly shoulder arthroscopy is constantly evolving with more surgeons preferring it and henceforth leading to a broader spectrum of indications. Although arthroscopic Bankart repair for anterior instability is widely performed, many surgeons are apprehensive and prefer open repair especially in cases of recurrent dislocations. Early results of arthroscopic repair were poor because of inappropriate choice of patients, insufficient release and repair of the labrum and also a steep learning curve for a technically demanding procedure. [5] However the recent reports on arthroscopic method are encouraging [1,2,3]. The advantages of arthroscopy include less surgical trauma, increased visualization, ability to repair multiple defects in a single sitting, minimal loss of external rotation and low cost [4] .The following study was done to evaluate the outcomes of arthroscopic Bankart repair using suture anchors.

Methods:

From 2007-2009, 24 patients with recurrent post-traumatic anterior shoulder instability were treated by arthroscopic Bankart repair using suture anchors in our center. 19 males and 5 females with a mean age of 26.6 years and range of 19-43 years were operated upon. It included 17 right and 7 left shoulders with 83.3% of them being on the dominant side. All the patients were treated conservatively prior to surgery with the exception of one patient who was treated by arthroscopic Bankart repair elsewhere. The inclusion criterion was recurrent anterior glenohumeral subluxation or dislocation after an initial episode of traumatic anterior shoulder dislocation. The exclusion criteria were multidirectional instability and Hill-Sachs lesions more than 25%.

The patients were diagnosed by medical history, physical examination and imaging prior to surgery. Detailed medical histories were obtained with regards to type of trauma and number of dislocations sustained; the time interval between the initial trauma to the surgery was also noted. Range of motion was measured using a goniometer and clinical examination done meticulously. All patients had a positive apprehension test and load and shift test. Radiographic evaluation was done with routine AP and Axillary views, and magnetic resonance imaging was done to rule out additional pathologies. No trial conservative management was offered and all the patients underwent arthroscopic stabilization. The ROWE score for shoulder instability was used for assessment of outcome [14].

Operative technique: All operations were performed under general anesthesia as a day care procedure. After the induction of anaesthesia, a thorough examination of the shoulder was done to assess the direction and magnitude of instability. The patients were then placed in lateral decubitus position and traction applied by means of pulley traction. Fluid irrigation was by means of arthroscopic pump and pressure set varied between 60-80; systolic BP was maintained at around 100mm Hg. The shoulder was prepared and draped in a sterile manner and bony landmarks were marked carefully. A standard posterior portal was made for initial inspection and guidance of other portals. 2 more portals – one superior and one anterior were made depending on the geometry of the labrum lesion. Complete diagnostic arthroscopy was done to assess the labrum, capsule, rotator cuff and to look for any Hill-Sachs lesions

Glenoid labrum was mobilized using an elevator and the glenoid was slightly abraded using a rasp. The first anchor was placed at 5.30-6.00 o clock position to create a lateral bumper effect. The second and third anchors were placed at 4 and 3 o clock positions respectively. Adequate care was taken to anchor the middle gleno-humeral ligament and superior gleno-humeral ligament in 0 degrees of rotation. We routinely used the fisherman's knot for all the cases .We would also like to stress that during knot tying a capsular shift was incorporated into the labral repair.

Postoperatively all the patients were placed in a sling with the arm in slight abduction for 6 weeks. Active wrist and elbow exercises were encouraged immediately after surgery. Patients were instructed to do pendulum exercises for the first 3 weeks, range of motion exercises barring abduction above 90 degrees were started after 3 weeks. Full shoulder mobilization and resistive exercises were allowed after 6 weeks. Gradual return to sports was allowed at 6 months post-operatively.

Results:

24 patients (19 males and 5 females) were evaluated. There were 17 right shoulders and 7 left shoulders with no bilateral cases. The dominant side was involved in 83.3% of the cases. The mean age at the time of operation was 26.6 years with a range of 19-43 years. All the patients had an initial first episode of traumatic anterior dislocation of the shoulder with sports trauma accounting for 16 (66.6%) of the cases. Road traffic accidents and fall injury contributed for the rest of the cases.

The mean number of dislocations per patient was more than 3 with a range from 2-9 dislocations. The mean interval time from the first traumatic event to arthroscopic stabilization was 3.7 years with a range of 10months-11 years. The mean duration of follow-up was 21.8 months with a range of 10-36 months. All the 24 cases demonstrated the classic Bankart lesion intraoperatively. However there were no bony Bankart lesions noted. 3 patients had associated SLAP type II lesions and 6 patients had a Hill-Sachs lesion less than 25%. We used 3 suture anchors for Bankart repair in 19 cases; 4 anchors in 5 cases. In 2 of the cases we were forced to reinsert an anchor due to loss of the anchor by backing out. There were no intra-operative complications related to the arthroscopic procedure with regard to neurovascular injuries or compartment syndrome. There was 1 case of mild infection noted on the 3rd postoperative day, which cleared up after an aggressive course of IV antibiotics.

The post-operative mean ROWE score was 80 with a range of 45-95. Functional results were excellent to good in 19 patients (79.1%), fair in 2 patients (8.4%) and poor in 3 patients (12.5%). Preoperative means for active flexion was 166°(range 120°-180°), external rotation was 68°(range 45°-90°), internal rotation was 78°(range 45°-90°); postoperatively it changed to 169° flexion (140°-180°), 65° external rotation (30°-90°) and 77° internal rotation (40°-90°). There was a mean 3° loss of external rotation. All the patients could return to work and resume their daily activities; among the sports related injuries (16 cases- out of which 11 were involved in active sports and rest 5 had stopped playing competitive games prior to surgery), 7 of them returned to pre surgery level of sports competition, 4 of them required minor modifications and the rest 5 cases who had stopped playing sports chose not to compete again.

Discussion:

Bankart lesion is the principal reason responsible for anterior glenohumeral dislocations and hence leading to instability. Bankart first described the Bankart lesion, as an avulsion of the labrum from the glenoid rim[7] .The anteroinferior labrum is the primary restraint for anterior humeral dislocation in abduction[6] .The currently accepted gold standard of treatment for anterior instability is repair of this Bankart lesion. Bankart repair can be done by either open or arthroscopic method [8].

Arthroscopic Bankart repair has numerous advantages compared to open repair. It is a minimally invasive approach with less trauma to the tissues. Recovery and hence rehabilitation is faster [9,10]. It has a cosmetic edge over open method; it results in small or minimal scars following the surgery. Early results were discouraging but the continuous evolution of arthroscopic surgery with modern techniques has made it a very viable option for labrum stabilization. The introduction of bio-absorbable

suture anchors reduces the risk of infection and removes fear of any unwanted metal being left behind in the shoulder joint.

In our series, all cases underwent an arthroscopic Bankart repair using suture anchors technique. Fisherman's knot was routinely used and a capsular shift incorporated into the labral repair [11]. There were no cases of redislocation and an excellent to good result in nearly 80% of our cases. These results compare favourably with those of open Bankart repairs and with recent studies comparing open and arthroscopic Bankart repairs [12,13]

The drawback of our study is the smaller number of cases and relatively short follow-up period. However with our short series, we would like to conclude that arthroscopic Bankart repair in the hands of a skilled and experienced surgeon is a safe and reliable method of treatment for recurrent anterior gleno-humeral shoulder dislocations.

References:

1. Kim SH, Ha KI, Cho YB, Ryu BD, Oh I. Arthroscopic anterior stabilization of the shoulder: Two to six-year follow-up. J Bone Joint Surg Am 2003; 85-A: 1511-8.
2. Sperling JW, Smith AM, Cofield RH, Barnes S. Patient perceptions of open and arthroscopic shoulder surgery. Arthroscopy 2007; 23:361-6.
3. Cole BJ, L'Insalata J, Irrgang J, Warner JJ. Comparison of arthroscopic and open anterior shoulder stabilization: A two to six- year follow-up study. J Bone Joint Surg Am 2000; 82:1108-14
4. Benedetto KP, Glotzer W. Arthroscopic Bankart procedure by suture technique: indications, technique, and results. Arthroscopy 1992; 8:111-5
5. Liu SH, Henry MH. Anterior shoulder instability. Current review. Clin Orthop 1996; 323:327-37.
6. Turkel SJ, Pavio MW, Marshall JL Girgis FG. Stabilizing mechanisms in preventing anterior dislocation of the glenohumeral joint. J Bone Joint Surg Am 1981; 63:1208-17.
7. Bankart ASB. Recurrent or habitual dislocation of the shoulder. BMJ 1920; 1:1132-3.
8. Guanche CA, Quick DC, Sodergren KM, Buss DD. Arthroscopic versus open reconstruction of shoulder in patients with isolated Bankart repair. Am J Sports Med 1996; 24:144-8.
9. Gartsman GM, Roddey TS, Hammerman SM. Arthroscopic treatment of anterior-inferior glenohumeral instability. Two to five-year follow-up. J Bone Joint Surg Am 2000; 82:991-1003.
10. Savioe FH 3rd, Miller CD, Field LD. Arthroscopic reconstruction of traumatic anterior instability of the shoulder. The Caspari technique. Arthroscopy 1997; 13:201-9.
11. Cole BJ, Romeo AA. Arthroscopic shoulder stabilization with suture anchors: technique, technology, and pitfalls. Clin Orthop 2001; 390:17-30
12. Karlsson J, Magnusson L, Ejerhed L, et al. Comparison of open and arthroscopic stabilization for recurrent shoulder dislocation in patients with a Bankart lesion. Am J Sports Med 2001; 29:538-42.
13. Kartus J, Ejerhed L, Funck E, et al. Arthroscopic and open shoulder stabilization using absorbable implants. A clinical and radiographic comparison of two methods. Knee Surg Sports Traumatol Arthrosc 1998; 6:181-8.
14. Rowe CR, Patel D, Southmayd WW. The Bankart procedure: a long-term end-result study. J Bone Joint Surg [Am] 1978; 60:1-16.

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Single Bundle versus Double Bundle in Anterior Cruciate Ligament Reconstruction The Concept of Complete Footprint Restoration

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Abstract

Guidelines for single- (SB) and double-bundle (DB) ACL reconstruction based on the concept of complete footprint restoration were introduced. The goal of the concept is to reconstruct a maximum of anterior cruciate ligament (ACL) insertion site area to regain a maximum of ACL function. It is based on the hypothesis, that the restored biomechanical envelope of the knee is a function of reconstructed ACL insertion site area.

Individual combinations of graft diameters and drill angles were calculated and matched for all individual insertion site lengths between 8 - 21 mm to maximize the percentage of anatomical footprint restoration. An "insertion site table" was developed to propose individual guidelines during ACL surgery for SB and DB ACL reconstruction based on the intraoperative measurement of the tibial insertion site length.

Our calculations support the use of SB in "small footprints" up to 13 mm, which may restore more than 95% of the native insertion site length. "Intermediate footprints" between 14 – 15 mm may be restored by both a SB or DB ACL reconstruction. For "larger footprints" of 16 mm or more DB has the potential to replicate 97% or more of the insertion site length which cannot be achieved by a SB ACL reconstruction.

Conclusion: The concept of complete footprint restoration aims to reconstruct a maximum of ACL insertion site area to restore a maximum of functional envelope of the knee. Depending on the individual situation different surgical approaches (SB/DB), graft diameters and drill angles may apply. An "Insertion Site Table" (see below) was designed to give guidelines for SB and DB reconstruction during surgery. According

to the new concept DB ACL reconstruction is only considered as a surgical tool for large footprints and is not indicated for smaller ones.

Introduction

Recent clinical studies document a rather mixed outcome between Single bundle- (SB) and Double bundle- (DB) ACL reconstruction with only view showing a significant advantage for DB [1,7-11,13,16]. This raised the question of its real advantage and it seems that only certain patients may benefit from the complex DB procedure - others may not.

Usually an anatomical SB procedure is performed by placing one single bone tunnel in the centre of the tibial and femoral ACL footprints. The bone tunnels are drilled according to the diameter of the prepared graft without considering the relationship between the size of the natural insertion site area (ISA) and the reconstructed one. This results in a randomized percentage of surgically restored ACL footprint.

However, several biomechanical studies demonstrated that ACL fibres of different parts of the insertion sites add different to knee function [2-6,12,14,15]. Consequently – by placing bone tunnels in a defined position of the ACL footprints the surgeon defines also the individual biomechanical envelope of the ACL reconstruction.

To restore a maximum amount of stability and function we developed the concept of “complete footprint restoration”. It is based on the hypothesis, that the restored biomechanical envelope of the knee is a function of reconstructed ISA.

This article introduces the new concept of “complete footprint restoration” and defines indications for SB and DB ACL reconstruction based on the individual size of the ACL insertion sites. An “insertion site table” with guidelines for graft sizes and drill angles was designed to match the surgical technique to the individual ACL insertion sites of the patient.

Guidelines for Single Bundle and Double Bundle ACL Reconstruction

The surgically restored ISA of the ACL is defined by the width and the length of the oval bone tunnel outlet(s), which is a function of the drill (graft) diameter and drill angle. The average width of the native tibial and femoral insertion sites is between 9 - 11 mm [3,15]. As this range is rather small it may sufficiently reconstructed by the width of the tunnel diameters during SB or DB ACL reconstruction in the majority of patients.

However, big individual variations do exist for the long axis of the tibial ACL insertion site in anterior-posterior direction and for the long axis of the femoral insertion site in superior-inferior direction. The surgically relevant range is reported to be between 9 - 21 mm on the tibia and between 11 - 21 mm on the femur [2-6,12,14,15].

Insertion site table

The “insertion site table” (Table 1) presents guidelines for SB and DB ACL reconstruction based on the concept of “complete footprint restoration”. The length of the individual tibial insertion sites (first column) is matched to an individual drill (graft)

Insertion Site Table.
Recommendations for anatomical ACL footprint reconstruction to maximize the restored insertion site area. Intraoperatively measured long axis of tibial ACL insertion (column 1), calculated drill diameter(s) and drill angle(s) for SB or DB (column 2), graft type (column 3) and restored ap-length and percentage of insertion (in DB including a 2 mm bone bridge between AM and PL) ((last column). ST semitendinosus 2x doubled, 3x trippled, 4x quadrupled, GT: gracilis tendon, BPTB: bone patella bone tendon, QTB: quadriceps tendon., BB: bone bridge between AM and PL.
SB: drill angle: 50° or 55°; DB: for AM and PL: 55° or 60° or 65° to the tibial plateau.

Measured (intra-op) insertion site length [mm]	Drill diameter [mm] & drill angle				Graft	Reconstructed insertion site length	
	SB					[mm]	[%]
8	6	50°			ST (2x)	7.8	98
	6.5	55°				7.9	99
9	7	55°			ST (3-4x)	8.5	94
10	7.5	50°			ST (3-4x)	9.8	98
	8	55°				9.8	98
11	8.5	55°			ST / ST + GT / BPTB / QTB	10.4	95
	9	55°				11	100
12	9.5	55°			ST + GT / BPTB / QTB	11.6	97
13	10	50°			BPTB / QTB	13	100
	10.5	55°				12.8	99
14	11	55°				13.4	96
15	11	50°			BPTB / QTB	14.4	96
	DB					... inclusive 2mm BB	
	AM		PL				
14	5	60°	5	60°	ST (2x + 2x)	13.6	97
	5.5	60°	5	65°		14.0	100
15	5.5	60°	5.5	60°	ST (2x + 2x)	14.7	98
	6	60°	5	60°		14.7	98
16	6	55°	5.5	60°	ST (2x + 2x)	15.7	98
	6	60°	6	60°		15.9	99
	6.5	55°	5	60°	ST +GT	15.7	98
	6.5	60°	5.5	60°		15.9	99
	7	60°	5	60°		15.9	99
17	6.5	55°	6	60°	ST + GT	16.9	99
	6.5	60°	6.5	65°		16.8	99
	7	55°	5.5	60°		16.9	99
	7	60°	6	65°		16.8	99
	7.5	55°	5	60°		16.9	99
	7.5	60°	5.5	65°		16.8	99
	8	60°	5	65°		16.9	99
18	7	60°	6.5	60°	ST + GT	17.6	98
	7	60°	7	65°		17.9	99
	7.5	60°	6	60°		17.6	98
	7.5	60°	6.5	65°		17.9	99
	8	60°	5.5	60°		17.6	98
	8	60°	6	65°		18.0	100
19	7.5	60°	7	60°	ST + GT	18.7	98
	7.5	60°	7.5	65°		19.0	100
	8	60°	6.5	60°		18.7	98
20	8	55°	7	60°	ST + GT (+BPTB, QTB)	19.9	100
	8	60°	7.5	60°		19.9	100
21	8	60°	8	60°	ST + GT (+BPTB, QTB)	20.5	98

diameter and drill angle (second column). Different grafts (third column) may be favourable depending on the size of the recommended drill diameters and individual patient requirements, e.g. kneeling profession, etc. The oval length of each articular bone tunnel outlet was calculated according to the formula: *drill size divided by sin* α based on a parallel alignment of the long axis to the sagittal plane from anterior to posterior (Table 1). Oblique drilling directions to the sagittal plane were not considered, as this complexes the calculation and may not play a significant role. The surgically restored insertion site length (last column Table 1) is displayed in milimeters and percentage of the native insertion site length (Table 1). To clarify the concept and to avoid overdrilling of the insertion site length the calculated numbers are given in millimeters with decimals. This accuracy cannot be achieved during drilling.

In contrast to the usual order of surgical steps the concept makes it necessary to first measure the length of the tibial ACL insertion site with a ruler from anterior to posterior. The drill diameter and -angle as well as the surgical technique (SB/DB) are assessed from the "insertion site table". Then the diameter of the graft is prepared according to the defined drill diameter and the ACL reconstruction is completed respectively (Table 1).

According to our calculations a *short tibial ACL insertion site between 8 - 13 mm* may be restored to more than 95% by an individually matched SB technique (Table 1). However, an insertion site length of *14 - 15 mm* is more critical to be reconstructed, as this length needs large SB bone tunnels of 10 - 11 mm (Table 1). To increase the reconstructed insertion site length additionally, smaller drill angles up to 45° minimum may be used to create a longer oval of the bone tunnel outlet. However, *a long insertion site of 16 mm or more* cannot be completely reconstructed by one SB bone tunnel (Table 1) and consequently the deficit of non-reconstructed ISA increase significantly with larger insertion sites. These are the patients, which may have the highest biomechanical and clinical benefit from a DB procedure as the reconstructed area is significantly larger than with a SB procedure.

Conclusion

The new concept of complete footprint restoration aims to maximize the reconstructed ACL insertion site areas to achieve an optimized functional outcome. An "insertion site table" was calculated for the surgeon, which defines drill diameters and drill angles as well as indications for SB and DB reconstruction depending on the length of the tibial insertion site. In this concept the DB technique is only considered as a surgical tool for large footprints and may not be indicated for smaller insertion sites.

References

1. Aglietti P, Giron F, Losco M, Cuomo P, Ciardullo A, Mondanelli N (2010) Comparison between single-and double-bundle anterior cruciate ligament reconstruction: a prospective, randomized, single-blinded clinical trial. Am J Sports Med 38:25-34
2. Colombet P, Robinson J, Christel P, Franceschi JP, Dijan P, Bellier G, Shibi A (2006) Morphology of anterior cruciate ligament attachment for anatomic reconstruction: A cadaveric dissection and radiographic study. Arthroscopy 22:984-992
3. Edwards A, Bull AM, Amis AA (2007) The attachments of the anteromedial and postero-

lateral fibre bundles of the anterior cruciate ligament: Part1: tibial attachment. Knee Surg Sports Traumatol Arthrosc 15:1414-1421

4. Edwards A, Bull AM, Amis AA (2008) The attachments of the anteromedial and posterolateral fibre bundles of the anterior cruciate ligament. Part 2: femoral attachment. Knee Surg Sports Traumatol Arthrosc 16:29-36
5. Hara K, Mochizuki T, Sekiya I, Yamaguchi K, Akita K, Muneta T (2009) Anatomy of normal human anterior cruciate ligament attachments evaluated by divided small bundles. Am J Sports Med 37:2386-2391
6. Harner CD, Baek GH, Vogrin TM, Carlin GJ, Kashiwaguchi S, Woo SLY (1999) Quantitative analysis of human cruciate ligament insertions. Arthroscopy 15:741-749
7. Hofbauer M, Valentin P, Kdolsky R, Ostermann RC, Graf A, Figl M, Aldrian S (2010) Rotational and translational laxity after computer-navigated single- and double-bundle anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 18:1201-1207
8. Järvelä T (2007) Double-bundle versus single-bundle anterior cruciate ligament reconstruction: a prospective, randomize clinical study. Knee Surg Sports Traumatol Arthrosc 15:500-507
9. Kondo E, Yasuda K, Azuma H, Tanabe Y, Yagi T (2008) Prospective clinical comparisons of anatomic double-bundle versus single-bundle anterior cruciate ligament reconstruction procedures in 328 consecutive patients. Am J Sports Med 36:1675-1687
10. Meredick RB, Vance KJ, Appleby D, Lubowitz JH (2008) Outcome of single-bundle versus double-bundle reconstruction of the anterior cruciate ligament: a meta-analysis. Am J Sports Med 36:1414-1421
11. Muneta T, Koga H, Mochizuki T, Ju YJ, Hara K, Nimura A, Yagishita K, Sekiya I (2007) A prospective rndomized study of 4-strand semitendinosus tendon anterior cruciate ligament reconstruction comparing single-bundle and double-bundle techniques. Arthroscopy 23:618-628
12. Petersen W, Zantop T (2007) Anatomy of the anterior cruciate ligament with regard to its two bundles. Clin Orthop Relat Res 454:35-47
13. Siebold R, Dehler C, Ellert T (2008) Prospective randomized comparison of double-bundle versus single-bundle anterior cruciate ligament reconstruction. Arthroscopy 24:137-145
14. Siebold R, Ellert T, Metz E, Metz J (2008) Femoral insertions of the anteromedial and postero-lateral bundles of the anterior cruciate ligament. Morphometry, arthroscopic landmarks and Orientation models for bone tunnel placement. A cadaver study. Arthroscopy 24:585-592
15. Siebold R, Ellert T, Metz E, Metz J (2008) Tibial insertions of the anteromedial and posterolateral bundles of the anterior cruciate ligament. Morphometry, arthroscopic landmarks and Orientation model for bone tunnel placement. Arthroscopy 24:154-161
16. Zaffagnini S, Bruni D, Marcheggiani Muccioli GM, Bonanzinga T, Lopomo N, Bignozzi S, Marcacci M (2011) Single-bundle patellar tendon versus non-anatomical double-bundle hamstrings ACL reconstruction: a prospective randomized study at 8-year minimum follow-up. Knee Surg Sports Traumatol Arthrosc 19:309-397

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The repair of rotator cuff tear using mini open surgery and the results for sequential acromioplasty

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Introduction:

Rotator cuff tears are one of the common shoulder problem of mid aged patients. Mid-term results of patients treated using mini open surgery due to rotator cuff tear were analyzed functionally.

Patients and Method:

The shoulders of 20 out of 21 patients who underwent surgery in our clinic between 2002 and 2009 were evaluated before and after the procedure.Twelve of these patients (60%) were women and 8 of them (40%) were men. The average age of the patients was 52(32-71) years old. There was an impigment on the right shoulders of 9 patients and on the left shoulders of 12 patients. Out of the 20 shoulders of 20 patients grade 3 and in one shoulder grade 2 subacromial narrowing syndrome was observed. The rotator cuff tear of all patients have been classified using MRI. We found partial rupture in 4 and total rupture in 17 patients. The physical therapy for the patients was started on the 5th day after the surgery by the same physician and in the same center. Our patients were evaluated using Constant and UCLA grading systems. Statistical analysis was performed by Student's t test.

Results:

We followed our patients in an average for 37 months (13 – 64). The average pre-operative Constant and UCLA score of the patients were 30 (10-48) and 10 (2-17), respectively. The average Constant and UCLA score were postoperatively determined as 87 (42-96) and 31 (11-35), respectively. The affect of mini open rotator cuff repairment, sequential acromioplasty and rehabilitation on the patients was found

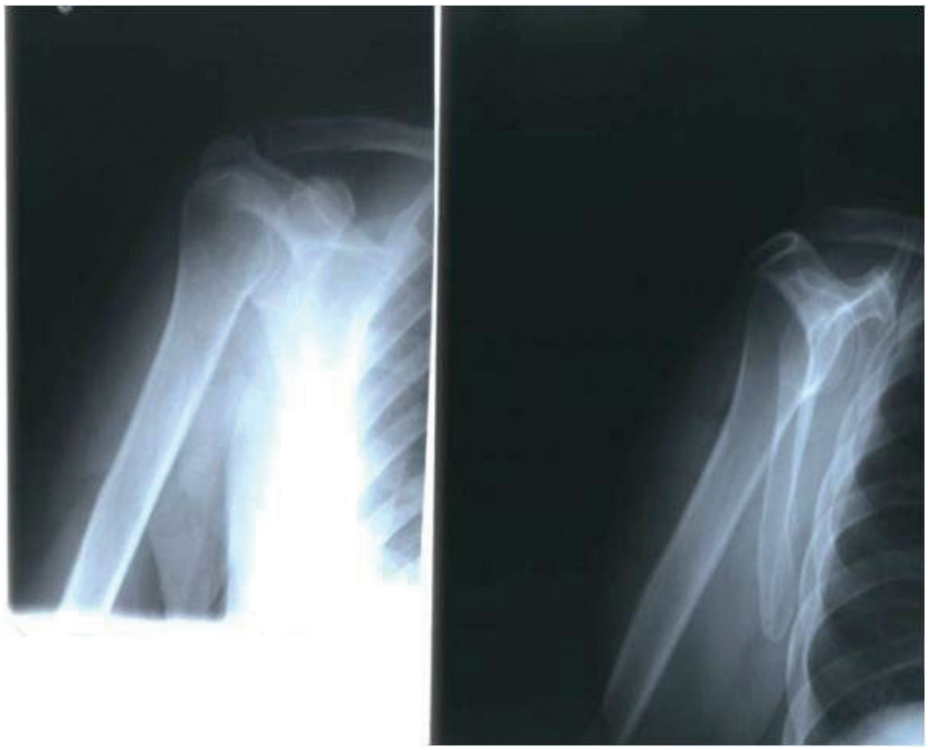

Figure 1

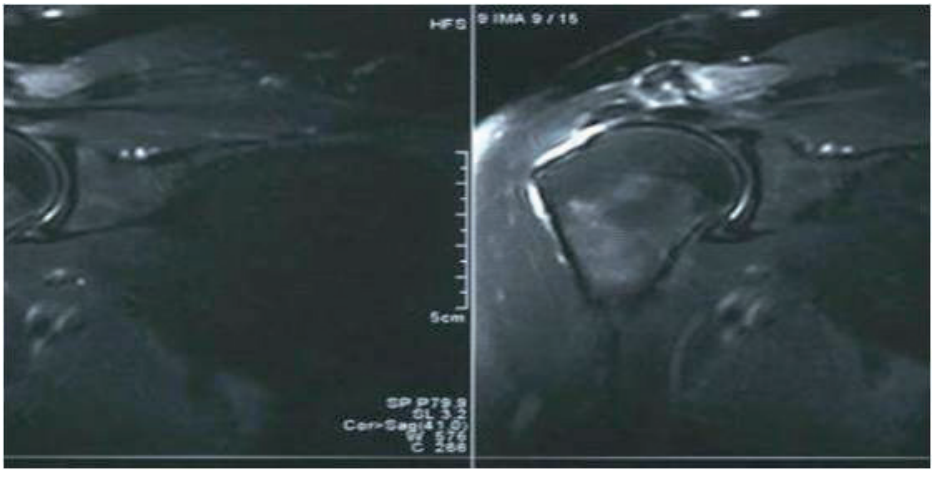

Figure 2

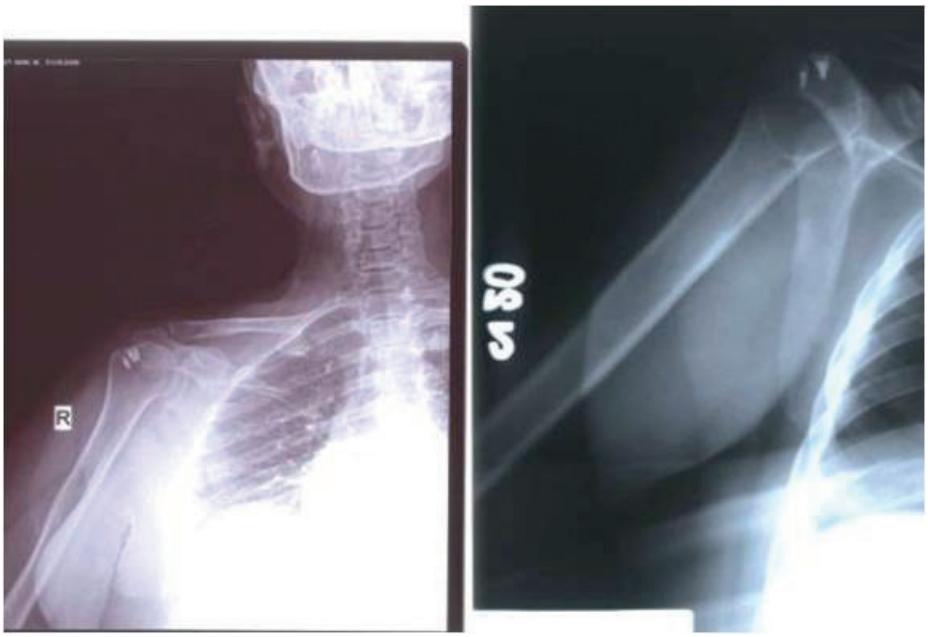

Figure 3

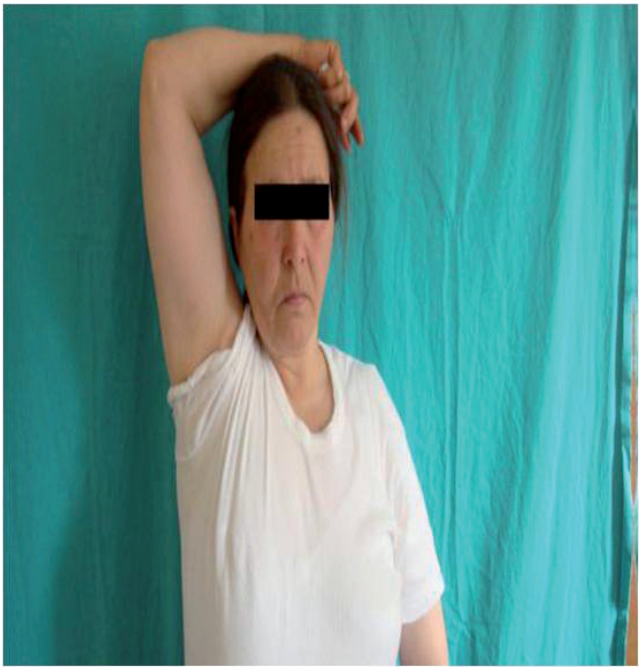

Figure 4

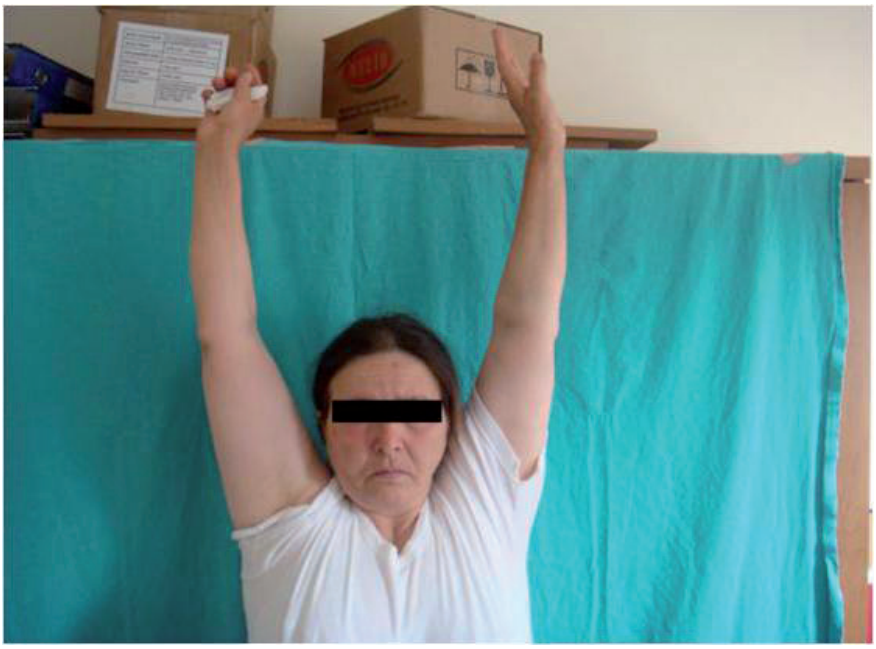

Figure 5

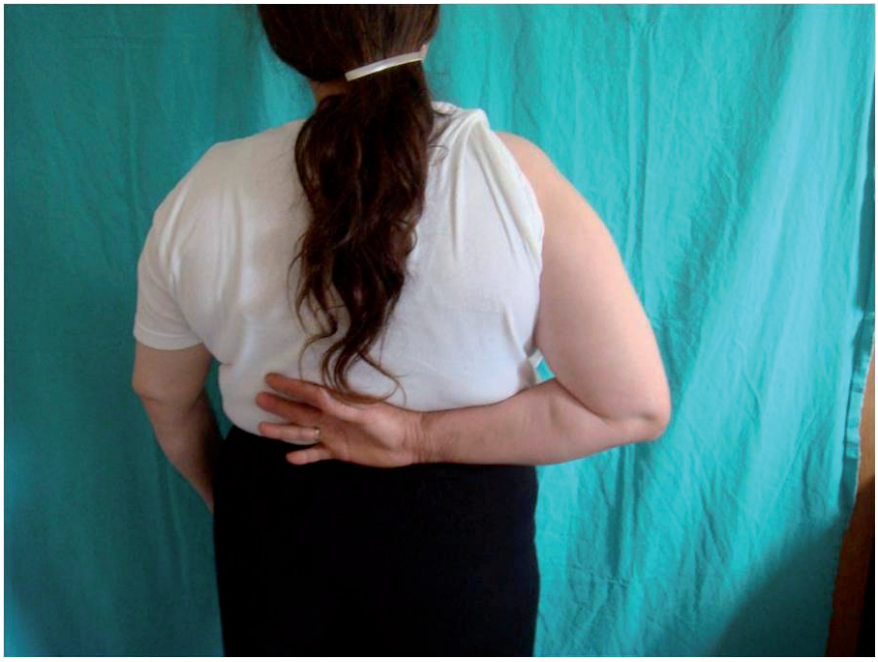

Figure 6

reasonable when pre-operative and post-operative Constant and UCLA scores were compared. We obtained %85 good to excellent results for 3 years.

Conclusion:

Besides, we obtained satisfied results functionally, the advantages of this technique in rotator cuff repair are: the protection of deltoid muscle, removing only the necassary amount of acromion using sequential acromioplasty, rapid postoperative rehabilitation and short hospitalization period.

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The iliotibial band syndrome treated with an arthroscopic technique in 40 patients

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Summary

The iliotibial band syndrome(ITBS) is an overuse injury mainly affecting runners. The initial treatment is conservative. Only, in recalcitrant cases surgery is indicated. Several open techniques have been described. Newer studies question the pathogenesis of the ITBS. Based on these findings a new technique was developed.

Forty athletes(42 knees) with a resistant ITBS were treated with a standardized arthroscopic technique, limited to the resection of the lateral synovial recess.

Thirty-six patients (38 knees) had good or excellent results. All patients went back to sports after 3 months.

Our results show that arthroscopic treatment of resistant ITBS is a valid option with a **consistently good out**come. In addition, this arthroscopic approach **allows excluding or treating other intra-articular pathology**.

Introduction

The iliotibial band syndrome is an overuse problem that is often seen in runners. It causes pain on the outside of the knee just above the joint. The initial treatment consists of activity modification, NSAIDs, stretching, physical therapy, shoe modification and local infiltration with steroids. Only is recalcitrant cases surgery is needed.

The earlier studies see the iliotibial band syndrome as a friction between the iliotibial tract and the lateral femoral condyle. Based on this theory several open techniques were published to lengthen the iliotibial tract.

Newer studies question this pathogenesis. MRI and cadaver studies found the iliotibial tract firmly attached to the distal femur. This was called the lateral recess. MRI and biopsy found inflammation in this recess. In no cadavers, volunteer or patient a bursa was seen.

All this together suggests that the pathogenesis is a form of enthesopathy of the femoral attachment of the ITB.

Table 1 Sports

Long distance running	27
Triathlon	4
Cycling	4
Athletics	3
Rugby	2
Soccer	3
Fencing	1
Basketball	1

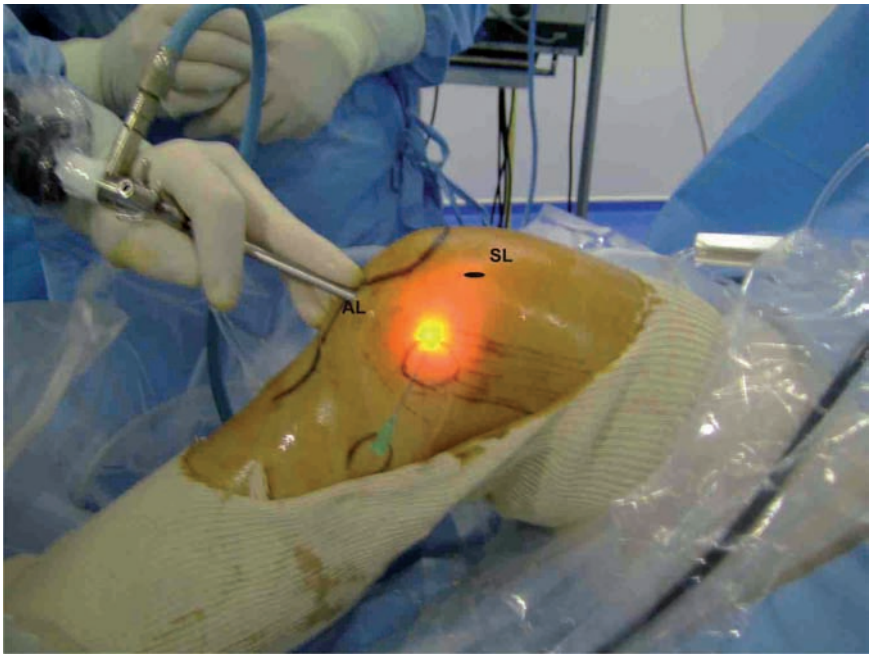

Figure 1 Positioning and arthroscopic portals. AL anterolateral portal, SL superolateral portal

Based on this findings a new technique was developed. Using an arthroscopic approach the attachment of the iliotibial band to the lateral femoral condyle was resected. The purpose of this retrospective study is to evaluate the results of this technique.

Material and Methods

Forty athletes with a resistant ITBS were treated, 37 were available for follow-up. All these patients had been treated conservatively during at least six months. All patients had at least 6 months follow-up with an average of 2 years 2 months. All

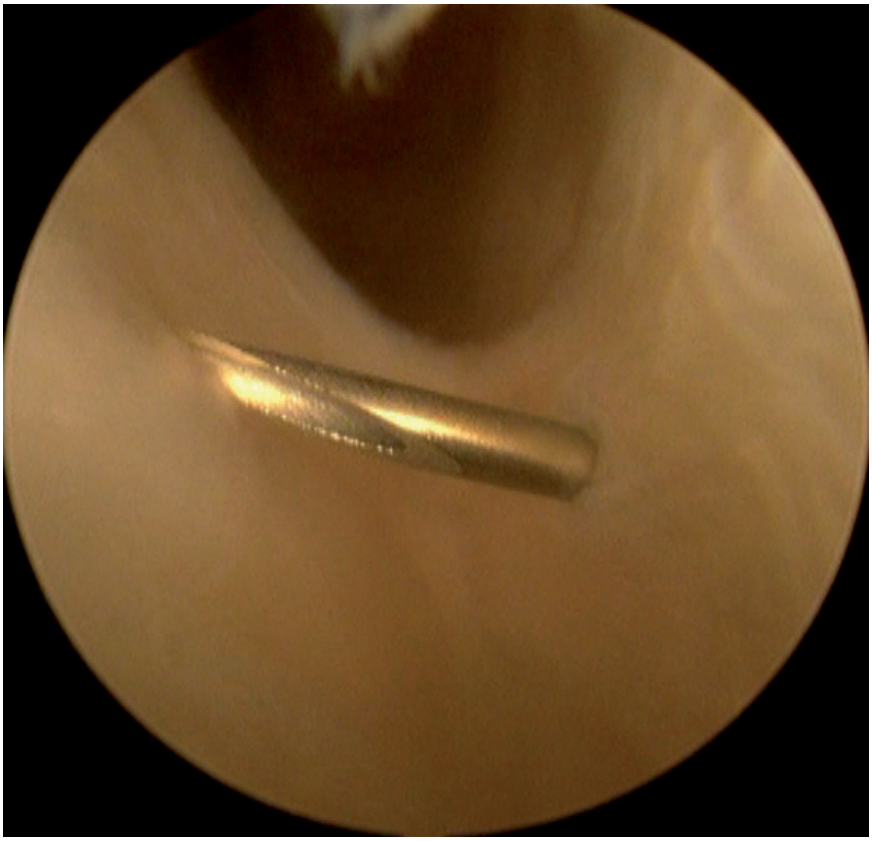

Figure 2 Lateral synovial recess in lateral gutter

patients were recreational or professional athletes: long distance running(27), triathlon(4), soccer(3), rugby(2), athletics(2), fencing(1), basketball(1). (Table 1)

The patient is placed in supine position with the leg in 30 degrees of flexion.(Fig. 1) The joint space is inspected through the anteromedial and anterolateral portals. Other possible lesions are searched for and treated if needed. In all the patients a lateral synovial recess was found in the lateral gutter. With the knee in 30° flexion, this recess corresponds with the lateral femoral epicondyle.(Fig. 2) Through a superolateral portal the synovial recess is debrided with thermocoagulation or a synovial shaver. The resection is completed when the bone of the lateral femoral condyle is visible.(Fig. 3)

Postoperative early range of motion exercises and full weight bearing is promoted. Running is started after 2 months.

Results

All the patients were able to return to sports after three months. Using the score

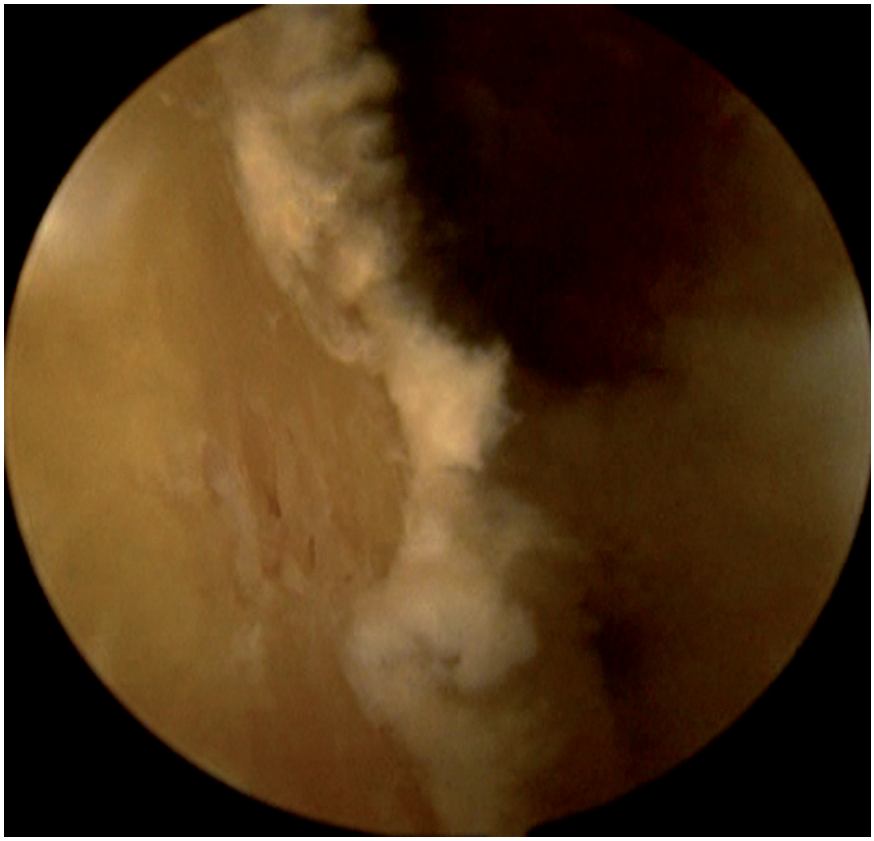

Figure 3 Lateral gutter after resection

of Drogset 81 percent had excellent results, only one patient had a fair result.(Table2) This patient had associated cartilage lesions of the femoral condyle.

In two patients a meniscal lesion was found which required treatment. The lesions had not been noticed on the preoperative MRI. One patient developed a haematoma requiring evacuation. With the use of thermocoagulation this complication was avoided in the following patients.

The good results of this technique confirm the hypothesis that the inflammation is limited to the fibrous attachments to the femur and the surrounding fat.

Conclusions

Our results show that arthroscopic treatment of resistant ITBS is a valid option with a consistently good outcome. This minimally invasive technique allows a fast return to sports. It is technically not demanding and can be performed by any surgeon with a experience in knee arthroscopy. The arthroscopic approach offers the advantage of a good intra-articular evaluation of associated meniscal or cartilage lesions.

Table 2 Results

Results	This study	Drogset et al
Excellent (no pain, complete return)	30 (81.0 %)	22 (48.9%)
Good (much less pain)	6 (16.2 %)	16 (35.6%)
Fair (little less pain)	1 (2.7 %)	6 (13.3%)
Poor (unchanged or worsened)	0	1 (2.2 %)

References

1. DROGSET J, ROSSVOLL I, GRONTVEDT, Surgical treatment of iliotibial band friction syndrome. A retrospective study of 45 patients. Scand J Med Sci Sports 9:296-298, 1999.
2. FAIRCLOUGH J et al, The functional anatomy of the iliotibial band during flexion and extension of the knee: implications for understanding iliotibial band syndrome. J Anat 208:309-316, 2006.
3. MARTENS M, LIBBRECHT P, BURSENS A, Surgical treatment of the iliotibial band syndrome. Am J Sports Med 17:651-654, 1989.
4. MUHLE C et al, Iliotibial band friction syndrome: MRI imaging findings in 16 patients and MR arthrographic study of six cadaveric knees. Radiology 212:103-110, 1999.
5. NEMETH W, SANDERS B, The lateral synovial recess of the knee: Anatomy and role in chronic iliotibial band friction syndrome. Arthroscopy 12:574-580, 1996.
6. NOBLE C, The treatment of iliotibial band friction syndrome. Br J Sports Med 13:51-54, 1979.

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Novel technology for cartilage repair

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Summary

There are many procedures for the treatment of cartilage injury such as bone-marrow stimulating techniques (drilling, microfracture) and autologous osteochondral grafting. We have developed two new surgical procedures for patients with wide cartilage defects who can't be treated with simple bone-marrow stimulating techniques and autologous osteochondral grafts. These surgical treatments comprise a distraction arthroplasty system for middle-aged patients, and implantation of tissue-engineered cartilage for younger patients. We have developed a novel, minimally invasive technique for cartilage regeneration, which uses mesenchymal stem cells labeled with super-paramagnetic iron oxide, in conjunction with an external magnetic device.

1. Introduction

There are many procedures for the treatment of cartilage injury such as bone-marrow-stimulating techniques (drilling, microfracture) and autologous osteochondral grafting[1,2]. However, there has been some controversy about the clinical results of these procedures. Regenerative medicine using mesenchymal stem cells (MSCs), tissue-engineered cartilage transplantation, various growth factors and scaffolds have been reported, and these procedures have been gradually applied to clinical cases[3,4,5]. We have developed two new surgical techniques for patients who have wide chondral defects and can't be treated with simple bone-marrow stimulation techniques and autologous osteochondral grafts. One of these methods uses a distraction arthroplasty device combined with a bone-marrow stimulation technique for middle-aged patients who have diffuse osteoarthritis (OA), and the other method comprises autologous chondrocyte implantation (ACI) for younger patients who have focal and wide chondral defects. In addition, we have studied cartilage regeneration using MSCs in an animal model.

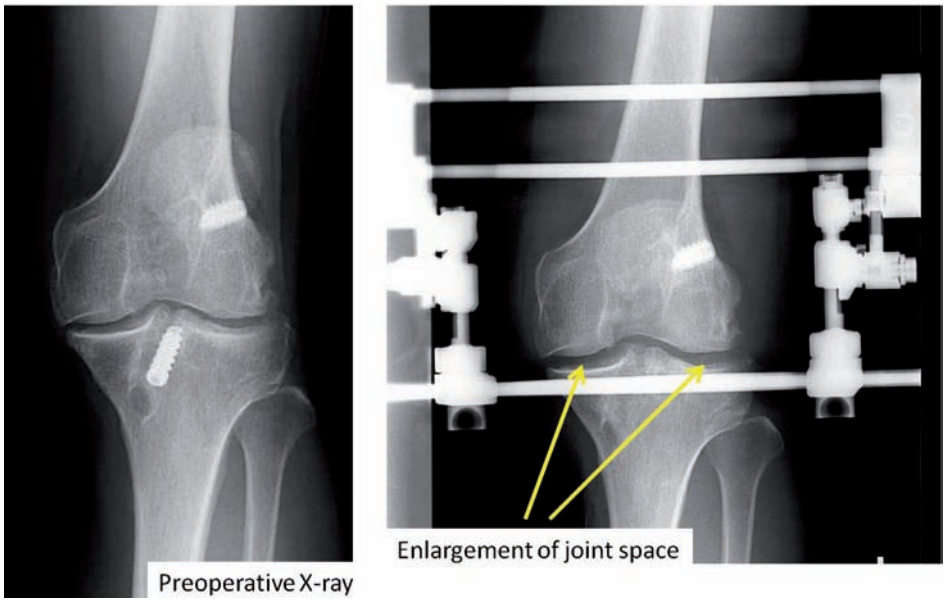

Fig. 1

2. Autologous chondrocyte implantation

In 1994, Brittberg et al. reported on the clinical results after autologous chondrocyte implantation using a monolayer culture[6]. Although their surgical procedure heralded a breakthrough in the field of cartilage repair, various problems have been identified in their procedures, such as risk of leakage of chondrocytes from the defect site, risk of dedifferentiation of chondrocytes and risk of uneven distribution of grafted chondrocytes. I have developed a novel technology that creates cartilage-like tissue by cultivating autologous chondrocytes embedded in atelocollagen gel[7,8]and thus avoids the drawbacks of their methods. However, my method also has some disadvantages. The first problem is that our chondrocyte harvest is limited, and the second problem is that we need a two-stage operation that involves the collection and then implantation of autologous chondrocytes in atelocollagen gel. In addition, arthrotomy is needed and there is no surgical indication for senior patients with osteoarthritis. Fpr these reasons, I have developed a distraction arthroplasty device, as a treatment tool for patients with osteoarthritis.

3. Distraction arthroplasty

Since April 2002, we have been performing distraction arthroplasty combined with bone-marrow stimulation on middle-aged patients (aged 42 to 63y) with osteoarthritis. The indication for this system was a grade of 3 or 4 on the Kellgren-Lawrence grading scale in the lateral or lateral and medial compartments of the tibiofemoral joint. The concept of the distraction arthroplasty is to widen the joint space and preserve the widened joint space during the weight-bearing load. In addition, this device allows

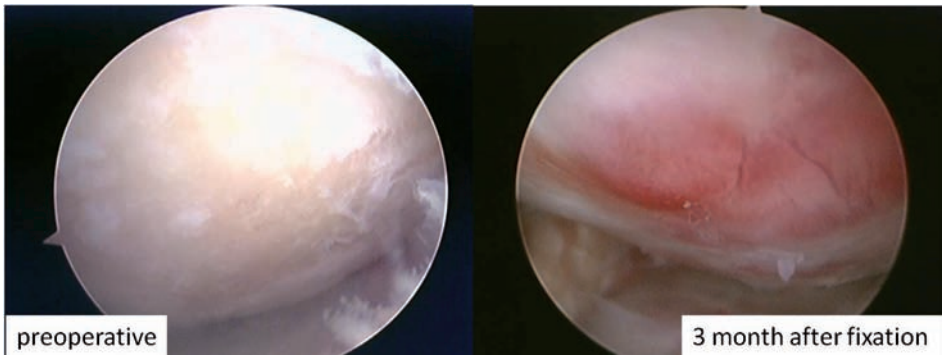

Fig. 2

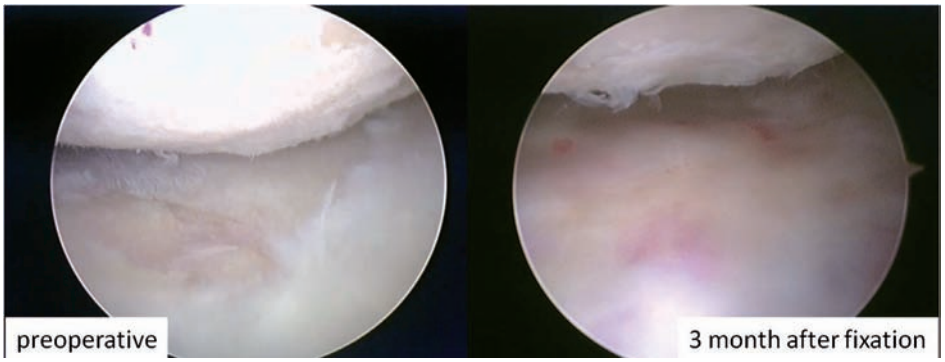

Fig. 3

patients to exercise ROM to promote cartilage regeneration. We usually use this device for about 3 months (Fig.1). In our department, Deie et al. reported that distraction arthroplasty was performed in conjunction with the bone-marrow stimulation technique on 7 knees, and the Japan Orthopaedic Association score and Visual analog scale significantly improved after the operation. Furthermore, the joint space significantly increased after surgery. When the device was removed, second-look arthroscopy was performed, and cartilage-like tissue at the site of the chondral defect was observed (Fig.2,3). Although we experienced a superficial skin infection in 2 cases, we did not experience any major complication such as nerve palsy or vascular injury, overall obtaining very good results[9,10].

4. Cartilage regeneration using an external magnetic device

Transplantation of MSCs has been gradually implemented via arthrotomy to treat cartilage injury. However, a large number of MSCs for cartilage regeneration is needed to treat a large cartilage defect. Agung et al reported that implantation of a

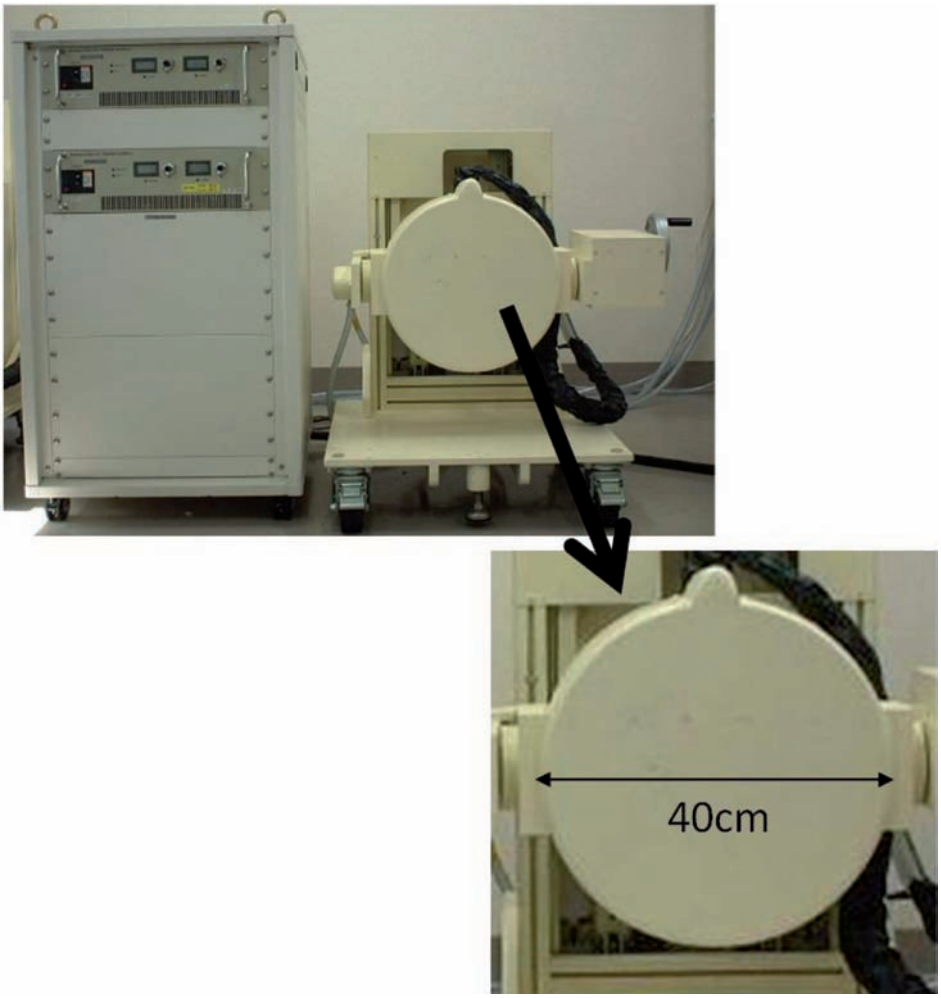

Fig. 4

large number of MSCs results in loose bodies of scar tissue in the joint. Therefore, to provide effective chondral defect treatment, it is essential to inject a small number of MSCs into the defect site. We investigated cartilage regeneration using MSCs labeled with super-paramagnetic iron oxide (m-MSCs) and an external magnetic force to accumulate MSCs in the site of the cartilage defect in an animal model. We used a variable direct-current electromagnet (Tamagawa, Japan), manufactured for the purpose of generating an external magnetic force. When a sample lies 8 cm from the center of the pole, the maximum magnetic field is 0.6 Tesla (Fig.4). In my department, Kobayashi et al. demonstrated that m-MSCs successfully accumulate in the desired site (chondral defect or osteochondral defect) using an external magnetic device [11] (Fig.5). Kobayashi et al. also studied the possibility of regeneration of degenerated

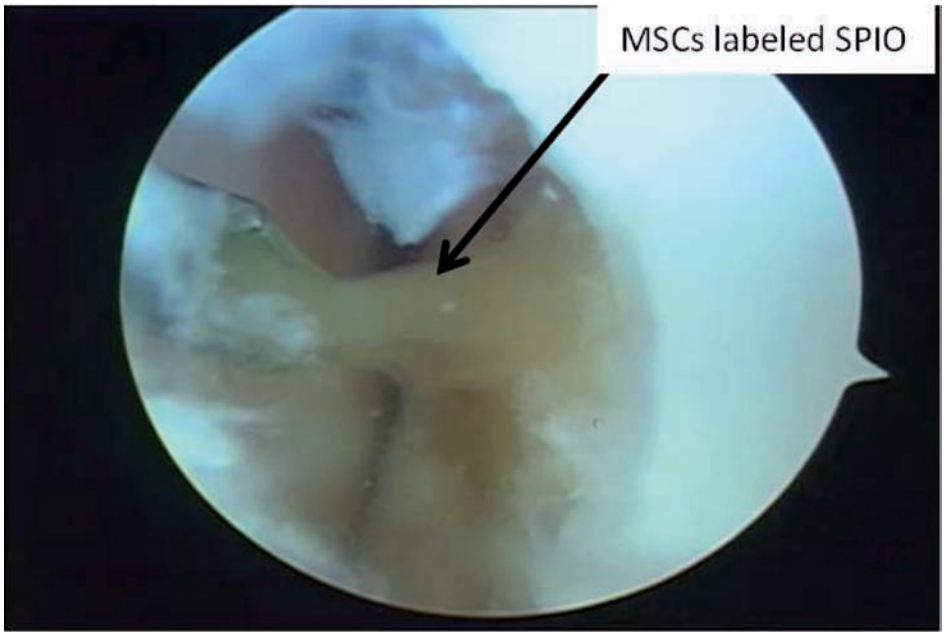

Fig. 5

knee cartilage using m-MSCs and an external magnetic force in vitro. We showed a newly formed cell layer that was stained with toluidine blue, safranin O and type II collagen immuno-staining in vitro in an OA model[12]. The new cell delivery system with m-MSCs and an external magnetic force shows potential to be a new treatment option for osteoarthritis and cartilage injury.

However, during clinical application of this new delivery system this device proves too big and the maximum magnitude too small to cause m-MSCs to accumulate precisely in the chondral defect. Therefore, a new external magnetic device with a smaller size (ca10 cm in diameter) and a larger magnitude (up to 6T) should be developed.

References

1. Steadman, J.R et al, Outcome of microfracture for traumatic chondral defects of the knee: average 11 year follow-up, Arthroscopy, 19, 477-484 (2003)
2. Matsusue et al, Arthroscopic multiple osteochondral transplantation to the chondral defect in the knee associated with anterior cruciate ligament disruption,Arthroscopy, 9, 318-321 (1993)
3. Peterson,L., et al, Two-to 9-year outcome after autologous chondrocytes transplantation of the knee, Clin Orthop, 374, 212-234 (2000)
4. Nakamura N, et al, Cell-based therapy in articular cartilage lesions of the knee, Arthroscopy, 25, 531-552 (2009)
5. Pei, M, et al, Repair of full thickness femoral condyle cartilage defects using allogenic synovial cell-engineered tissue constructs, Osteoarthritis Cartilage, 17(6),714-722 (2009)

6. Brittberg et al, Treatment of deep cartilage defects in the knee with autologous chondrocyte transplantation, N Engl J Med, 331, 889-895 (1994)
7. Ochi M, et al, Transplantation of cartilage-like tissue made by tissue engineering in the treatment of cartilage defects of the knee, J Bone Joint Surg Br, 84,571-578 (2002)
8. Ochi M, et al, Current concepts in tissue engineering technique for repair of cartilage defect, Artif Organs, 25, 172-179 (2001)
9. Deie M, Ochi M, et al, A new articulated distraction arthroplasty device for
10. 833-838(2007)
11. DeieM, Ochi M et al, Knee articulated distraction arthroplasty for the middle-aged osteoarthritis knee joint, Techniques in knee surgery, 9, 80-84 (2010)
12. Kobayashi T, Ochi M, et al, A novel cell delivery system using magnetically labeled mesenchymal stem cells and an external magnetic device for clinical cartilage repair, Arthroscopy, 24, 69-76 (2008)
13. Kobayashi T, Ochi M et al. Augmentation of degenerated human cartilage in vitro using magnetically labeled mesenchymal stem cells and an external magnetic device, Arthroscopy, 25, 1435-41 (2009)

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Neglected ruptures of the Achilles tendon. Combined V-Y sliding flap with Bosworth middle tendon strip with plantaris tendon reinforcement

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Summary

One of the most usefull techniques in treating old, chronic, neglected ruptures of the Achilles tendon is the Abraham-Pankovich V-Y sliding flap wich can be combined with plantaris tendon reinforcement. Unfortunately using this technique it is difficult to achieve approximation of the tendon ends if the gap is larger than 4-5cm. For larger gaps we have developed a new technique, combining the Abraham-Pankovich V-Y sliding flap with the tendon strip technique described by Bosworth that was reinforced with a plantaris tendon autograft. Using this technique we were able to repair defects of more than 8 cm(approx. 4 cm from the V-Y flap and approx 4 cm from the middle strip of the Achilles tendon. Plantaris tendon reinforcement provides extra strength.

On a case series of 5 patients all male, aged between 36 and 54 years, with a mean age(median) of 47 years, with chronic ruptures of the Achilles tendon we have combined the V-Y plasty with the Bosworth technique, reinforced with spread plantaris tendon membrane. The defect size after the debridment of the ruptured ends was betwen 6.2 and 8.4 cm. We have initially perfomed the V-Y plasty without beeing able to achieve end to end approximation. Therefore we have continued with the midline strip, reflected distally, and reinforced the repaired tendon with plantaris tendon. Postoperatively the patient was placed in an extention cast, below the knee for 4 weeks. After that the foot was progressively mobilised to 90° during 4 weeks of imobilisation.

The patients were evaluated using the ATRS (Achilles Tendon Rupture Score). All the patients were weightbearing at 8 weeks postoperatively. The ATRS mean(median) value was 79(46-91). No reruptures of the Achilles tendon were recordes and no surgical site complications.

The main advantages of this combination of techniques are that it can be used to repair large defects of the Achilles tendon using only one incision and the tendon itself to create continuity between the ruptured ends.

Introduction

The Achilles tendon is the largest and the most frequently injured tendon in the human body, it's presence beeing the expresion of our bipedal human nature, and essential to locomotion. The Achilles tendon is therefore not found in our closest of kin, the large primates.

It's name is derived form Homer's "Iliada" where Achille is a greek hero that has been sunk by his mother Thetis in the Styx river (one of the five rivers of the greek underworld) in order to make him invulnerable. While doing this she held the boy by his heel that remained the only unprotected part of his body. During the siege of Troy Achilles is killed by a poisoned arrow shot by Paris, the trojan prince, in his heel. From this legend the term "Achilles heel" has it's origins. The translation from "Achilles heel" to "Achilles tendon" was probably made in 1693 by Phillippe Verheyen (1648–1710) Regius Professor of Anatomy and later of Surgery at the University of Louvain, Belgium, who recorded the term tendo Achillis instead of the then used tendo magnus or tendo hippocratis[1].

The number of ruptures of the Achilles tendon is on the rise, studies have shown a six time increase since the seventies and eighties. It has a bimodal age distribution with an incidence peak between 30-39 years and a smaller peak between 50-59 years, predominantly affecting male individuals (2:1 to 12:1), probably reflecting a higher prevalence of male involed in sports.On average, Achilles tendons in women have a smaller cross-sectional area than in men. This possibly suggests that less force is generated in a woman's Achilles tendon than the figures noted above, which may account for the lower rate of rupture in women[3]. Complete Achilles tendon ruptures area associated with sports, 60-75% of all ruptures beeing associated with sports activities[1,2].

There are two main theories explaining the rupture of the tendon: the mecanical theory and the degenrative theory wich hypothesises that chronic degenerative modifications within the tendon structure lead to a rupture without any mechanical loads.

Kannus and Jozsa[4] performed a study on 397 Achilles tendon ruptures wich they compared to 220 control tendons using conventional and polarized light microscopy, and also scanning and transmission electron microscopy. They found that none of the ruptured tendons had a healthy structure compared to the control group wich they found to be healthy in ⅔ of the cases. In the ruptured group 97% of the pathological changes were degenerative (hypoxic, mucoid, tendolipomatous, calcifying tendinitis or combinations). The normal tendon is comprised of 95% type I collagen, with type III colagen beeing present only in small amounts. In ruptured Achilles tendons there was a significantly greater proportion of type III collagen, less resistant to tensile forces and may predispose the tendon to spontaneous rupture.

Corticosteroids have been administered locally, intralesional and perilesional for a variety of diseases, but their utility for Achilles's tendinopathy is questioned in a meta-analysis by Shrier et. Al[6]. Also, orally administered corticosteroids have been implicated in the ruptures of the Achilles tendon.

The use of fluoroquinolones has been implicated in tendon ruptures, ultrastructureal changes of the Achille's tendon have been demonstrated in rats treated with fluoroquinolones (decrese in fiber diameter, increase in the distance between fibrils, vacuoles enad vesicles in the cytoplasm of tenocytes, densified nuclei), abnormalities wich may also be present in humans.

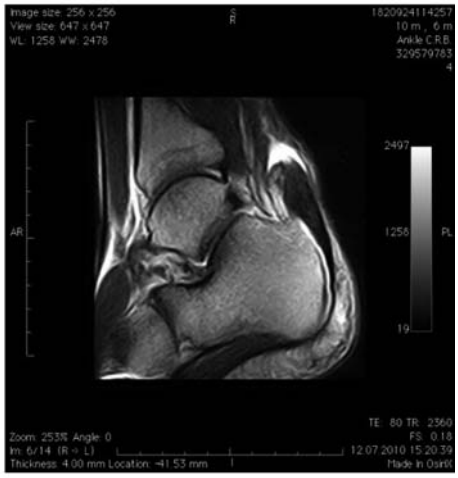


Fig.1 Chronic rupture of the Achilles tendon: preoperative MRI

Usually, in the young and otherwhise healthy patient the tear is limited to the "watershed" region of the Achilles tendon 2-6 cm proximal of the calcaneal insertion. The progresive degeneration of the tendon, wich can be associated with the use of fluoroquinolones and/or corticosteroids can lead to a rupture in the presence of a small mechanical trauma, with large defect in the structure of the tendon. When this is combined with an old, neglected injury with retraction of the muscular end and tendinous fiber reorganisation wich further increases the tendinous gap the diagnosis and reconstruction of the tendon becomes even more problematic.

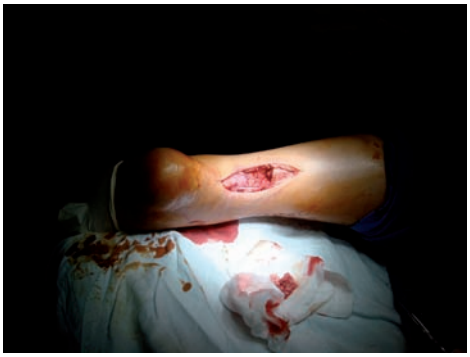
While for acute ruptures the clinical examination is sufficient for the diagnostic, in cronic ruptures the tendon gap can be filled with fibrous tissue, the calf muscles wasted and yet some plantar flexion can be produced by the long toe flexors, tibialis posterior combined with the peronei. Calf squeeze tests may not be conclusive aswell.

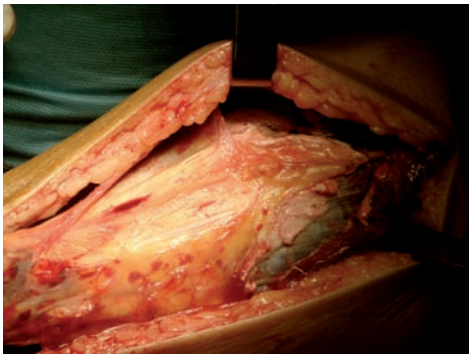
Imaging studies are recomended in this cases to confirm the diagnosis, with ultrasonography and MRI beeing the most usefull[7,8,9].

Materials and method

There are two classification systems used for chronic Achilles tendon ruptures, both of them using the length of the defect as the basis for management.[10,11]. Myerson's classification categorizes defects greater than 5 cm as Myerson 3 and recomends tendon transfer alone or in combination with V-Y sliding flap. Kuwada's classification categorizes defects over 6 cm as type IV and recomends a gastrocnemius recession, a free tendon graft and/or a synthetic tendon graft for management.

We have used a different combination of techniques to reconstruct large defects of the Achilles tendon (Myerson 3, Kuwada type IV). First an extensive debidment of the stumps is made, obtaining healthy tendon on both ends of the rupture, the resulting





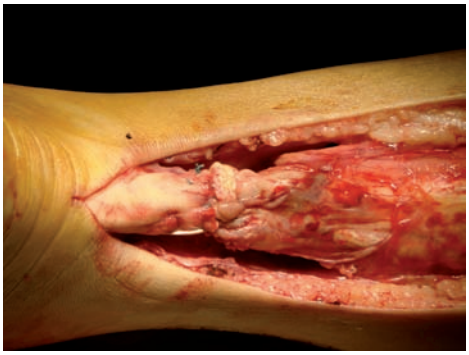


Fig. 2, 3, 4 Intraoperative aspect of a chronic Achilles tendon rupture - defect asessement; preparation of V-Y sliding flap; aspect after repair and augumentation with plantaris tendon

defect is measured and end-to-end approximation is atempted. Then the V-Y sliding flap[12] is prepared and end to end approximation is atempted with the foot in plantar flexion. In defects larger than 6 cm we were not able to achieve complete approximation or the tension in the stumps was too high we then perform a Bosworth middle tendon turndown flap: the median part of the proximal stump is disected, reflected distally, passed trough the proximal stump from medial to lateral, then trough the distal stump, from lateral to medial and then again trough the proximal stump from lateral to medial and sewed to itself. To provide further reinforcement the plantaris tendon is harvested and spread over the repair site and fixed in place with sutures[13].

Postoperatively the foot is placed in plantar flexion (cast or variable angle orthosis) without weightbearing for 4 weeks, then it is progressively dorsiflexed to 90°(15° every two days), with partial, progressive weight bearing commenced. Immobilisation is kept for another 4 weeks. After immobilisation removal the patient begins ankle ROM and calf strenghtening exercises.

We have used this technique on 5 patients, all male, practicing recreational sports (soccer, tennis), aged between 52-58 years (mean age of 54.4). Three were overweight and all had associated at least one metabolic disease (diabetes mellitus type 2, hipercholesterolemia, gout). They reported minimum energy trauma during recreational

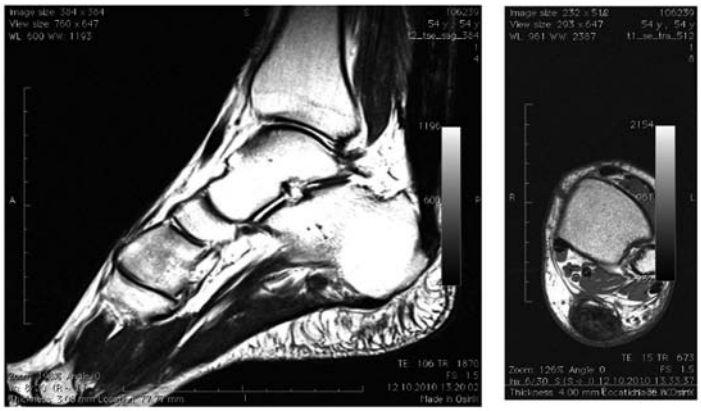


Fig. 5 & 6 MRI images showing an repaired Achilles tendon 6 months postoperative

sports in four cases and one reported the onset of symptoms during stair climbing with extra load. None reported use of fluoroquinolones or corticosteroids, and only one had previous symptoms (tendinopathy) in the Achilles tendon.

Time from injury to surgery was between 2 months and 1 week to 4 months and 2 weeks. The diagnosis was confirmed trough MRI.

Intraoperatively the defect size was measured between 6.2 and 8.4 cm (mean value = 7 cm). We found the body of the tendon replaced with fibrous tissue that was very adherent to the peritendinous structures and still provided continuity between the stumps, explaining the small amount of plantar flexion that the patients could perform. The proximal stump was degenerated (atrophy in 3 cases and mucoid degeneration in 2 cases), conically shaped, with the tip pointed distally, continued with the fibrous tissue that span to the distal stump, with similar degeneration as the proximal stump. The technique described before was used, with initial V-Y plasty and subsequent Bosworth middle tenon turndown flap and plantaris tendon reinforcement.

The main advantages in using this technique are that it restores the body of the tendon by using the tendon itself, it's performend trough a single incision, there is no donor site morbidity and it can be used to repair large defects of the Achilles tendon.

Results

All 5 cases progresed well, with no surgical site complications. Ankle dorsiflexion was started after 4 weeks of plantar flexion, by progresively mobilising the foot to 90°, with partial weight bearing allowed. At 8 weeks postoperatively all the patients were weightbearing as supported, imobillisation was removed. Important limitation to ankle ROM and calf muscle wasting were present at this stage with patients beeing able to walk with support on a plane surface. Ankle ROM exercises were commenced with calf strenghtening exercises continued.

The patients were evaluated using the ATRS (Achilles Tendon Rupture Score)[14]

because it is a patient-reported instrument with high reliability, validity, and sensitivity for measuring the outcome of total Achilles tendon rupture repairs.

We have evaluated the patients at 3 months and at 6 months postoperatively. At 3 months the ATRS score had a mean value of 61 (52-71). All 5 cases were able to walk on plane surfaces without support, stair climbing was possible unasissted, altough difficult. Calf muscle strenght was subjectively lower than unaffected side and there was a difference in diameter of 2,3 cm on average (1,6-2,8 cm). 1 patient reported a painfull scar in the distal portion. Ankle swelling was present in different degrees in all cases especially.

At 6 months the ATRS mean value was 79(46-91). Motor function was improved, full ankle ROM present, all patients were fully ambulant, light running and jumping was possible, all patients beeing able to perform routine, everyday tasks. Subjectively 2 patients reported a slight decrease in calf muscles strenght compared to the unaffected side.

No reruptures of the repaired Achilles tendon were recorded.

Conclusions

The chronic tear of the Achilles tendon poses a very serious problem to locomotion and can be deabilitating as it causes difficulty and impairment to the plantarflexion. Various tehniques have been advocated for the repair of large defects, including grafts from peroneus brevis, flexor hallucis longus, flexor digitorum longus, gracilis, fascia lata, allografts, syntheic materials. Autografts have been used successfully to reconstruct a large defects of the Achilles tendon, but apart from a more demanding technique, some require a second incision for harvesting with associated donor site morbidity, the use of peroneus brevis or the flexor hallucis longus grafts causes destabillisation of the foot[15]. For this reason we only consider them as a salvage procedure for defects without sufficient distal and/or proximal stumps that would require tenodesis to the calcaneus. Synthetic grafts provide a theoretical advantage because they can be cut to length and they lack donor site morbidity but the strcture and mechanical proprieties of the graft differ from the original tendon and there is an increased risk of rerupture at the tendon-graft junction[16,17].

Currently the V-Y sliding flap combined with the turn down flap are able to repair large defects of the Achilles tendon using only the tendon structure trough a one incison technique. This combination of techniques has been described in literature[18] with good results, but due to the poor vascularisation of the region it may be at risk by itself. Further augumentation with plantaris tendon[19] provides added strength to the repair, allowing for a much lower complication rate. Postoperative results are favorable, with no skin problems, and tendon continuity trough the tendon body itself.

References

1. MAFFULI N, ALMEKINDERS LC. The Achilles Tendon, London, Springer-Verlag, 2007
2. NIEK VAN DIJK C, KARLSSON J, MAFFULI N, THERMANN H. Achilles Tendon Rupture Current Concepts, London, DJO Publications, 2008.
3. KADER D, SAXENA A, MOVIN T, MAFFULLI N. Achilles tendinopathy: some aspects of basic science and clinical management. Br J Sports Med. Aug 2002;36(4):239-49

4. KANNUS P, JOZSA L. Histopathological changes preceding spontaneous rupture of a tendon: A controlled study of 891 patients. J Bone Joint Surg 1991; 73-A:1507–1525.
5. MAFFULLI N, EWEN SW, WATERSTON SW, REAPER J, BARRASS V. Tenocytes from ruptured and tendinopathic achilles tendons produce greater quantities of type III collagen than tenocytes from normal achilles tendons: An in vitro model of human tendon healing. Am J Sports Med 2000; 28: 499–505
6. SHRIER I, MATHESON GO, KOHL HW. Achilles tendonitis: are corticosteroid injections useful or harmful? Clin J Sport Med 1996; 6: 245-250
7. KABBANI YM, MAYER DP. Magnetic resonance imaging of tendon defects of rabbit with tissue engineering method. Chin J Traumatol 2002; 5: 200-208
8. MAFFULI N, DYMOND NP, CAPASSO G. Ultrasonographic findings in subcutaneous rupture of Achilles tendon. J Sports med Phys Fitness 1989; 29: 365-368
9. MAFFULI N. Rupture of the Achilles tendon. J bone Joint Surg Am 1999; 81-A: 1019-1036
10. KUWADA GT. Classification of tendo Achilis rupture with consideration of surgical repair techniques. J Foot Surg, 1990; 29: 361-365
11. MYERSON MS. Achilles tendon ruptures. Instr Course Lect, 1999; 48: 219-230
12. ABRAHAM E, PANKOVICH AM. Neglected rupture of the Achilles tendon. Treatment by V-Y tendinous flap. J Bone Joint Surg Am 1975; 57-A: 253-255
13. BOSWORTH DM. Repair of defects in the Tendo Achillis. J Bone Joint Surg AM 1956; 38-A: 111-114
14. NILSSON-HELANDER K, THOMEÉ R, GRÄVARE-SILBERNAGEL K, THOMEÉ P, FAXÉN E,. ERIKSSON BI, KARLSSON J. The Achilles Tendon Total Rupture Score (ATRS): Development and Validation Am J Sports Med published online before print December 7, 2006, doi 10.1177/ 0363546506294856
15. WILL AND GALEY. Outcome of single incision flexor hallucis longus transfer for chronic achilles tendinopathy. Foot Ankle Int (2009) vol. 30 (4) pp. 315-7
16. PARSONS JR, WEISS AB, SCHENK RS, ALEXANDER H, PAVLISKO F. Long-term follow-up of Achilles tendon repair with an absorbable polymer carbon fibre composite. Foot Ankle 1989; 9(4):179–184.
17. AMIS AA, CAMPBELL JR, KEMPSON SA, MILLER JH. Comparison of the structure of neotendons induced by implantation of carbon or polyester fibres. J Bone Joint Surg 1984; 66–B(1):131–139
18. US AK, BILGIN SS, AYDIN T, MERGEN E. Repair of neglected Achilles tendon ruptures: procedures and functional results. Arch Orthop Trauma Surg 1987; 116:108–111.
19. KESSEL CG. Repair of neglected Achilles tendon ruptures—procedures and functional results. J Foot Ankle Surg 1984; 33(1):46–52.

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Cartilage overuse: surgical interventions in Cartilage lesions. Case report in an high-performance athlete

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Summary:

Regarding cartilage lesions and the different types of impairment there are variable options of treatment. Massive cartilage defects denote in the past very often the end of the career in high-performance athletes. Is there a surgical treatment for a possible re-entry?

Case: A professional soccer player with medial femoral and tibial cartilage defect and varus malalignment was treated in our department with Microfracture combined with HTO opening wedge. After 13 month of rehabilitation he was able to completely participate in 2. league professional soccer. This case clarifies a possible re-entry to high-performance sports after cartilage repair including HTO. Regarding the variation of cartilage defects it is not possible to declare a golden standard for the treatment in high-performance athletes, but taking into account certain parameters, a return to a high sports level after major surgery is possible.

Introduction:

Sport and especially high-performance sports are highly demanding on the musculoskeletal system and its respective structures. Particularly in the knee joint traumatic and degenerative cartilage defects occur frequently [Patrascu et al, 2010; Mithoefer et al 2009]. This often means the end of the professional career for an athlete. For this reason the challenge in the treatment of articular cartilage lesions in athletes is the return to preinjury level of sports. In our department, athletes from different sports showed a return to their previous level of sports after surgical cartilage repair techniques, such as microfracture, osteochondral autograft transfer and autologous chondrocyte transplantation. The following case describes even a successful comeback to professional sports after microfracture combined with a high tibial osteotomy which is rather rare.

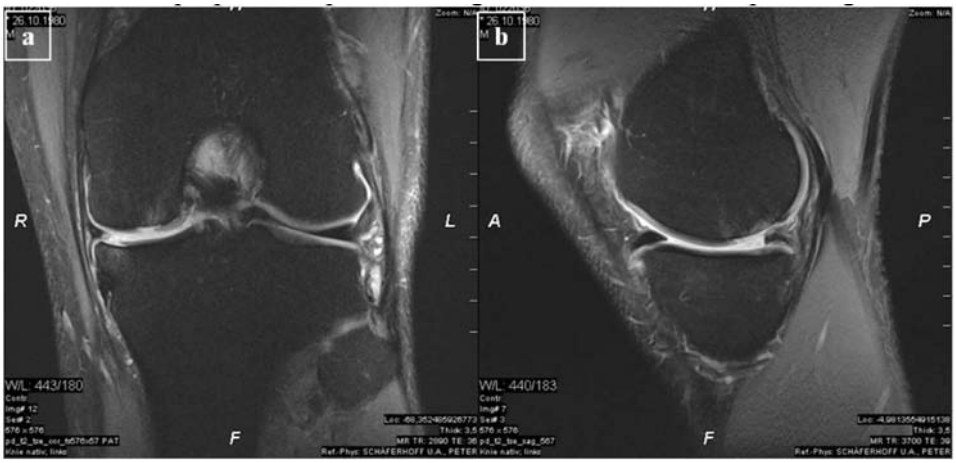

Figure1: (a+b) MRI preoperative with cartilage defects of the medial tibial and femoral side.

Case presentation:

At first presentation in our department on 26.06.2008, the 28-yr-old professional soccer player reported sudden sharp pain of his left knee on the medial side after a twisting trauma during a soccer game one day ago, especially during rotational movements and a squatting position. After clinical evaluation and magnetic resonance imaging (MRI) the following details of the left knee were diagnosed:

- Little effusion
- Extension / Flexion 5/0/130 °
- Lachman test negative
- Steinmann test negative
- Pressure pain at medial joint line
- Collateral ligaments stable
- Posterior drawer test negative
- Pivot shift test negative
- Zohlen sign negative
- No pressure pain in patellar facet
- Varus malalignment both sides (3 fingers intercondylar distance)

Post-traumatic assessment by MRI (Fig 1) revealed a sharply defined defect of the cartilage located in the medial femoral condyle and medial on tibial side, but not as kissing lesion. According to the Outerbridge classification [Outerbridge, 1961] the defects were categorized as grade IV. The menisci were intact and small cartilaginous loose joint bodies were in the suprapatellar space. The ligaments were without pathological findings.

Because of the specific situation as professional soccer player we started an intra-articular injection therapy with autologous conditioned plasma (ACP, Arthrex, Naples). Additionally he received physical therapy and a forced rehabilitation program. On the 26.07.2008, he returned to full team-training and competition. Two month later he showed up again in our department because of increasing pain located at the medial

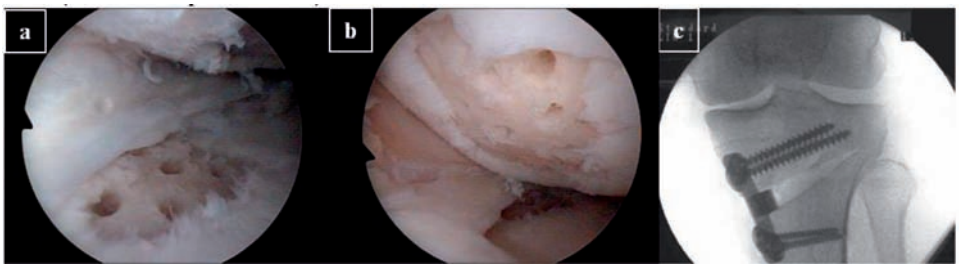

Figure 2: The microfracture medial tibial (a) medial femoral (b) and the intraoperative x-ray after HTO (c).

side of the left knee. The MRI-control showed a slight increase on both defect sizes (tibial and femoral). A new series of ACP-injections could not improve the pain significantly. Because of recurrent effusion and discomfort another MRI was done on 11.12.2008. This assessment detected a significant increase in the size of the medial femoral cartilage lesion. The defect size was now 1.5x2cm femoral and 0.5x1cm tibial. The persistent and increasing complaints and the deterioration of cartilage situation detected by MRI made us decide for a surgical treatment.

The cartilage lesion was carefully debrided down to the subchondral bone without penetrating the subchondral plate. As cartilage repair technique a standard microfracture procedure was then performed medial on the femoral and tibial side. This technique attempts to stimulate regeneration of the cartilage. Based on the chondral damage and concomitant malalignment, we combined chondral resurfacing procedure (microfracture) with valgising high tibial opening wedge osteotomy (Fig 2) using the Arthrex instrumentation including the Puddu Plate (Arthrex, Naples, Florida).

The operation was performed on 09.01.2009 without any complications. Continuous passive motion (CPM) for 6 weeks started immediately. The physiotherapy also started at first day postoperatively including lymphatic drainage, manual therapy and passive physiotherapy. After 6 weeks postoperative, the knee was widely symptom-free. There was no effusion or tenderness over the joint line and in the area of the Puddu Plate. The mobility (Ex/Flex) was 0/0/120 °. Therefore the athlete started with partial weight-bearing (20 kg), slight isometric strength training and switched from CPM to stationary bicycling. Within the 8th week postoperatively, the soccer player reached half-body weight-bearing and in the 10th week full weight-bearing. Additionally he begins with coordinative skills training. After moderate exercises without any complaints the patient started training on the cross trainer and squats with a barbell 4 month after surgery. This increasing training caused mild symptoms at the pes anserinus tendons whereas the knee was otherwise unremarkable. He started running on the treadmill during 6th month postoperative and one month later individual soccer- training could be conducted. Beside irregular discomfort at the pes anserinus, the complete training was symptom free during or after the exercises. On the base of the clinical control, an x-ray (Rosenberg View) confirmed the good healing process (Fig 3).

Within the 8th month after surgery further increase of the training with submaximal sprint exercises combined with changes of direction was done without pain or swelling in the knee. 10 months postoperatively, the Puddu Plate and its four captive screws were removed on 15.10.2009 surgically. After surgery the patient started his

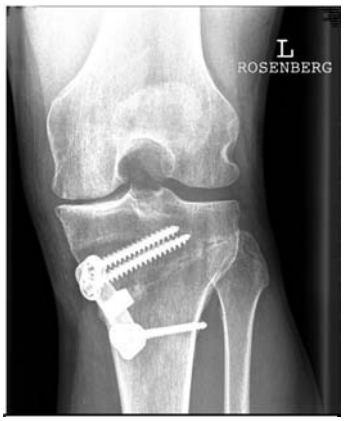

Figure 3: X-ray in Rosenberg view

rehabilitation training and 10 days later he was able to continue the soccer-specific training. After continuous increasing sport-specific exercises without any discomforts in the knee joint (no swelling, no pain, no problems in the area of the pes anserinus) during the 13th month postoperatively, the athlete was able be fully integrated into the team training on 22.02.2010.

14 month after the surgical cartilage treatment (microfracture/HTO) the professional soccer player completed his first soccer game successfully.

Discussion and Conclusion:

For the management of articular cartilage defects of the knee, many treatment options have been defined. The current surgical cartilage repair techniques, such as microfracture, osteochondral autograft/allograft transfer and autologous chondrocyte transplantation, have shown good outcomes in improving knee function and reducing pain. The optimal cartilage therapy is determined by the characteristics of the defect and like in this case the alignment of the lower extremity. But what about the return to preinjury level in sports? Most athletes evaluate a postoperative come back to their preinjury activity as most important fact for a successful treatment. Beside the optimal cartilage treatment and surgical experiences, several factors exist that influence the participation of activities. Among other things, the preoperative duration of symptoms, lesion size, athlete's age, sports level, the rehabilitation and the patient's compliance play an important role regarding the postoperative sport ability [Asik et al. 2008, Mithoefer et al 2009]. In the literature review of Mithoefer et al. the medical databases from 1966-2009 were analyzed regarding the athletic participation after articular cartilage repair. They found twenty studies in which more than 70% of patients could perform sports after different cartilage treatments. Postoperatively the highest average Tegner activity score reached 6.1 points and could be graded as recreational participation. In our case, we reported a return to the high level professional sports which is the highest possible result in the Tegner score. Our aim is performing an individual treatment as close and constant as possible with consultation

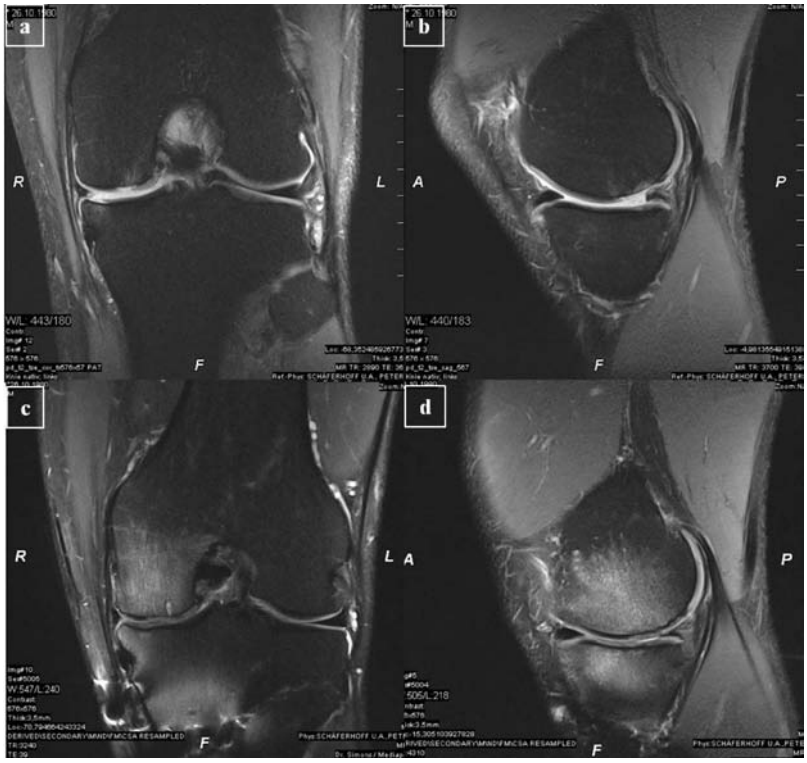

Figure 4: MRI of the cartilage lesions preoperative (a+b) and 20 month postoperatively (c+d).

of the physicians, physical therapists, sports scientists and the patient. This enables us to notice first irregularities early and react immediately and adequately in the current training phase if necessary. In this case the soccer player showed a full re-entry to the team-training at 13 month and complete his first soccer game 14 month postoperative. This example clarifies a possible re-entry to high-performance sports after chondral resurfacing procedure (microfracture) and combined opening wedge osteotomy (HTO). Until now the athlete plays without any discomfort of the knee in the second german soccer league. A MRI examination (Fig 4) of the left knee because of patella femoral complains 20 month after surgery confirmed the positive development of the cartilage treatment.

Regarding the variation of cartilage defects it is not possible to declare a golden standard for cartilage treatment in athletes. There are several independent factors that influence the return to high-performance sports. Further observations are essential and need to be done in other studies to get more information in larger quantity of high-performance athletes.

References:

1. Outerbridge RE. The etiology of chondromalacia patellae. J Bone Joint Surg [Br], 43-B:752-7, 1961.

2. Mithoefer K, Hambly K, Della Villa S, Silvers H, Mandelbaum BR. Return to Sports Participation After Articular Cartilage Repair in the Knee: Scientific Evidence. Am J Sports Med, 37:167S, 2009.
3. Asik M, Ciftci F, Sen C, Erdil M, Atalar A. The Microfracture Technique for the Treatment of Full-Thickness Articular Cartilage Lesions of the Knee: Midterm Results. Arthroscopy, 24, 11: 1214-1220, 2008.
4. Patrascu JM, Freymann U, Kaps C, Poenaru DV. Repair of a post-traumatic cartilage defect with a cell-free polymer-based cartilage implant. A follow-up at two years by MRI and histological review. J Bone Joint Surg [Br], 92-B:1160-3, 2010

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