Treatment of meniscal injury: a current concept review

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Abstract Meniscal injury is one of the most common injuries to the knee. The menisci are important for normal knee function. And loss of a meniscus increases the risk of subsequent development of degenerative changes in the knee. Now there are different techniques available for meniscal injury. These techniques include expectant treatment, meniscectomy, meniscal repair, meniscal replacement, and meniscal tissue engineering. Expectant treatment is the appropriate treatment for minor tears of the menisci. Meniscectomy being favored at the beginning is now obsolete. Meniscus repair has become a standard procedure. Meniscal replacement and tissue engineering are used to deal with considerable meniscal injuries. The purpose of this paper is to provide current knowledge regarding the anatomy and function of the menisci, incidence, etiology, symptoms, signs, investigations and treatments of meniscal injury.

Key words: Menisci, tibial; Knee injuries; Tissue engineering; Review

Meniscus has an important role in load transmission, shock absorption, stability, congruence, lubrication and proprioception of the knee joint. Meniscal injury is a common traumatic injury in the knee. And meniscal injury may lead to long-term degenerative joint changes, such as osteophyte formation, articular cartilage degeneration, joint space narrowing, and symptomatic osteoarthritis. In this paper, we review current treatments of meniscal injury including expectant treatment, total or partial meniscectomy, meniscal repair, meniscal replacement, and meniscal tissue engineering.

Anatomy and function of the menisci

The menisci of the knee are two crescentic wedges of fibrocartilage, positioned between the tibia and the femur in the medial and lateral compartments. Menisci possess collagen fibers oriented circumferentially. These circumferential fibers are bound by radially oriented fibers. The menisci are centrally avascular, relying on diffusion from synovial fluid for their nutrition. Peripherally, the menisci are nourished by a perimeniscal capillary plexus originating in the knee’s capsular and synovial tissues from the superior and inferior medial and lateral geniculate arteries. Anterior and posterior horn-insertions contain types I and II neuroreceptors with possible proprioceptive and mechanoreceptive capacities.

The fibrocartilage menisci have many important functions in the knee joint. The menisci transmit 50% of joint compressive forces in full extension and approximately 85% of the load in 90° of flexion. And they contribute to shock absorption, augment lubrication, rotation of the opposing articular surfaces, and joint nutrition. The menisci also help the tibiofemoral joint stability and overall joint congruency. A proprioceptive structure has been found that provides a feedback mechanism for joint position sense.

Incidence and etiology of meniscal injury

Meniscal injury is the most common injury of the knee. The reported annual incidence of meniscal injury is about 61 per 100,000 population. Medial meniscal injuries are generally seen more frequently than injuries of the lateral meniscus, to a ratio of approximately 2:1. Meniscal injuries may occur in acute knee injuries in younger patients or as part of a degenerative process in older individuals. The acute injuries frequently result from sport injuries where there is a twisting motion on the partially flexed, weight-bearing knee. Acute meniscal injuries may also occur as part of more major, combined injuries to the knee.

Symptoms, signs and examinations

The classic symptoms of a meniscal injury are pain around the affected side of the joint, possible locking of
the joint, and swelling. Ongoing symptoms include pain
around the joint line, clicking, giving way and locking.
McMurray’s test is commonly performed as part of the
routine knee examination in order to test for the pres-
ence of a meniscal injury. Plain anteroposterior and lat-
eral radiographs are used to determine meniscus width
and length. Spiral CT arthrography and MRI with proton
density, fast-spin-echo techniques may be used to evalu-
ate the status of the articular cartilage and subchon-
dral bone. But arthroscopy is infallible in the diagnosis
of meniscal injuries.

Treatment

Expectant treatment Not all meniscal injuries
require surgery. Some of them have the ability to heal.
The meniscal tear pattern and the presence of adequate
vascularity are both key points. Tears within 3 mm of
the meniscosynovial junction usually have an adequate
blood supply that allows healing. Tears of 5 mm or more
from this junction are considered avascular and need
surgical intervention. The intervening area between
3 mm and 5 mm from the meniscosynovial junction
has variable vascularity, so the treatment depends on
clinical judgment. The decision of expectant treatment
must be considered by tear pattern, site, vascularity,
size, stability, patient’s age, tissue quality, and associ-
ated pathology within the knee joint and the patient’s
goals.

Meniscectomy In the past, open total menis-
cetomy was the appropriate treatment for tear of the
menisci. This technique could relieve the symptoms
effectively and improve the knee function fast. However,
some unhealthy changes after meniscectomy have been
shown in both short-term and long-term follow-up
studies. After total meniscectomy, the tibiofemoral con-
tact area decreases by approximately 50%, while con-
tact forces increase 2-to-3 folds. So poor results have
been reported following meniscectomy, including dis-
ruption of load-sharing and shock absorption, diminu-
tion of joint stability and nutrition, flattening of the femoral
condyle, development of osteophytes, narrowing of the
tibiofemoral joint space, and deterioration of articular
cartilage with progression to arthrosis. Roos reported
a 21 years’ follow-up and found 14% of patients having
radiographic signs of osteoarthritis after meniscectomy
as compared with controls.

Now adverse effects of total meniscectomy are
clearly demonstrated and universally accepted. And in
the more frequent cases with irreversible damage of
meniscal tissue, partial instead of total meniscectomy
is the treatment of choice to minimize loss of this im-
portant anatomical structure. So much interest has fo-
cused on the partial meniscectomy.

Universally, in the more frequent cases of extensive
tear of the posterior horn, not the loose central part of
the meniscal body, the risk of completely cutting
through the meniscal periphery or insertional ligament
in order to resect all damaged tissue, is high. And if the
meniscus is cut through its periphery, its load distribu-
tion function will probably be completely disrupted, de-
spite the fact that most of the meniscal body (central
region and horns) remains intact. Such a partial menis-
cetomy probably results in a similar increase of peak
stresses on the tibial plateau and therefore a potential
risk of the joint developing osteoarthrosis. Partial me-
niscectomies are thus in reality total ones.

In a biomechanical study of partial versus total
meniscectomy, Andersson-Molina showed that there
was a linear correlation between increase in peak stress
on the tibial joint surfaces and the amount of meniscal
tissue removed. In a review of patients undergoing ei-
ther partial or total meniscectomy, the function of the
knee was inversely related to the amount of meniscal
tissue excised. But there were still a significant num-
ber of complaints from patients after partial
meniscectomy. Until now we still do not know in the
individual case today if the so-called advancement in
therapy using partial instead of total meniscectomy
really means improvement of the long term prognosis
of knee function.

Meniscal repair Over the past two decades,
there has been great effort towards avoidance of
meniscectomy. Techniques to repair appropriate me-
niscectomies have been developed in a way to preserve
tissue and function.

Animal studies of the response of the menisci to
injury have shown that at its periphery, meniscal tissue
is capable of producing a reparative response. Cabaud
performed transverse medial meniscal lacerations and
repaired with a single Dexon suture in 20 canine and
12 rhesus monkey knee joints. By four months, only
6% of the menisci had failed to heal. Newman per-
formed a complete midportion transaction of the medial meniscus in 38 canine knees. He showed that the response originated from the peripheral synovial tissues, and that the menisci had completely healed by fibrovascular scar within 10 weeks. Longitudinal incisions in the inner, avascular portion of the meniscus failed to heal.

Meniscal injuries are classified according to the location of the injury relative to the blood supply of the meniscus. In the ‘red–red’ region, both the peripheral and inner margins of the injuries have an enough blood supply, and these peripheral tears have the best prognosis for healing. In the ‘red–white’ region, injuries have vascularised tissue on the peripheral side and avascular tissue on the inner side. In the ‘white–white’ region, injuries are completely in the avascular zone and are least likely to heal. 15

Various techniques have been described in an attempt to facilitate healing of injuries in the inner, avascular portion of the meniscus, including the creation of vascular access channels, trephination, rasping of the paramenisical synovium, and use of exogenous fibrin clot or free synovial autografts, or even laser welding.

Techniques of open, inside-out, outside-in and all-inside arthroscopic repair have been described, and each has its merits. 16 Open repair was first reported in 1885 by Annandale, 17 but was not widely used. An arthroscopic inside-out meniscal repair was pioneered by Henning in the early 1980s with later contributions made by Clancy and Graf. 18 The outside-in approach was developed to decrease the risk of injury to posterior neurovascular structures. 19 Advances in technology have led to all-inside techniques for posterior horn meniscus repair further reducing neurovascular injury and decreasing operative time. 20

A number of biomechanical studies have investigated the properties of meniscal repairs using various different techniques of suturing, 21 and all have confirmed that the vertical loop suture is the strongest, exhibiting the greatest load to failure when compared with horizontal or mulberry-knot sutures. Furthermore, numerous meniscal repair devices, such as bioabsorbable arrows, fasteners, and ‘T-bar ended sutures, are now available that may offer potential benefits compared with the traditional method of meniscal repair by suturing. 22

Having tried many of the meniscal suturing devices available, our preference is towards the use of the FasT-Fix device. This is an all-inside suture repair system comprising two 5 mm polymer suture bar anchors, with a pre-tied self-sliding knot of 0° non-absorbable polyester suture. It allows easy and rapid insertion of strong, tight horizontal or vertical loop sutures, which biomechanically remain the gold standard. 23 However, at the same time the FasT-Fix avoids some of the potential complications that have been observed with some of the bioabsorbable arrows or dart-like devices, such as foreign body reactions in the soft tissues due to migrating broken devices, or severe chondral damage from broken or protruding implants within the knee. 24 The results reported with the use of the FasT-Fix for meniscal repair have been highly encouraging. Barber reported on the outcome of 41 meniscal repairs at an average follow-up of 30.7 months, and observed that just over 83% of repairs were clinically successful, with absence of joint-line tenderness, locking, or swelling, and a negative McMurray test. In another prospective case series of 61 meniscal repairs using the FasT-Fix, Kotsovolos reported that patients (88%) had their results as good or excellent at an average of 18-month follow-up.

Summarily, meniscal preservation has gained a high level of awareness in the recent years. It is beneficial to avoid the development of knee arthritis. So the surgeon makes every attempt to repair tears in both the periphery and central one-third avascular zone. meniscal repair devices offer many advantages, including decreased surgical time, less risk of injury to neurovascular structures and better cosmesis. Because of these advantages, more and more meniscal repairs are being performed. Self-adjusting suture devices (FasT-Fix and RapidLoc) offer more flexibility in the repair construct and most closely approximate the “gold standard” suture repair. 27 However, these repair devices have the disadvantages of increased costs, retained polymer fragments, implant migration, foreign body reactions, inflammation, a significant learning curve, chondral injury, and concerns over lower successful healing rates.

Meniscal replacement While many menisci injuries can be successfully repaired, not all of them are salvageable, especially if considerable tissue damage has occurred. A large proportion of meniscal injuries remain irreparable, and partial, subtotal or total me-
nisecotomy may still unavoidably be performed. In the past, a number of different tissues or materials have been used as an attempt to replace excised meniscal tissue. These include the use of silastic, carbon fibre, Dacron, and Teflon prostheses, patellar, Achilles or semitendinosus tendon autograft, fat pad autograft, and autologous rib perichondrial grafts. Few of them are available to relieve postmeniscectomy compartmental pain or to reduce the likelihood of the subsequent development of secondary arthritis.

As an alternative, the concept of meniscal allograft transplantation has been developed. Meniscus allograft transplantation represents a potential biological solution for the symptomatic meniscus-deficient patient who has not developed advanced osteoarthritis. The indications for meniscus allograft transplantation are age of 50 years or less, prior total meniscectomy, clinical symptoms of pain in the involved joint or articular cartilage degeneration, and 2 mm or more of tibiofemoral joint space on 45° weight-bearing posteroanterior radiographs. The contraindications for meniscus allograft transplantation include diffuse subchondral bone exposure, axial malalignment, and instability.

The first published study describing meniscal allograft transplantation in animals was a canine study in 1986 by Canham. Since this study, meniscal transplantation has been described in sheep, rabbits, mice, rats, goats, and monkeys. The first human meniscal allograft transplantation was reported by Milachowski in 1987, and again in 1989. Since then, numerous clinical studies have reported results of meniscus transplantation. Differences in tissue processing, secondary sterilization, preservation, operative techniques, and rating schemes make comparisons between studies difficult. Clinical evaluation, using physical examination or subjective symptoms, may not reliably correlate with the condition of the allograft. Both MRI and second-look arthroscopy have been used to obtain objective evaluation of the status of meniscal allografts post-transplantation. Although more invasive, arthroscopy may correlate better with outcome than MRI.

The short-term results of meniscal allograft transplantation are encouraging in terms of reduced knee pain and increased function. Deie reported the largest series of patients in 2007. The outcomes of 32 allografts, performed in 29 patients at a mean follow-up of 3.3 years, showed good-to-excellent results in 96% of cases. Although the published studies are often difficult to compare, meniscal allograft transplantation appears to have reliable results in pain relief and function improvement. Most studies with mid-term follow-up describe healing of the allograft to the periphery and symptomatic improvement. Series with mid-term follow-up are beginning to be published. Van der Wal described 63 procedures and survival analysis showed that pain relief and functional improvement persist in approximate 71% of patients at 13.8 years follow-up. An additional finding is that medial and lateral meniscal transplantsations have similar longevity unless the transplanted knee is lacking a functional anterior cruciate ligament (ACL), in which the survival of medial implants tends to be compromised.

But long-term transplant function and chondroprotective effects remain unknown and require continued investigation. Future research should determine if the beneficial effects will persist in long-term follow-up. Additional and long-term studies are needed to evaluate the optimal timing of meniscal allotransplantation in humans and the actual function and condition of the allografts. An ultimate question is whether or not this procedure provides long-term prevention or delay of articular cartilage degeneration and osteoarthritis.

Although meniscal replacement is in its relative infancy in China, several thousand procedures have been performed in the USA and Europe. The future of meniscal replacement probably lies with the field of tissue engineering, and currently experimental work is directed at the development of bioabsorbable scaffolds, cell culture and implantation, and gene therapy.

Tissue engineering Given the poor results following prosthetic meniscal replacement and the highly variable results of autografting using alternative tissues, now much interest and study is currently being directed towards the field of tissue engineering. It may offer new treatment modalities for the regeneration of meniscal lesions or for the complete replacement of a degenerated (part of total) meniscus by the production of newly synthesizing meniscal tissue, in part or in whole. Tissue engineering is based on a smart and unique combination of exogenous cells, matrix scaffold, specific stimuli (growth factors, mechanical stress), in an in vitro or in vivo environment. In terms of cell sources, three
basic cell types have been identified as potential sources for the meniscal tissue engineering: the meniscal fibrochondrocyte, the mesenchymal stem cell and the pluripotent fibroblast. These cells could synthesize appropriate extracellular matrices and restore meniscal function. The future research should be directed to the effect of using ideal matrix and growth factors for their stimulation into an optimal phenotype in combination with a mechanically loadable scaffold material.42

The ideal matrix would allow cell proliferation, free diffusion of nutrients, access to cytokines, and be mechanically durable and resorbable as the tissues own extracellular matrix develops. So far, several growth factors have been demonstrated to have an effect on meniscus explants or on isolated meniscus cells in culture. In particular, growth factors that stimulate synthesis and inhibit degradation of extracellular matrix production could be very useful to direct the cells into an optimal phenotype. Transforming growth factor (TGF-β) and platelet-derived growth factor (PDGF) are candidates to stimulate proliferation of meniscus cells. A recent study showed that both TGF-β and PDGF may be involved in a shift of the chondrogenic or meniscus-cell-like phenotype into a phenotype in which smooth muscle actin is expressed. Alternatively, gene transfer techniques are also very useful for the local up-regulation of specific factors involved in the stimulation of an optimal vascularity of tissue-engineered constructs. Some experiments, vectors expressing therapeutic proteins such as growth factors have been investigated to assess their potential to improve remodeling and healing of meniscus allografts and tissue-engineered cells or constructs.43

As regards to scaffold, an ideal scaffold material should be biocompatible and biodegradable in the long term. Moreover, it should permit unrestricted cellular ingrowth, allow free diffusion of nutrients, may be used as a carrier for stimulatory and inhibitory growth factors and it should be strong enough to withstand the load in the joint and maintain its structural integrity under these loaded conditions. Furthermore, it should have a degradation profile that allow ingrowth of new tissue and thereafter allow remodeling of these tissues under the influence of load.44 In the light of all these different prerequisites, many scaffold materials of different categories may be considered for application for tissue engineering of the meniscus.

Tissues have been used as natural scaffold materials. Examples are periosteal tissue, perichondral tissue, small intestine submucosa and meniscus tissue itself. But the results of these whole tissues used as scaffold material have met with poor results. Isolated tissue components, for instance, collagens, proteoglycans or elastin molecules, can be reconstituted into tailor-made scaffolds with optimal three-dimensional architecture. But the mechanical properties of such scaffolds may be a problem, since they are low for load-bearing applications in many cases. The most popular reconstituted scaffold is based on isolated collagen molecules. Thus, these new scaffolds are very promising, optimising with respect to the initial load-bearing capacity. The control of the creation of pores for new tissue ingrowth and the biological turnover in the body may be subjected to further research.

The second option is to use completely synthetic polymer-based scaffolds. Most polymers used currently in tissue engineering are produced from the polyester family of biomaterials and degraded by gradual hydrolysis.45 Polymers have been produced using polyglycolic acid, polylactic acid, polyurethane and combinations of these and of other copolymers. A great advantage of polymers is that the porosity, the degradation rate and the mechanical properties can be adapted to the desired specifications. In this respect, the biodegradable polyester urethanes based on l-lactide/ε-caprolactone might be particularly promising materials for tissue engineering of the meniscus.46

To deal with tears located in the avascular, inner one-third of the meniscus, a variety of techniques have been developed to restore the structural integrity of these menisci tears. Several studies in different animal models (rabbits, canines, sheep) have already showed that particularly the porous and biodegradable polyurethane-based polymers scaffolds can promote the formation of fibrocartilage and can induce healing of the lesion.45 However, there are also problems with this technique. In some cases integration between the polymer and meniscus tissue is insufficient, resulting in impaired healing of the lesion.

In some cases, some patients have to take a total meniscectomy. After that, they need an ideal implant that could be used to replace their own menisci. Al-
lografts or synthetic menisci have been used with varying success to prevent early degenerative joint disease in these cases. Problems related to reduced initial and long-term stability, as well as immunological reactions, prevent widespread clinical use so far. In a search for alternatives for above-mentioned prosthesis, further work has recently been directed towards the role of gene therapy for meniscal injury. In Sandmann’s study, human meniscus samples were successfully acellularized using sodium dodecyl sulphate (SDS) without negatively affecting the main biomechanical properties. These cell-free constructs could serve as excellent scaffolds with a preserved extracellular matrix maintaining the natural biomechanical properties. Future research is necessary to evaluate the in vivo consequences of SDS acellularization.

The discipline of tissue engineering is in its relative infancy. Many questions pertaining to tissue engineering of the meniscus still remain unanswered. But technological advances are enabling the application of new techniques at a rapidly increasing rate, and instead of merely being in the realms of science fiction, the prospect of creating tailor-made replacement tissues by order now seems even more likely to be a reality.

Conclusion

The principles of meniscal treatments have undergone considerable changes over the past years. Total meniscectomy being favored in the beginning is now obsolete. The importance of the meniscus has been recognized and leads to the basis for the modern meniscus surgery. Then meniscus repair has become a standard procedure. With the help of modern techniques the healing of the meniscus can be enhanced even in less vascularized areas of the meniscus. To deal with the considerable meniscal injuries, the concept of meniscal replacement and tissue engineering are developed. Although both of them are in their relative infancies. There is a great scope for further research.

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