Arch Orthop Trauma Surg (2002) 122: 217–221
DOI 10.1007/s004020100331

ORIGINAL ARTICLE

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The cartilage of the tibiofibular joint: a source for autologous osteochondral grafts without damaging weight-bearing joint surfaces

Received: 17 January 2001 / Published online: 8 September 2001

Abstract Within the past few years, autologous osteochondral transplantation has become an established procedure in the therapy of articular cartilage defects of the knee. One significant disadvantage of this technique is the harvesting of grafts from the weight-bearing area. The tibiofibular articulation is less loaded. The purpose of this study was to evaluate the question of whether this joint is suitable as a donor site for osteochondral grafts. Ten fresh human knees were dissected to perform histology, immunohistochemistry, and thickness measurement of the tibiofibular cartilage. Favourable approaches and establishing of anatomical landmarks were investigated in 44 fixed tibiofibular joints. In knee extension, the shortest distance between the joint cleft and common fibular nerve was measured. A total of 389 bone specimens was analysed morphometrically (cartilage area, orientation of the joint line, signs of arthrosis). Histological and immunohistochemical examination showed hyaline cartilage and type II collagen. The area of cartilage amounted to 3.58 cm^2 (mean) at the tibia and at the fibula with a thickness of 1.6 mm (mean). The joint line is mainly orientated perpendicular to an axis course from craniomedioventral to caudolaterodorsal. Depending on the available instruments, two approaches are possible: from anteromedial or from posterolateral. The mean distance to the common fibular nerve was 19.5 mm. Signs of arthrosis were found in 1 of 10 fresh knee specimens and in 11.4% of the bone specimens. Transplantation into three patients showed no intra- or postoperative complications and a rapid and uneventful recovery. The proximal tibiofibular joint is an excellent donor site for autologous osteochondral grafts.

Keywords Anatomy · Autologous bone-cartilage transplantation · Proximal tibiofibular joint · Femoropatellar joint

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Introduction

Damage of the hyaline joint cartilage is a frequent problem. In injuries of the knee joint with a haemarthrosis, 16% of the patients suffer from a chondral lesion. Spontaneous healing cannot occur if the diameter of the lesion exceeds 2–4 mm, and in these cases early degenerative joint disease may appear [10, 12, 13, 28, 35].

In 32% of the cases, juvenile osteochondrosis dissecans (JOCD) leads to radiological abnormalities when the patients reach the age of 34 years; only 50% of these patients show good or excellent joint function [2].

In general, there are five different treatment modalities for the surgical management of cartilage lesions. The damaged area can be restored, replaced (alloarthroplasty), resected (resection arthroplasty), fused (arthrodeses) or released (correction osteotomy).

Cartilage-inducing techniques like abrasion arthroplasty [26], micro-fracturing [39] and Pridie-drilling [34] have an analogous biologic approach. By opening the subchondral space, the growing of fibrous cartilage is induced. Short-term results show that these techniques are relatively easy to perform and rather inexpensive; however, the long-term results are controversial [25, 29]. In the older patient population, an increase in function and a decrease in pain can be achieved with joint replacement [24]. However, there still remains a large population group after trauma or JOCD which are much too young for alloarthroplastic replacement.

Interest has grown in autologous bone-cartilage transplantation, and it was developed into a standardised procedure. Its significant disadvantage is that the osteochondral cylinders are harvested from an intact hyaline cartilage area of the knee joint.

The proximal tibiofibular articulation is located close to the knee joint. Occasionally, a marked variability in its morphological characteristics has been described [16]. Therefore, basic data on topographical and morphological parameters is necessary. Furthermore, scientific publications lack relevant information on the frequency of osteoarthritic changes, and the type and amount of the covering cartilage have to be evaluated. The purpose of this study was to investigate the question of whether this joint and its cartilage represent a suitable donor site for osteochondral grafts and to establish a procedure for approach and withdrawal.

Patients and methods

The bodies donated to the Institute of Anatomy were from both genders. Their median age was 79 years, with a range of 58–90 years of life span. Ten fresh human cadavers were used for histology, immunohistochemistry and measuring the thickness of the tibiofibular cartilage. The proximal tibiofibular joints of 22 embalmed bodies were dissected for morphometrical and topographical purposes. In total, 389 bone specimens (tibia and fibula) were analysed morphometrically.

Withdrawal of osteochondral grafts

Two different approaches to the proximal tibiofibular joint were performed.

1. The cranial parts of the tibialis anterior and the extensor digitorum longus muscles were mobilised, and the ventral part of the joint capsule was exposed. A square gouge was driven ahead parallel to the joint surfaces and medial to the fibular collateral ligament. Then, the osteochondral graft was harvested with a round gouge from both joint surfaces.
2. A round gouge was driven ahead into the free dorsocaudal bone surface of the fibula cranial to the course of the common fibula nerve and between the origins of the soleus and the fibularis longus muscles close to the subchondral cancellous bone of the tibial plateau.

Histology and immunohistochemistry

The graft was taken from subchondral bone to avoid a decalcification procedure. For histochemistry and immunohistochemical investigations the tissue blocks were fixed in formaldehyde and Bouins fluid, respectively, for 2 days, washed, dehydrated in alcohol, embedded in paraplastand cut into 7-µm sections. Sections were deparaffinized in xylene and rehydrated in graded ethanol.

Subsequently, the sections were stained with haematoxylin and counterstained with eosin for qualitative assessment. With special regard to the connective tissue, Masson’s trichrome stain modified according to Goldner and azocarmine-aniline blue stain according to Heidenhain were applied.

Tissue digestion was performed with pronase for 6 min. For antisera application, the sections were equilibrated in phosphate buffer at pH 7.4, containing 0.2% bovine serum albumin. As the primary antibody, mouse $IgG_{2a/k}$ anti-type II collagen was used. Immunoreactivity was tested using the avidin-biotin technique. For control, the primary antibody was replaced by buffer.

Preparation and morphometry

The fixed knee specimens were dissected, taking particular care in the region of the proximal tibiofibular joint, the lateral collateral ligament, the common fibular nerve and the anterior tibial artery.

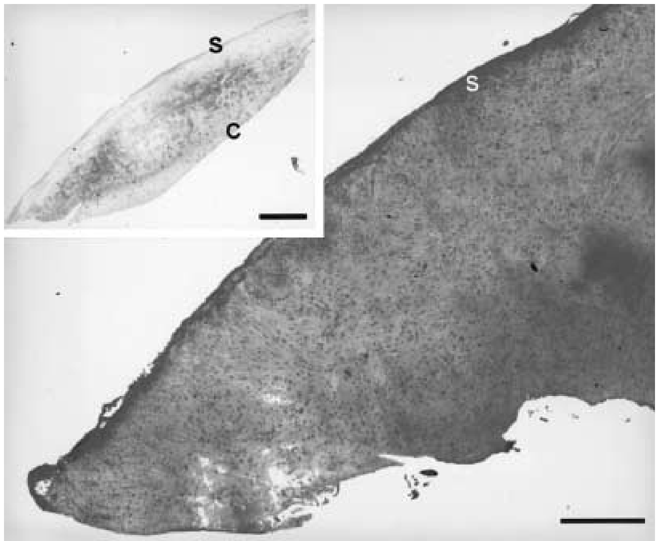

Fig. 1 Haematoxylin and eosin-stained tibial hyaline cartilage (*c*) of the proximal tibiofibular joint, slice cut parallel to the surface (*s*). *Inset:* Detection of type II collagen, slice cut perpendicular to the surface. *Bar:* 500 µm

In knee extension, the shortest distance was measured between the ventral border of the knee’s lateral collateral ligament at the level of the proximal tibiofibular joint cleft and the ventrocranial margin of the commune fibular nerve passing the fibular neck. Next, the ligaments as well as the capsule were removed, and the joint was opened. The following parameters were measured: cartilage area (area was assumed to be approximately elliptical and calculated by the minimal and maximal diameter), orientation of the joint line and signs of arthrosis (osteophytes, cartilage defects).

Case report

In three patients, the tibiofibular cartilage was harvested for bone-cartilage transplantation to the ipsilateral knee joint. All were male, and they were aged 16, 17 and 28 years. In all cases, the lateral condyle was involved. In one patient the cartilage defect was located in the lateral trochlea contacting the patella. In the other two cases, the defect was in the weight-bearing area of the femoral condyle. Due to the marked variability in morphological characteristics, the harvesting of osteochondral grafts from the proximal tibiofibular joint was performed under X-ray supervision (Fig. 1). There is no long term follow up available so far. All patients have been operated on within the last three months. There were no intra- or postoperative complications and not one case in which the fibular nerve was damaged. The short term follow-up showed a rapid and uneventful recovery of every patient.

Results

Preparation and withdrawal of osteochondral grafts

Surgical approaches to the proximal tibiofibular joint especially endanger the common fibular nerve, the anterior tibial artery, and the lateral collateral ligament. The mean distance to the common fibular nerve was 19.5 mm (SD 3 mm). In one case out of 44 knees, the nerve had a high course passing the fibular head instead of the neck, thus showing a distance of 12.3 mm to the joint cleft. This variation interferes with the anteromedial approach. In

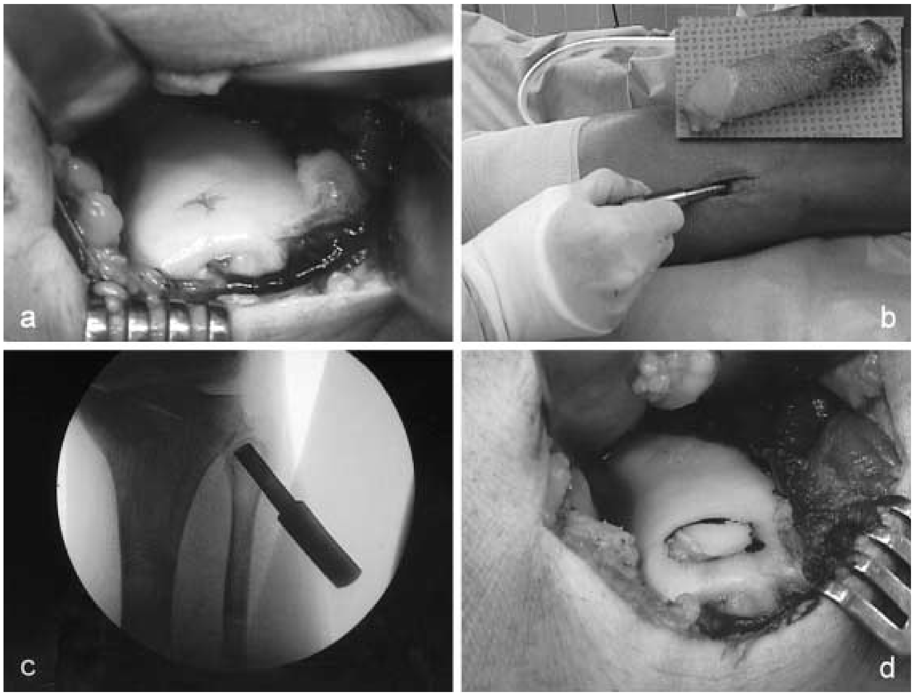

Fig. 2a–d Osteochondral autograft transplantation. **a** Intraoperative aspect of a circumscript cartilage defect of the lateral femoral condyle. **b**, **c** Posterolateral approach with a round gouge, driven ahead under X-ray supervision. The *inset* in (**b**) shows the osteochondral graft. **d** Aspect of the situation shown in **a** after successful transplantation of the graft

general, neither the anterior nor the posterolateral approach were harmful to theses structures. However, the anterior approach traumatizes the soft tissue to a higher degree. Both approaches allow the easy withdrawal of osteochondral grafts.

Histology and immunohistochemistry

The histological examinations showed the typical configuration of hyaline cartilage (Fig. 2) with predominately small chondrons (4 cells) and with narrow interterritories. Unmasked fibres were sporadically found. Immunohistochemically, type II collagen was detected (Fig. 2).

Morphometry

In all specimens, the articular surfaces showed good cartilage coverage at the tibial as well as at the fibular site. The diameter of the cartilage surface at the tibial site was 1.7 cm (SD 0.26)×1.9 cm (SD 0.22) and at the fibular site, 1.6 cm (SD 0.31)×1.8 cm (SD 0.32). Calculation of the area comes to a mean of 3.58 cm^2 at the tibia and at the fibula. No significant difference was seen between the tibial and fibular cartilage areas. The mean thickness of the cartilage was 1.6 mm (SD 0.3 mm). The joint line is mainly orientated perpendicular to an axis course from craniomedioventral to caudolaterodorsal. Signs of arthrosis were found in 1 of 10 fresh knee specimens and in 11.4% of the bone specimens.

Discussion

Efficacious treatment of full-thickness cartilage damage of weight-bearing articular surfaces of the knee represents one of the most frequent problems of daily orthopaedic practice. Circumscript chondral and osteochondral defects of the weight-bearing gliding surfaces can cause several problems for the patient (pain, swelling, instability, clicking, etc.) and may lead to early osteoarthritis.

To restore this defect joint cartilage, two different strategies can be differentiated: first, the regrowth of local tissue; second, the transplantation of cartilage tissue. The conventional approach is the stimulation of multipotential cells with Pridie-drillings, abrasion arthroplasties or microfracture techniques. However, this subchondral penetration has been shown to be of limited value due to the poor biomechanical characteristics of ingrowth reparative fibrocartilage [9].

Bentley and Greer [2] were the first who were able to show that chondrocytes which are transplanted into a cartilage defect can increase healing compared with a control group. Multiple studies have proven the chondrogenic potency of other tissue like perichondrium [3, 11, 33] and periosteum [1, 15, 36]. The autogenous chondrocyte transplantation (ACT) was first performed in animal studies by Grande et al. [19, 20] and later further developed and published by Brittberg et al. [6, 7]. Although there is significant enthusiasm in the scientific and non-scientific public for this technique, some scepticism is also indicated. For example, Breinan et al. [5] could not demonstrate in a prospective, controlled animal model any difference between cartilage defects that were treated with ACT below a periosteal flap, a periosteal flap alone and the non-treated control group.

Osteochondral allografts have been performed for a long time in a small number of centres [13, 14, 27]. The enormous organisation that is necessary for this technique prevents a more widespread acceptance today and will continue to do so in the future.

Due to these problems, especially due to the costs of the ACT, the interest in osteochondral autologous cartilage transplantation has increased within the past few years [4, 21]. This technique is technically less demanding and can be performed arthroscopically. The short-term results of the different autogenous osteochondral transplantations show promising results (osteoarticular transplant system, mosaicplasty, cartilage osteo repair) [4, 21, 22, 23].

One significant limitation is the restricted availability of graft material and, on the other hand, the morbidity caused to the donor site. Brown et al. [8] showed an increase of the contact stress concentration at the border of the iatrogenic osteochondral defects. It is unknown whether this is sufficient to induce degenerative joint disease, but the donor site will never show hyaline cartilage again. In general, Simonian et al. [38] could demonstrate that significant contact pressures are present in all clinically used donor site areas of the knee joint.

Based on these findings, the search for less critical donor sites is of importance. Our results show that even in the older bodies donated to the Institute of Anatomy the hyaline cartilage of the proximal tibiofibular joint is of surprisingly good quality. The amount of available osteochondral surface area seems to be sufficient for most of the indications for this technique.

Certainly, the different thicknesses between the donor site of the tibiofibular joint and the recipient site at the femur condyle need to be discussed. However, this is a problem which other conventional donor sites also face. The thickness of the tibiofibular cartilage widely corresponds to the thickness of other donor sites. One may assume that the cartilage will adapt in relation to the new anatomic and biomechanic environment. At least this was not a problem in the published reports on mosaicplasty or comparable techniques.

A few papers can be found concerning theoretical problems that may follow harvesting osteochondral grafts from the tibiofibular joint. Ogden [31] described two types of joint, horizontal and oblique, the latter being considered less stable. In our population only 2% had a horizontal orientation, but 49% showed a vertical or nearly vertical joint line. Instability of the proximal tibiofibular joint can be traumatic or idiopathic and is classified into four types: type 1, subluxation; type 2, anterolateral dislocation (the most common); type 3, posteromedial dislocation; and type 4, superior dislocation [17]. Chronic instability may result in degeneration of the joint, leading to pain on the lateral aspect of the knee. Very few references address the problem of chronic instability associated with arthritic changes in the tibiofibular joint. One of the two recommended solutions suggests fibular head resection, the other arthrodesis of the joint [17, 30, 37]. No significant loss of functionality has been reported [18]. Taking this information into consideration, either fusion or resection of this joint may be possible after taking osteochondral autografts.

Eichenblat and Nathan [16] reported more frequent osteoarthritic changes in the proximal tibiofibular joint than we found. They described osteoarthritis to ‘some degree in 27 to 38%’ on dried bone specimens. The noticeable difference from our findings (10%) might be due to the difficulty to differentiate in bone specimens between physiological small osseal limbs and e.g. osteophytes. Possible signs to distinguish physiological and pathological aspects are the evenness and the border to the surrounding bone. We counted clear signs of osteoarthrosis, and the amount correlates well with the moist specimen. Considering the fact that osteochondral grafting is not recommended in patients older than 45 years, this donor site seems to provide excellent graft material.

The proximal tibiofibular joint is a stable diarthrosis between the lateral tibial condyle and the head of the fibula designed to dissipate torsional stress of the ankle joint. Articular stability is attained anteriorly by a thick anterior capsule and reinforced by both anterior tibiofibular ligaments and the extension of the biceps femoris tendon. The posterior aspect of the capsule consists of a single weak band running from the fibular head to the posterior aspect of the popliteal tendon. These anatomical aspects support our preference for the posterolateral approach, which leaves the anterior stabilising elements intact. Superiorly, support to the joint is provided by the fibular collateral ligament [32].

The three patients who were treated according to the described method above showed a rapid and uneventful recovery and will be followed up under close observation. Such individual treatment options would be beneficial not only for the patients but also for society, because this approach would be able to reduce the costs to the health care system. The tibiofibular joint contains cartilage which may be a reasonable donor site even for the elderly patient. Harvesting the graft from this area may avoid iatrogenic damage of the intra-articular weight-bearing cartilage of the knee joint.

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