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Review article

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The possibilities of drilled tunneling in the treatment of knee joint osteoarthritis

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Abstract

Introduction Surgical treatment of knee osteoarthritis is a controversial issue. Knee replacement is the treatment of choice in the orthopedic practice for patients with severe knee osteoarthritis. However, total knee arthroplasty (TKA) has not only beneficial results and implant survivorship is limited in time. In recent years, the number of publications devoted to the limitation of indications for TKA in patients with osteoarthritis has been increased. The use of drilled tunneling in its modern modifications enables to delay or, in some cases, avoid knee joint arthroplasty. **Purpose** To substantiate the safety, low invasiveness and effectiveness of the tunneling method as a minimally invasive organ-preserving treatment for knee joint osteoarthritis. **Materials and methods** The electronic Pub-Med/MEDLINE and eLibrary databases were searched for works published for the last 30 years. The search was carried out with keywords and phrases: knee joint osteoarthritis, articular cartilage, bone drilling, arthroscopy of the knee joint. **Results** The effectiveness of tunneling is based on the concept of simultaneous revascularization, drainage and decompression of the subchondral sections of the knee joint and the medullary cavity of the tubular bones. Up to 96 % of patients report a positive effect of tunneling immediately after surgery. Intraosseous pressure decreases for up to 2 years in 88 % of patients. **Discussion** The tunneling method in the treatment of knee osteoarthritis helps to reduce pain in the projection of the femur and tibia, including night pain, improves the functional parameters of the joint, inhibits the progress of cartilage destruction, improves the quality of life of patients and reduces the need for replacement of the affected joint. In addition, tunneling does not require serious economic costs. Due to the fact that this method is a minimally invasive surgical intervention, the risk of infection is noticeably lower than with TKA. Conclusion Thus, the tunneling of the articular ends is a simple, safe, low invasive and effective method of treating knee joint osteoarthritis.

Keywords: osteoarthritis of the knee joint, articular cartilage, tunneling, pain syndrome, arthroscopy

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INTRODUCTION

Degenerative destruction of the knee joint is a common disease that is diagnosed in every second person over the age of 65 and in more than 80 % of cases over the age of 75. The first manifestations of osteoarthritis (OA) of the knee joint are seen in 6 % of patients older than 30 years and in 15 % of the population over the age of 45 years. [1]. To date, total knee arthroplasty (TKA) is considered the operation of choice in the treatment of advanced OA stages [2, 3]. An increase in the number of TKA operations is observed both in Russia and around the world [4, 5, 6]. However, many researchers do not note a significant reduction in the incidence of complications and poor results after TKA [7, 8, 9].

Indications for joint replacement with an implant are very wide, which frequently result in arthroplasty without sufficient grounds. Thus, in the United States, the number of unreasonably performed knee arthroplasty reaches one third of cases [10]. Some authors note that TKA is performed prematurely in 7-34 % of cases [11, 12]. Moreover, data are provided that physical activity does not restore in 82 % of patients who undergo knee joint arthroplasty, and they are forced to lead a low activity lifestyle, as before the operation [13]. Despite the general TKA positive results, the implant survivorship is not unlimited. In its long-term essence, this operation is crippling. It forces orthopedic surgeons to shift TKA to a later period and use the potential of minimally invasive organ-preserving interventions. One such is the method of drilled tunneling.

Tunneling as a treatment for knee OA has been performed since 1959 after K.H. Pridie described his method for the treatment of osteoarthritis of the articular surfaces of the knee joint (KJ) in the proceedings of the Congress of the British Orthopedic Association which he called subchondral drilling [14]. This publication has become one of the most cited articles on the treatment of KJ diseases. K.H. Pridie, based on clinical experiments, presented a technique to stimulate the bone marrow by releasing mesenchymal stem cells from cancellous bone which fill pre-drilled bone defects, what promotes the growth of fibrocartilage. Developing the technique, the scientist was guided by numerous animal studies, which, since 1905, have repeatedly

confirmed that bone perforation stimulates the repair of cartilage tissue by improving vascularization.

Although the technique described in the original article by K.H. Pridie has been repeatedly modified over the past decades, the concept of bone marrow stimulation and subsequent chondrogenesis, proposed by him, remains the most commonly surgery used in cartilage tissue repair [15].

Purpose: to substantiate the safety, low invasiveness and effectiveness of the tunneling method as a minimally invasive organ-preserving treatment for osteoarthritis of the knee joint.

MATERIAL AND METHODS

The literature data were searched in open electronic databases of scientific literature PubMed and eLIBRARY. The search was carried out with keywords and phrases: osteoarthritis of the knee joint, articular cartilage, tunneling, pain syndrome, arthroscopy. The depth of the search was 30 years.

Inclusion criteria: full-text articles that contain definite quantitative data.

Exclusion criteria: case reports and abstracts of presentations.

RESULTS

The development of pathological changes in the knee joint is associated with involutive structural and functional disorders of the cartilage tissue of the joint (fibrillation, splitting, loss of cartilage mass), which are clinically manifested by pain, restriction in the range of motion, and joint deformity [16, 17]. Moreover, these changes begin already at the age of 30-40 years. Thus, an increased interest in cartilage repair techniques in OA that can relieve pain, slow the progression of the degenerative disease, and delay or avoid the need for joint replacement is pathogenetically justified.

It is obvious that there were many unresolved issues related to the tunneling technique at the initial stage. The main issue of particular attention was the size of the bone tissue holes and the distance between them. Poor results of the operation were associated with the large size of the holes and the wide distance between them, although the diameter of the instruments used by K.H. Pridie was unknown. The work of J.N. Insall (1967, 1974) should be also mentioned who attempted to modify the K.H. Pridie technique and used quarter-inch drill bits (6.35 mm), assuming they were smaller than the ones used by K.H. Pridie [18, 19].

Subsequently, the tunneling technique has been repeatedly improved. Thus, R.P. Ficat et al. (1979) extended the concept of K.H. Pridie and proposed the spongialization technique, by which the affected cartilage was excised and the subchondral plate was completely removed, exposing the “spongy tissue” that served as the base for the growth of fibrous tissue [20]. The authors reported 85 patients who underwent spongialization. After 6 to 36 months (mean 15 months) of follow-up, 79 % of patients had good or excellent results of the operation, despite the fact that there was severe damage to the cartilage tissue of the knee joint in each case.

Auto- and allochondroplasty that enable to replace even more extensive cartilage defects became a new stage in the development of the KJ tunneling technique [21, 22].

Steadman et al. (1997, 2010) performed drilling using small instruments, performing closely spaced microfractures (microfracturing) under arthroscopy [23, 24]. The authors noted that the method is cost-effective, technically uncomplicated, accompanied by a low complication rate, and can be combined with other treatment options.

Koshino (1982) reported better outcomes in the treatment of knee OA according to radiography, when tibial osteotomy was combined with bone grafting or tunneling than if osteotomy was performed alone [25].

Chinese researchersTian et al. demonstrated in 1997 the results of subchondral tunneling in 21 patients (38 KJs) with OA. After 6 to 12 months of follow-up, there was an improvement in the functional KJ parameters from 18-48 points (average 30.78) before surgery to 61-96 points after surgery (average 87.95) along with an increase in the indicators of "satisfactory" and "good" in terms of functional scales from 5 to 86.84 %, as well as pain relief [26].

In 2000, Schneider et al. in a prospective clinical study involving 69 patients with knee OA (136 knee joints) accompanied by severe pain demonstrated a decrease in intraosseous pressure by 88 % due to decompression one year after tunneling compared with baseline, which was clinically accompanied by a decrease in pain intensity, and the achieved positive effect persisted for more than three years [27]. This work was a continuation of the concept of the important role of intraosseous hypertension in the pathogenesis of joint pain at rest, especially at night [28, 29, 30]. Due to drilled bone defects, tissue fluid leaks out of the bone marrow cavity and, as a result, bone marrow pressure decreases.

Benthien and Behrens (2010) proposed a one-stage technique combining subchondral drilling and autologous matrix-induced chondrogenesis (Autologous Matrix-Induced Chondrogenesis, AMIC). The tissue released from the drilled holes was fixed with a collagen I/III membrane. Thus, a matrix was obtained for cartilage regeneration, resulting in the formation of a stronger fibrous cartilage layer [31].

In 2017, Martin R and Jakob RP presented their technique of osteochondroization, in which, after scraping and removing the sclerotic layer and subchondral plate to a depth of 4 mm, similar to the "spongiolization" procedure proposed by R.P. Ficat et al. (1979), the resulting bone marrow defect was filled with fresh spongy tissue extracted from the tibia, at the same level as the adjacent subchondral plate. A two-layer collagen I/III membrane was applied on top. The authors evaluated the result of the proposed technique in 5 clinical cases with an average area of the cartilage defect of 3.9 ± 1.7 cm^2, on average, 1.1 years after the operation. The severity of pain after surgery decreased from 6.4 to 2.4 points, functional indicators according to the Kujala questionnaire improved from 40.8 to 74.2 points. In one case, arthrofibrosis developed, which required arthrolysis. In 4 other cases, according to magnetic resonance imaging after 6 and 12 months, complete filling of the defect and the formation of a subchondral plate were revealed. The obvious limitation of the study is the small number of cases [32].

It should be noted that the operation of tunneling for knee OA treatment did not immediately take its place among organ-preserving techniques in domestic surgery. It was supposed that the effect of tunneling is unstable, since the drilled holes are quickly replaced by bone tissue, which is accompanied by recurrence of pain [33]. Therefore, tunneling for knee OA was rarely used in our country until about the 1980s of the 20th century.

However, with the accumulation of scientific data on the role of disorders of the intraosseous microvasculature and venous stasis in the OA pathogenesis which cause congestion, intraosseous hypertension, and metabolic disorders in the bone tissue, the attention of the medical community has again turned to methods that stimulate the restoration of cartilage tissue by activating microcirculation [34 , 35, 36, 37].

Thus, Sklyarenko ET and Haddadin MKh presented good results of subchondral tunneling in 1981 in 24 patients with knee OA that had a decrease in the severity of pain and an improvement in the architectonics of the KJ tissues [38].

DISCUSSION

A great contribution to the development and popularization of the tunneling technique in patients with knee OA was made by the staff of the Ilizarov National Medical Research Center for Traumatology and Orthopedics. In particular, Shevtsov et al (1999) proposed stimulation of KJ vascularization using a device with pins, wires and fixing elements, which was attached through transverse bone tunnels. This technique was successfully used in the clinic of the Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopedics; its employees subsequently continued active work on optimization and implementation of the tunneling technique in the practical work of orthopedic traumatologists [39, 40, 41, 42, 43]. Moreover, a technique was developed for "cone-shaped" tunneling of the epimetaphyses of the femur and tibia in knee OA with peripheral circulatory disorders.

Subsequently, Yushenin et al (2000) proposed a technique that included preliminary tunneling of the soft peri-articular tissues and then drilling of the femoral condyles and tibial metadiaphysis. The idea was to improve blood supply to the joint and decompression due to communication between the intraosseous cavity and the microvascular component of the musculo-connective tissue complex [44].

Some authors considered options for combined organ-preserving surgical interventions in knee OA. Thus, high efficiency of simultaneous high tibial osteotomy and decompression tunneling of the patella and epimetaphysis of the femur according to K.H. Pridie technique was shown. Relief of pain was noted in 88 % of cases, including at night, with the preservation of the effect for 2 years after surgery, as well a mechanical alignment of the lower limb axis.

Saw et al (2015) evaluated the quality of articular cartilage regeneration in the medial compartment after arthroscopic subchondral drilling followed by postoperative intra-articular injection of autologous peripheral blood stem cells and hyaluronic acid with concomitant medial open wedge tibial osteotomy in 8 patients with knee varus deformity. A repeated postoperative arthroscopy revealed satisfactory healing of the regenerated cartilage, and histological analysis showed a significant amount of proteoglycans and type II collagen. Moreover, according to histological evaluation, the rate of cartilage repair approached 95 % of that of the normal articular cartilage. There were no complications in the postoperative period in any case [46].

Sveshnikov et al. (2002) examined 101 patients with gonarthrosis using radionuclide methods and found that osteoperforation of the lateral and medial condyles of the femur and tibia stimulates regenerative-hypertrophic changes in bone tissue, leads to growth of new vessels and formation of collaterals between them. At 1.5-2 months after surgery, patients with stages II-III of the disease showed a uniform restoration of the epiphyseal cartilage with a significant increase in its height in most cases [47].

Similar results were obtained in an experimental histomorphological study, presented by Stupina et al. (2012). The authors showed that tunneling of the subchondral zone with the introduction of autologous bone marrow into the canals stimulates reparative regeneration of chondral tissue by inhibiting joint destruction [48].

Shevtsov et al. (2008) studied long-term results (1-7 years after surgery) of knee OA treatment

through total subchondral drilling of the articular regions in 88 patients (97 knee joints). In general, a positive outcome, relief or reduction of pain intensity, increased exercise tolerance, improved quality of life, normalization of gait, as well as an increase in the range of motion in the knee joint was noted in 96.9 % of cases. At the same time, good results were recorded in 77.3 % of patients, fair ones in 19.6 % of cases, and poor outcomes in 3.1 % of patients (3 knee joints) [49].

Shchurova et al (2016) assessed the state of blood flow in the subchondral region of the tibial epiphysis after drilling and administration of autologous blood with bone marrow elements in 26 patients with grade II-III gonarthrosis. In 46.2 % of cases, there was a significant increase in blood flow according to Doppler ultrasound data (by 42-108 % compared with the baseline), while in 58 % of patients this indicator persisted after the administration of autologous blood with bone marrow elements. It should be noted that patients with a significant increase in blood flow in the subchondral region had higher indicators of joint function and quality of life compared with the patients who did not show a pronounced improvement in blood supply to the subchondral region of the tibia [50].

Research conducted by the staff of the Nizhny Novgorod Research Institute for Traumatology and Orthopedics since the mid-1980s led to the development and implementation in clinical trauma and orthopedic practice of the technique of tunneling the articular surfaces of the knee joint in combination with demineralized allopins using arthroscopic techniques [51]. An improvement in the function of the affected KJ was recorded at 5-year follow-up after surgery and there was no progression of the degenerative process according to the clinical and radiological examination.

In elderly patients, the implementation of decompression drainage interventions is accompanied by a significant improvement in the quality of life in general and recovery of everyday skills, primarily self-service and motion which is of great social importance [52].

According to Grinev SA (2019), 21 knee tunneling procedures were carried out at military hospital No. 411 of the Ministry of Defense of the Russian Federation in the period 2015-2019. To perform the operation, 1.8-mm wires were used, about 40 drilled tunnels were made in the metaphyses of the femur and tibia using an electric drill. Besides good clinical and functional results, a decrease in the number of patients who needed KJ arthroplasty was noted over this period of time [53].

Chebotarev et al (2021) studied long-term outcomes of treatment of 223 patients with traumatic and degenerative damage to the articular hyaline cartilage of the knee joint up to 2 cm in size, who received surgical treatment using debridement of the damaged zone and osteoperforative techniques (drilled tunneling, microfracture) in the period from 2009 to 2019. The best results were observed in patients with articular cartilage damage in the period from 1 to 4 years after the operation, however, after more than 4 years and, especially, more than 8 years post-surgery, the results got worsened and mostly due to increased pain [54].

To date, technologies of chondrogenesis have been actively developed to replace hyaline cartilage defects in knee OA, both with the use of integumentary membranes and with the use of specialized guiding matrices [55, 56]. At the same time, despite the fact that the long-term results of using such techniques are generally good, their implementation in real clinical practice is limited by their high cost and complexity of performance. In view of this, classical tunneling can be considered as a more accessible method of cartilage restoration in case of destructive processes in the joints.

An important issue of the knee OA treatment is the choice of surgical technique. Thus, Shevtsov et al (2008) opine that it is advisable to use total tunneling of the articular bones in a unilateral lesion of stages I-II with a preserved biomechanical axis of the lower limb and intense pain that is not relieved by medication; in bilateral lesions, total subchondral drilling of the articular regions and the patella is performed on both sides; in a combination of a degenerative process in the femorotibial joint with femoropatellar osteoarthrosis with a pronounced limitation of the mobility of the patella in the frontal plane, the total tunneling technique should be supplemented with the release of the ligaments supporting the patella [49].

The operation of tunnel drilling in knee OA can be performed by orthopedic traumatologists, surgeons and rheumatologists of specialized departments at district, city or republican hospitals, as well as at specialized departments and departments of research institutes for traumatology and orthopedics. However, in modern conditions of workload of specialized hospitals and staff shortages, an important organizational moment in the provision of specialized care to patients with knee OA is the possibility of performing tunnel drilling of the articular ends of the knee joint at outpatient clinics if there are specialists with the necessary qualifications and experience in their staff [57].

According to the literature, the disadvantages of drilled tunneling include the risk of burns in adjacent tissues by improper use of instruments resulting in disorders of the microcirculatory bed in the subchondral bone. Under such conditions, a full-fledged viable cartilage tissue cannot be formed [58]. Therefore, the microfracturing technique, which is essentially close to drilling, excludes thermal burns. However, it is believed that the cartilage-like fibrous tissue formed as a result of microfractures is unstable to physical stress, quickly lyses, and does not provide proper functional recovery of the knee joint [43].

CONCLUSION

Summarizing the above, it should be said that the basis for the effectiveness of drilled tunneling technique is the concept of simultaneous revascularization, drainage and decompression of the subchondral parts of the knee joint and the medullary cavity of the tubular bones. The essence of the operation is the formation of small drilled tunnels (canals) in the epimetaphyseal zones of the tubular bone. The use of tunneling in knee OA promotes pain relief, including nocturnal pain, in the projection of the femur and tibia due to the structural remodeling of the bone and cartilage tissue of the joint, improves the functional performance of the joint, inhibits the progressive destruction of cartilage tissues, improves the quality of life of patients and delays the need in replacement of the affected joint. Moreover, the technique does not impose serious economic costs. Thus, tunneling of the articular ends is a simple, safe, low-traumatic and effective limb-preserving method for the treatment of osteoarthritis of the knee joint which allows delaying arthroplasty, and may be more widely used in clinical practice.

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