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# Knee Joint Medial Compartment Osteoarthritis Treatment with High Tibial Opening Wedge Osteotomy and Arthroscopic Chondroplasty

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## Abstract

**Background:** Osteoarthritis is a pathological condition that affects movable joints, marked by cellular stress and the breakdown of the extracellular matrix. It is triggered by both micro and macro injuries, which initiate maladaptive repair mechanisms, including pro-inflammatory pathways associated with innate immunity. The disease initially presents as a molecular disturbance, involving abnormal metabolism of joint tissue. This is subsequently followed by anatomical and/or physiological disruptions, marked by cartilage breakdown, bone remodeling, osteophyte development, joint inflammation, and impaired joint function. These progressive changes can ultimately lead to illness. As of 2010, around 250 million people worldwide, or 3.6% of the population, were affected by knee osteoarthritis. Hip osteoarthritis, on the other hand, impacted approximately 0.85% of the global population. Both conditions held the 11th position among 291 disease-related causes of disability assessed globally. In the United States alone, there were roughly 964,000 hospitalizations due to osteoarthritis in 2011, equating to a rate of 31 stays per 10,000 individuals. These hospitalizations incurred a total cost of $14.8 billion, with an average expense of $15,400 per stay. This made osteoarthritis the second most expensive condition treated in U.S. hospitals that year. When categorized by payer, it was also the second-costliest condition billed to both private insurance and Medicare. **Objectives:** Our approach emphasizes preserving the knee joint and postponing knee arthroplasty in older individuals. The objective of our work is to demonstrate the effectiveness of simultaneously performing high tibial osteotomy (HTO) and arthroscopic chondroplasty in patients with medial compartment osteoarthritis of the knee. The correction of varus deformity in

knee osteoarthritis is guided by the patient's knee morphology, range of motion (ROM), findings from X-rays and MRI, as well as the patient's symptoms, their duration, expectations, and recovery time. **Methods:** Patients presenting with knee joint osteoarthritis have been systematically evaluated through a detailed collection of medical history (anamnesis), clinical examinations of both the knee and hip joints. Preoperative instrumental diagnostic procedures involve standard anteroposterior (AP, standing position) and lateral-medial (LM) radiographic imaging of the knee joint, a topographic scan of the entire lower extremities, and magnetic resonance imaging (MRI) of the knee joint. To assess and quantify the clinical condition of the knee, two validated outcome measures have been utilized: the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) as well as the Knee Injury and Osteoarthritis Outcome Score (KOOS). Surgical management of this condition involved arthroscopic chondroplasty combined with high tibial osteotomy. During the high tibial osteotomy, Puddu and T shaped LCP (Locking Compression Plate) titanium implants were used to achieve stable fixation. The chondroplasty procedures include microfracture techniques, autologous mosaic chondroplasty interventions, and contemporary single-stage minced cartilage procedures. These methods were implemented with the goal of optimizing cartilage restoration and enhancing joint functionality. **Results:** We have performed 50 high tibial osteotomy in combination with knee joint arthroscopy chondroplasty. We have reached functional improvement in 85% of clinical cases. **Conclusions:** Preliminary results showed Roentgenological and Functional improvement. We can conclude that combination of these two procedures improve knee joint osteoarthritis treatment outcome and delay or prevent knee joint replacement surgery with artificial joint. The single staged chondroplasty method, which had good preliminary result was used in our work, however long-term observation is required to make final positive conclusion.

## Keywords

Knee Joint Osteoarthritis, High Tibial Osteotomy, Arthroscopic Chondroplasty

## 1. Background

Osteoarthritis is derived from the prefix osteo—(from Ancient Greek: ὀστέον, romanized: ostéon, lit. "bone") combined with arthritis (from ἀρθρῖτῐς, arthrîtis, lit. "of or in the joint"), which is itself derived from arthr—(from ἄρθρον, árthron, lit. "joint, limb") and -it is (from -ῖτις, -îtis, lit. "pertaining to"), the latter suffix having come to be associated with inflammation [1]. Some clinicians refer to this condition as osteoarthrosis to signify the lack of inflammatory response, the suffix -osis (from -ωσις, -ōsis, lit. "(abnormal) state, condition, or action") simply referring to the pathosis itself [2].

Osteoarthritis is a disorder involving movable joints characterized by cell stress and extracellular matrix degradation initiated by micro- and macro-injury that activates maladaptive repair responses including pro-inflammatory pathways of innate immunity. The disease manifests as a molecular derangement (abnormal joint tissue metabolism) followed by anatomic, and/or physiologic derangement (characterized by cartilage degradation, bone remodeling, osteophyte formation, joint inflammation and loss of normal joint function), that can culminate in illness [3].

Worldwide, as of 2010, nearly 250 million people had osteoarthritis of the knee joint (3.6% of the population). Hip joint osteoarthritis affect approximately 0.85% of the population. Both, knee and hip osteoarthritis had a ranking for disability worldwide of 11th among 291 disease conditions assessed [4]. In the United States, there were just about 964,000 hospitalizations for osteoarthritis in 2011, a rate of 31 stays per 10,000 population [5]. With a summary cost of $14.8 billion ($15,400 per stay), it was the second most expensive condition seen in USA hospital stays in 2011. By payer, it was the second most costly condition billed to private insurance and Medicare program [6] [7]. Aiyong Cui *et al.* included 88 studies in the current analysis, 18 were published between 2017 and 2020. Based on the study findings, the global prevalence of knee joint OA was 16% among individuals aged 15 years or more and 22.9% among those aged 40 years or more. Further, about 654.1 million individuals aged ≥ 40 years globally had knee joint OA in 2020. The global incidence of knee joint OA was 203 per 10,000 person-years in individuals aged 20 years or more. Appropriately, just about 86.7 million people aged 20 years or over, had an incident of knee OA worldwide in 2020. The ratios of prevalence and incidence of knee OA in female and male were 1.69 and 1.39 correspondingly [8]. OA has a multi-factorial etiology and can be considered the product of an interaction between systemic and local factors. Old age, female gender, overweight and obesity, knee injury, repetitive overuse of joints, bone density, muscle weakness, and joint laxity (unstable knee joint)—all play role in the development of joint osteoarthritis, particularly in the weight-bearing joints. Modifying these factors may reduce the risk of osteoarthritis and prevent subsequent pain and disability [9]. Females are not only more likely to have OA than males, they also have more severe condition of OA [10]. The definite increase of OA in women around the time of menopause has led investigations hypothesize that hormonal factors may impact on the development of OA. However, results on effect of estrogen, either endogenous or exogenous, on OA from observational studies have been conflicting [11] [12]. In a randomized clinical trial (the Heart and Estrogen/Progestin Replacement Study) in a group of older postmenopausal women with heart disease, no significant difference was found in the prevalence of knee pain or its associated disability between those taking estrogen plus progestin therapy or those taking placebo [13]. Data from the Women's Health Initiative showed that women on estrogen replacement therapy were 15% less likely to require total knee or hip replacement surgery than those not taking such medication, but that estrogen

combined with progestin therapy was not associated with the risk of joint arthroplasty [14]. Results from several studies have shown that OA is inherited and may vary by joint location. Twin and family studies have estimated the heritable component of OA to be between 50 and 65% with larger genetic influences for hand and hip joint OA than for knee joint OA [15] [16]. In a genome-wide association study, Kerkhof *et al.* reported that the C allele of rs3815148 on chromosome 7q22 was linked with a 1.14-fold increased prevalence of knee joint and/or hand OA and also with a 30% increased risk of knee OA progression. Several studies also found that an inverse association between general joint hypermobility, alone benign trait, with hand and knee OA and serum cartilage oligomeric matrix protein levels [17]-[19]. A few congenital or developmental abnormalities (*i.e.*, congenital subluxation, Legg-Calvé-Perthes disease, and slipped capital femoral epiphysis) have been associated with occurrence of hip joint OA in later life [20]-[22]; however, because these developmental deformities are uncommon, they probably only account for a small proportion of the hip OA in the general population. Several studies have examined sub-clinical acetabular dysplasia, a more common, milder developmental abnormality, in relation to hip OA, with conflicting results [23]-[27]; Lane and colleagues reported that abnormal center-edge angle or acetabular dysplasia were each associated with an approximately threefold increased risk of incident hip joint OA in female patients, suggesting that subclinical acetabular dysplasia may be a significant risk factor for the development of hip OA [23]. Dietary factors are the subject of considerable interest in OA, results of studies, however, are conflicting. One of the most promising nutritional factors for OA is vitamin D. Without sufficient vitamin D, bones can become thin, brittle, or deformed. In the Framingham Study subjects in the lowest <27 ng/ml and middle 27.0 - 33.0 ng/ml tertile of serum 25-hydroxyvitamin D had a 3-fold increased risk for progressive knee OA compared with those in the highest tertile; nevertheless, no such effect was observed for risk of incident disease [28]. However, results from two cohort studies failed to confirm protective effect of vitamin D on the structural worsening of knee joint OA [29]. McAlindon *et al.* have made conclusion in A Randomized Controlled Trial, Vitamin D supplementation for 2 years at a dose sufficient to elevate plasma levels of 250HD to > 36 ng/ml, when compared with placebo, did not reduce knee pain or cartilage volume loss in patients with symptomatic knee osteoarthritis [30].

Nowadays, a widely used knee joint replacement with artificial endoprothesis in the age of 60 or over. Expected revision rate after knee joint replacement surgery is about 6% after five years and 12% after ten years. Revision rate is one of the most important outcome measures of joint replacement surgery. The lifetime risk of requiring revision is 22.4% in those aged between 46 and 50 years at the time of the initial surgery. The three commonest indications for revision are aseptic loosening, infection, and unexplained pain. Young males, aged between 46 and 50 years, have the highest lifetime risk of revision (25.2%). Therefore, in young population there is a big challenge to treat knee joint osteoarthritis.

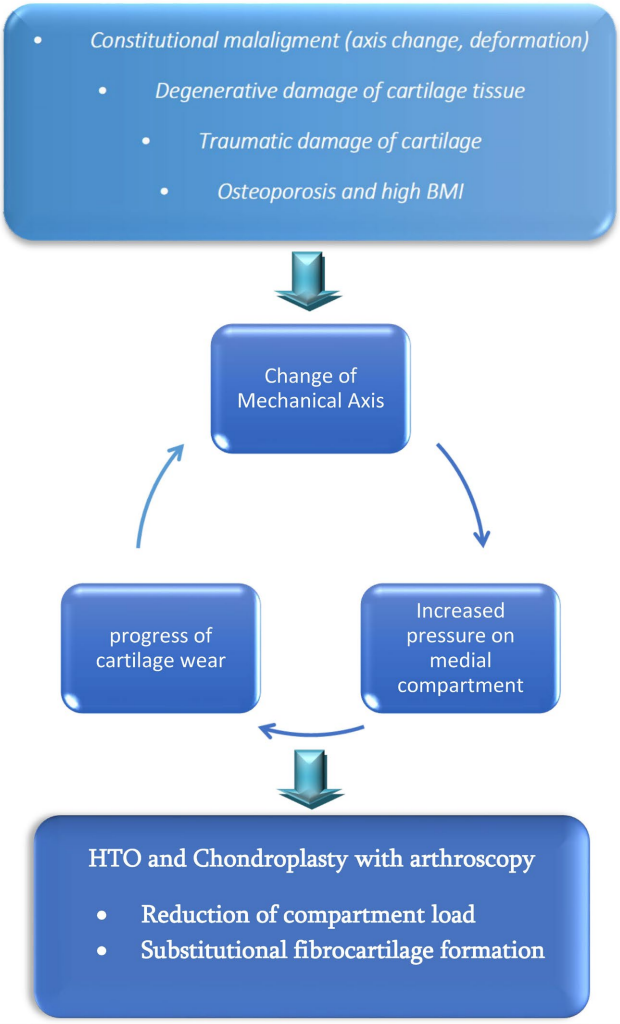



**Figure 1.** The Schematic photo of knee joint osteoarthritis (OA) development, mechanical etiological and biological multiple factors and vicious cycle of OA. HTO as a possible mechanical solution to break through vicious cycle which is mainly based on the redistribution or shifting of the deforming axial mechanical forces on the two condyles of the knee joint.

## Actuality and Current State of the Issue

Osteoarthritis is a chronic disease with degenerative cartilage tissue damage, wear and tear, the etiology of which is not fully known. Although there are risk factors that lead to the development of osteoarthritis. E.g.: trauma, chondromalacia after excessive physical loading, high BMI, genetic predisposition. It is also known that NSAIDs are the most effective and simple treatment method for osteoarthritis of large and small joints. This opinion is supported by the document of the third revision of the clinical practice guideline for the management of osteoarthritis of the knee developed by the AAOS (American Academy of Orthopedic Surgeons), which is dated 2022 [31]. Food supplements, chondroprotectors help to maintain the cartilage structure and prolong cartilage tissue breakdown in the initial stage of osteoarthritis. Food supplements include glucosamine, proteoglycans and hyaluronic acid products, which are mainly used for per os administration. Multiple

intra-articular injections of viscoelastic lubricants, such as high-molecular-weight hyaluronic acid, improves the nutrition of the cartilage tissue on the one hand and decreases friction force which is generated by the motion of joint surfaces between each other on the other hand. Conservative procedures like this improve the sliding capability of the joint surfaces. Tissue growth factors, which are also used for intra-articular injections are on the research stage and their effectiveness has not been proven yet. Most patients with knee osteoarthritis have varus or valgus deformity of knee joint, but mostly patients have varus deformity. The total arthroplasty procedures performed in our institution (LJ CLINIC-Kutaisi), clearly revealed that patients who had III - IV degree osteoarthritis with varus deformity of the knee joint in 80% of clinical cases the articular cartilage of the lateral compartment of the knee joint was affected only by grade II - III chondromalacia. This fact gives us sense, that high tibial osteotomy should be effective in a relatively less damaged knee joint. Because the philosophy of the above mentioned procedure is mainly based on the redistribution or hypercorrection of the deforming axial mechanical forces, which are acting on the two condyles of the knee joint (**Figure 1**). This postulate is testified by the abundance of randomized trials and publications of evidence-based medicine. E.g.: Koshino and Takahashi *et al.* have publicated that HTO (high tibial osteotomy) is followed by the reduction of osteosclerosis of the subchondral layer of the articular surfaces in the medial compartment of the knee joint and areas of degenerated cartilage are completely or partially covered by a layer of fibrocartilage tissue [32]. This neo-tissue is not hyaline cartilage. It is predominantly represented by the first type of collagen and not by the second type of collagen, which is one of the main distinguishing features of the extracellular matrix of fibrocartilage at the molecular level, while macroscopically, fibrous cartilage has a very white color, whereas hyaline cartilage is macroscopically characterized by a pale white-yellowish color. This consideration was confirmed by a second look arthroscopies, which we had performed after 2 - 6 years from initial HTO and microfracture procedures. Above mentioned fibrocartilaginous tissue is the result of the substitutive reparative regeneration process, and it is an inferior tissue that wears out faster than hyaline cartilage in the following years. This challenge pushes forward the field of modern tissue engineering to search for new ways to regenerate hyaline cartilage. However, regenerated fibrocartilage tissue layer reduces the pain to some extent, especially in case of decreased axial loading on medial compartment. Nowadays there are several types of chondroplasty procedures which can give fibro-cartilage tissue as a result: Abrasive chondroplasty, drilling (drilling of the subchondral layer-bone marrow stimulation), mosaic chondroplasty, microfracture procedure, autochondroimplantation/ACI (2-step cultivation and biomembrane induced secondary implantation in a cartilage defect). We suggest that, both operative interventions carried out at the same time, HTO and chondroplasty ultimately improves the final results of the combined treatment method. We performed microfracture and mosaic autochondroplasty with arthroscopy guidance. The modern procedure of arthroscopic chondroplasty includes the chondroplasty with minced cartilage fragments, which is single stage

procedure comparatively to ACI procedure. So we have been used minced cartilage technique during arthroscopy procedures and made some modifications during harvesting and impalnting. Nowadays chondroplasty with minced cartilage shows promising results, but it needs more time for follow up and evidence to make definitive conclusions. However, from the current method available in the literature, we increased the degree of micronization of autocartilage by the small diameter shaver and burr during harvesting procedure and reduced the time of its collection and preparation with Artrex Graftnet device. T-shaped and Paddu-type locking plates are mainly used after osteotomy. Also, extrafocal devices are used for external fixation of osteotomy site. In most cases, locking plates allow us to achieve stable fixation, which avoids the need for prolonged immobilization of knee joint and allows early rehabilitation and contracture prevention. We have used Paddu type and T-shaped locking plates, both with and without artificial bone tissue matrix (beta tricalciphosphate) (**Figure 2(a)**).

The filling of the open wedge (diastasis/gap) with bone graft after high tibial osteotomy depends on the length of the base of the triangle created during the osteotomy. Various literature sources recommend to use bone graft, when gap height is more than 10 mm, however we observed that, even in the less than 10 mm gap, the use of bone substitute materials can reduce consolidation time and accelerate rehabilitation time (Clinical Case **Figure 2(a)**).

The presence of bad habits of the patient, endocrinological disorder (diabetes), age and osteoporosis also should be considered.

The result of HTO depends on the accurate selection of patient and the precisely performed surgical procedure. Patients under 60 - 65 years of age, with isolated medial osteoarthritis of the knee joint, and stabile ligament apparat of the knee joint with full range of motion are considered ideal candidates for osteotomy. Strict indications for surgery, accurate preoperative planning, and precise operative technique is essential circumstance for success. HTO prevents the development of a vicious cycle in unicondylar osteoarthritis.

## 2. Objectives

The aim of our work is to prove the effectiveness of the simultaneously performed HTO and arthroscopic chondroplasty in patients with medial compartment osteoarthritis (osteoarthritis) of the knee joint. Correction of varus deformity in knee joint OA is based on: patient's knee joint morphology, ROM (range of motion), X-ray and MRI results. It depends on patient's complaints and duration, patient's expectations and rehabilitation time, on general factors such as cigarette smoking, presence of concomitant diseases, status of peripheral blood vessels, nutritional status, presence of diabetes, sports activity or less active lifestyle. The primary indication for HTO is an active patient between the ages of 40 and 60, with varus deformity of the knee joint, as well as a patient whose tibia has been radiographically confirmed to be free of lateral subluxation. Patient should not have symptoms of OA of the patellofemoral compartment. Also, the patient should have knee joint pain only in the projection of medial compartment, during physical

activity. Patient must have possibility to make full extension in knee joint and the ROM should be equal or more than 100˚. However, in reality, there is a certain contingent of patients who do not fit into these idealized criteria, but who receive the desired results if osteotomy is performed (Hanssen & Chao) (Table 1). The following table lists patients for whom osteotomy is absolutely indicated, relatively indicated, or contraindicated. The table has been modified by the International Society of Arthroscopy, Knee Surgery and Orthopedic Sports Medicine.

**Table 1.** *Ahlbäck grading system for degenerative arthritis (Brinkman *et al.*, 2008; Frey *et al.*, 2008; Hofmann *et al.*, 2009; Kolb *et al.*, 2009; Rand & Neyret, 2005; Song *et al.*, 2010). (Hanssen & Chao) HTO absolute indication, relative indication and contraindication.

| Absolute indication | Relative indication | Absolute contraindication |
|---|---|---|
| Patients' age from 40 to 60 years | Patients' age >60 years or <40years | Open growth (physeal) plates |
| Varus deformity of the lower extremity, that is less than 15˚ | Varus deformity >15˚ (sometimes double on different location) | Rheumatoid arthritis |
| Absence of patellofemoral symptoms | Presence of mild patellofemoral symptoms | Severe patellofemoral symptoms |
| the presence of pain in the projection of the medial compartment after physical overloading | | the presence of pain in the projection of the lateral compartment |
| Full extension | Flexion contracture >15˚ | Flexion contracture >25˚ |
| Knee joint ROM should be equal or more than 100˚ | ROM >90˚ | ROM <75˚ |
| Presence of soft tissues in medial area of knee joint | Previously transmitted infection | Other inflammatory diseases |
| Stable knee joint | Insufficiency of the anterior cruciate ligament, posterior cruciate ligament, or posterior outer corner of the knee | Medio-lateral insufficiency |
| Absence of patellofemoral osteoarthritis | patellofemoral osteoarthritis II - III degree | IV - V grade patellofemoral osteoarthritis |
| Non smoker | Smoker (<15 cigarettes/day) | Smoker (>15 cigarettes/day) |
| BMI <30 | BMI 30 - 40 | BMI >40 |
| Patients with high physical activity, but not for athletes with elements of running and jumping | Patients who want to continue all types of sports activities | Severe osteoporosis |
| Varus of Proximal tibia metaphysis (TBVA + >5˚) (tibial bone varus angle) | Presence of varus deformity of the distal femoral metaphysis and valgus deformity of the proximal tibia | Extra articular deformation |
| Normal lateral compartment, I - III grade medial compartment osteoarthritis | IV grade medial compartment osteoarthritis | V grade both compartment (medial & lateral) osteoarthritis |
| Intact Meniscus | Partial resection of medial meniscus | Lateral meniscetomy |
| | Presence of Koenig's desease (osteochondritis dissecans) | Poor peripheral vascular status (Absence of pulse on dorsal arteries of foot) |
| | Medial femoral condyle osteonecrosis (SPONK) | Presence of bone regeneration (healing) disease |

### HTO Surgery Has 2 Main Goals

1) Shifting the loading forces from the medial surface of the knee joint articular cartilage, to the lateral side of the knee where exists intact or less damaged articular cartilage.

2) Slowing down or stopping the process of damage to the articular cartilage of the medial compartment of the knee joint, which in turn avoids the need for total knee arthroplasty or postpones the date of surgery and buys time for the patient until joint replacement surgery.

In the case of carrying out the above mentioned procedure, it remains controversial which type of surgical technique should be used to perform the HTO; E.g.: (1) Open or closed wedge technique; (2) The type of transplant and the method of harvesting; (3) Selection of bone fixation method and implant; (4) Evaluation of the superiority of HTO, compared to unicondylar knee arthroplasty procedure [33]. (5) Selection of the method of chondroplasty according to the severity of the cartilage damage and the ways of its performance with minimal invasion (arthroscopically) or open arthrotomy.

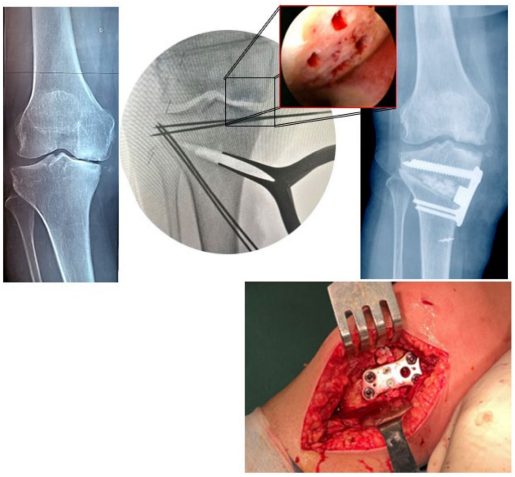
## 3. Methods

**Table 2.** According to Ahlback grading, knee OA classified as grade 1 joint space narrowing (less than 3 mm), grade 2 joint space obliteration, grade 3 bone defects/loss (0 - 5 mm), grade 4 moderate bone defects/loss (5 - 10 mm), grade 5 severe bone defects/loss (more than 10 mm).

| The Ahlbäck classification | |
|---|---|
| **Grade 1** | Joint space narrowing (less than 3 mm) |
| **Grade 2** | Joint space obliteration |
| **Grade 3** | Minor bone attrition (0 - 5 mm) |
| **Grade 4** | Moderate bone attrition (5 - 10 mm) |
| **Grade 5** | Severe bone c (more than 10 mm) |

We have been revealing patients with knee joint osteoarthritis by collecting anamnesis and clinical assessment of the knee and hip joint. The assessment of the range of motion in the hip joint, and especially assessment of hip rotation. Preoperative instrumental investigation includes X-ray of the knee joint AP view (standing position) and LM view, topogram of whole lower extremities and MRI scan of knee joint. To evaluate the clinical condition of the patient's knee joint, the following is used: The Western Ontario and McMaster Universities Osteoarthritis Index/Knee-WOMAC and KOOS knee survey—Knee injury and Osteoarthritis Outcome Score. This allows us to evaluate the condition subjectively perceived by the patient with points, which in turn simplifies the comparison of pre- and post-operative results. It is also noted that the following conditions are bad prognostic factors: According to "Ahlback" classification (**Table 2**, **Figure 2(b)**) III - IV or higher grade osteoarthritis of the knee joint, patient more than 65 years

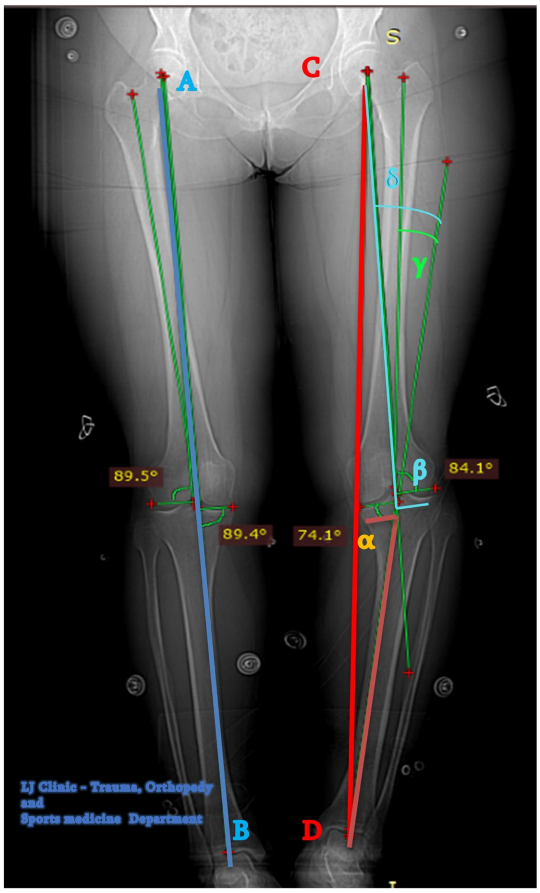
old, severe osteoarthritis of the hip joint, knee range of motion less than 90˚, flexion contracture equal to or greater than 15˚, joint instability, lateral subluxation of the tibia, 20˚ or more correction angle and rheumatoid arthritis. The majority of authors are coming in agreement that in overweight patients, the procedure of tibial osteotomy is a more valid intervention than single-compartment endoprosthesis. However, the influence of a large body mass index on the outcome of the HTO procedure remains controversial [9] (**Table 2**).



48-year-old lady. A 15 mm titanium block was used for the varus deformity correction. The open wedge was filled with beta tricalcium phosphate granules. An arthroscopic microfracture procedure was performed on the medial condyle of the femur and tibia.

(a)


(b)




(c)

**Figure 2.** (a) Clinical Case/LJ Clinic. (b) The Ahlback classification. LJ Clinic Cases According **Table 2** with different degrees of joint space narrowing and varus deformation. (c) Lower Extremities' Topogram of 60 years old lady; A-B line is Normal Axis of lower limb; C-D line is Mechanical Axis of left lower limb. It's shifted on the medial edge of the tibia and femur medial condyles. α angle is aMPTA, anatomic medial proximal tibial angle. β angle is aLDFA, anatomic lateral distal femoral angle. γ angle is the femoral shaft-tibial shaft angle (anatomic angle). δ angle is the hip-knee-ankle angle (mechanical angle).

Knee joint should be evaluated with the X-ray in Anterior-posterior and Lateral view to assess osteoarthritis grading, as well as bone loss on the tibial plateau and patella position with Insall-Salvati ratio. In case of "patella alta or Baja" osteotomy of the tibial tuberosity may be necessary in combination with HTO to optimize extension apparat of knee joint and prevent contracture. The axis of the lower limb should also be evaluated (**Figure 2(c)**).

Magnetic resonance imaging of the knee joint can also be used to reveal osteochondral injuries of articular surfaces, meniscal injuries, ligament injuries, cartilage injuries, condyle osteonecrosis, subchondral injuries and loose bodies.

## 4. Preoperative Planning

Preoperative planning has great importance to achieve a successful outcome of the operative intervention. The outcome of the operation strongly depends on the

calculation of the correction angle and the precisely performed valgisation, therefore have been developed various methods to calculate angle of correction. Normally, the center point of the femoral head, the center of the knee joint plateau and the center of the ankle joint are located on the same line of the mechanical axis of the lower limb (Figure 2(c)). 3˚ - 5˚ valgus deviation from the mechanical axis or 8˚ - 10˚ anatomical valgus is considered the ideal axis of the lower extremity after surgery. Fujisawa *et al.* published in his publication that the postoperative mechanical axis should pass through the border of the lateral third and middle third of the tibial plateau.

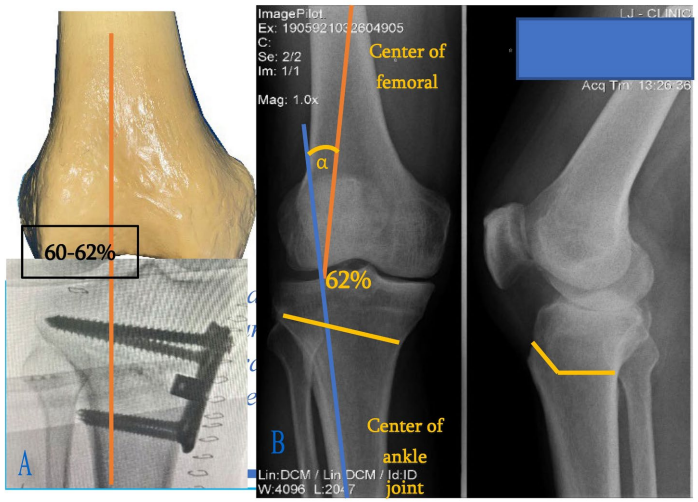



Figure 3. (A), (B) Calculating new loading axis of the lower limb according to dugdale.

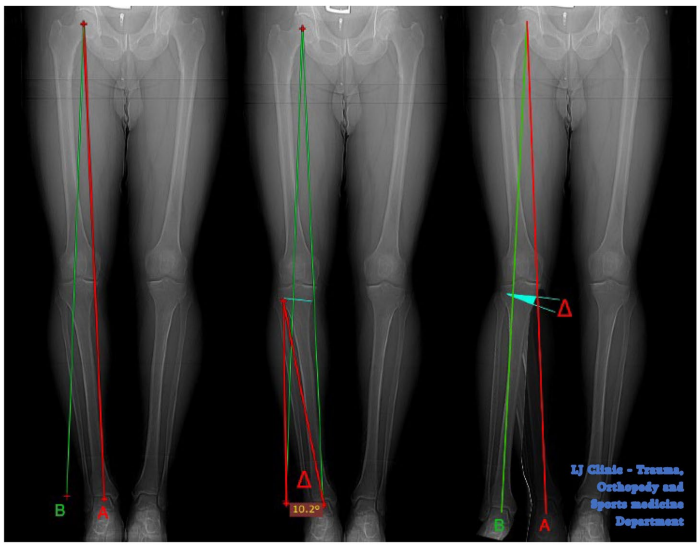



Figure 4. Calculating new loading axis of the lower limb according to Miniaci.

Jakob and Jacobi proposed that the mechanical axis correction depends on the thickness of the cartilage in the medial compartment of the joint. E.g.: If 1/3 of the

medial compartment's cartilage is worn away, then the mechanical axis should be shifted 10% - 15% laterally from the center of the tibial plateau. If the 2/3 of articular cartilage is worn away, then the mechanical axis should be shifted 20% - 25% laterally from the center of the tibial plateau. And if the cartilage is completely worn away, then the mechanical axis should be shifted 30% - 35% laterally from the center of the tibial plateau. The Dugdale method is also used for pre-operative planning, which is calculated by the lines drawn from the center of the femoral head and the center of the ankle joint, which intersects lateral tibial condyle, namely at the point of 60% - 62.5% of the total transverse diameter of the tibial plateau, which is anatomically located slightly lateral to the lateral eminence and corresponds to 3˚ - 5˚ valgus deviation from the mechanical axis. The α angle obtained by crossing these two lines represents the size of the correction angle. [**Figure 3(A)-(B)** (shows the Dugdale method of calculating the correction angle for HTO with open wedge surgical technique].

One of the ways to calculate the angle of the bone section is called Miniaci method. According to Miniaci, as with other methods, first of all, the mechanical axis of the lower limb is determined. Line has drawn vertically distally from the center of the femoral head, which crosses the knee joint and connects to the center of the ankle joint (a). The second line (b) is placed again from the center of the head of the femur, which crosses the knee joint in the area of the lateral condyle of the tibia, namely at the point of 60% - 62.5% of the total transverse diameter of the tibia, which represents new loading axis of the lower limb; **Figure 3**, **Figure 4** descends to the level of the articular surface of the ankle joint.

The third line starts from the point of the medial condyle of the tibia bone where it is planned to carry out the bone osteotomy and joins the hinge point of rotation, which is located on level of fibular head, 1cm medially from lateral cortex of tibia and at least 1.5 cm away from the articular surface (c). Subsequently, the point of rotation of the bone is connected with the old and new centers of the ankle joint. The angle created by the abovementioned action represents the amount of correction angle (Δ delta) for the valgisation. Thus, the correction angle must be calculated and performed precisely, because an inappropriate correction angle can lead to the recurrent varus deformity, whereas hypercorrection can lead to poor cosmetic and functional results. Achieving the pre-operatively calculated correction angle during valgisation is a great challenge, as it requires: sophisticated mastery of the surgical technique, handling of locking plate system and instrument set, and control of the procedure steps with the C-arm (**Figure 5**).

## 5. Surgical Technique

We have performed most of operations under the spinal anesthesia, which reduces the risk of post-operative complications and length of hospital stay for patients. C-arm is used intraoperatively to assess the corrected limb axis in AP and lateral projection. The operation is performed with the support of an electric pneumatic tourniquet. At the first stage, arthroscopy of the knee joint is performed. Removal

of free osteochondral bodies, joint debridement, resection of degeneratively damaged medial meniscus, resection of osteophytes with electric burr head and shaver. After debridement we do articular surface chondroplasty procedure: microfracture, mosaicplasty with osteochondral autograft or minced cartilage is been harvested from healthy layer of articular surface of lateral femoral condyle and pasted it in the chondral defects of medial compartment. After completing the arthroscopy, a longitudinal medial descending incision from joint level with size of ≈ 8 - 10 cm is made in the pes anserine region of the proximal tibia. Subsequent deep dissection includes longitudinal incision of the sartorial fascia, elevation of the tendons of the semitendinosus and gracilis muscles and anterior fibers of the medial collateral ligament are released. An osteotomy of the tibia is made by an oscillating saw under the fluoroscopy control (**Figure 5**).

The osteotomy is followed by applying valgus stress with special in situ distractor to create open medial wedge until a pre-calculated correction angle is achieved. After the limb axis is corrected, bone fragments are fixed by puddu type or T shaped locking titanium plate and screws (**Figure 6**). If there is a diastasis of 10 - 12 mm between bone fragments after osteotomy, open wedge gap is filled with synthetic bone building material, which reduces the time of bone tissue consolidation. The wound is closed, 1 active vacuum drain is placed in it and definitive fluoroscopy is performed. The patient is admitted to the intensive care unit for the next 24 hours, following antibiotic and thromboprophylaxis is administered. The average length of stay of the patient in the hospital is 4 - 5 days.

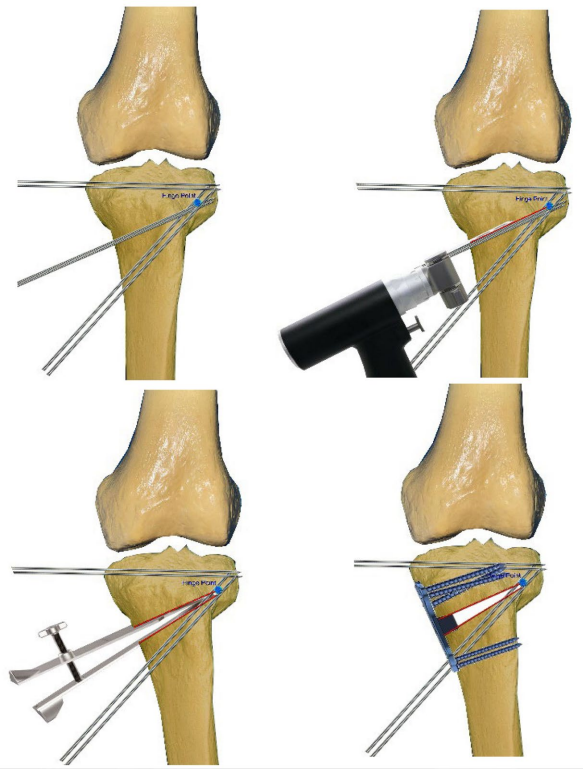


**Figure 5.** Sequential schematic image of the surgical technique.

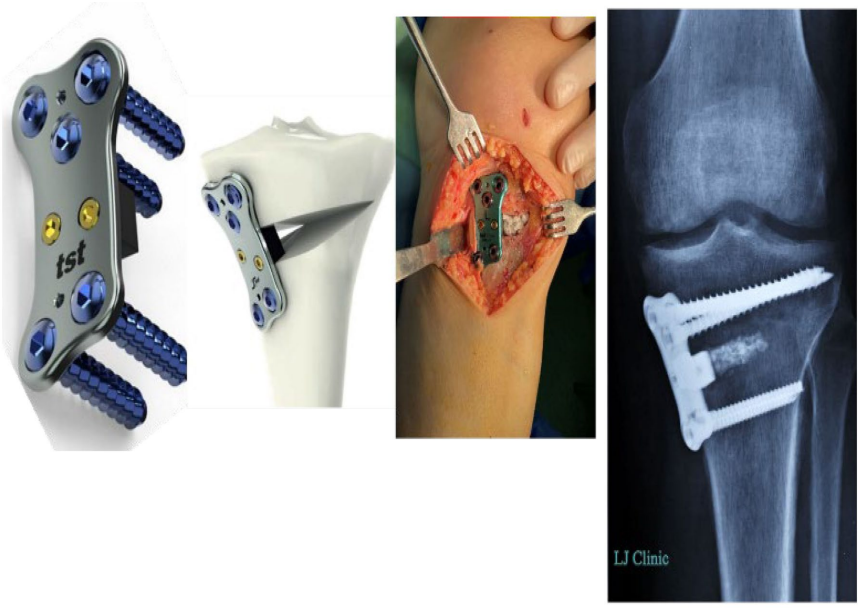



**Figure 6.** Schematic and radiographic image of Paddu type locking LCP plate (OWO plate—tst medical company) with osteoconductive material of Beta tricalcium phosphate granules.

Taking into account the bone density of the patient and the strength of the achieved fixation, the movement of the knee joint with the CPM (continuous passive motion machine **Figure 7**) machine starts from the second day. This measurement reduces the risks of postoperative contracture and thromboembolic complications.

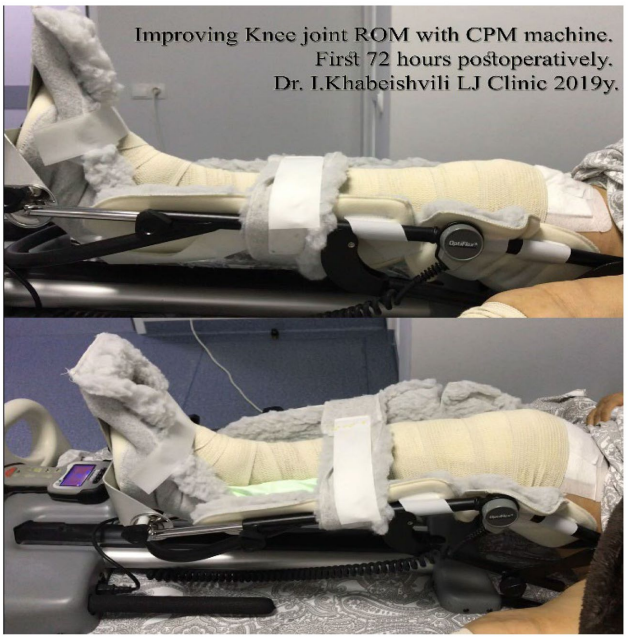



**Figure 7.** CPM machine -Improving Knee joint ROM with CPM Machine first days after the surgery.

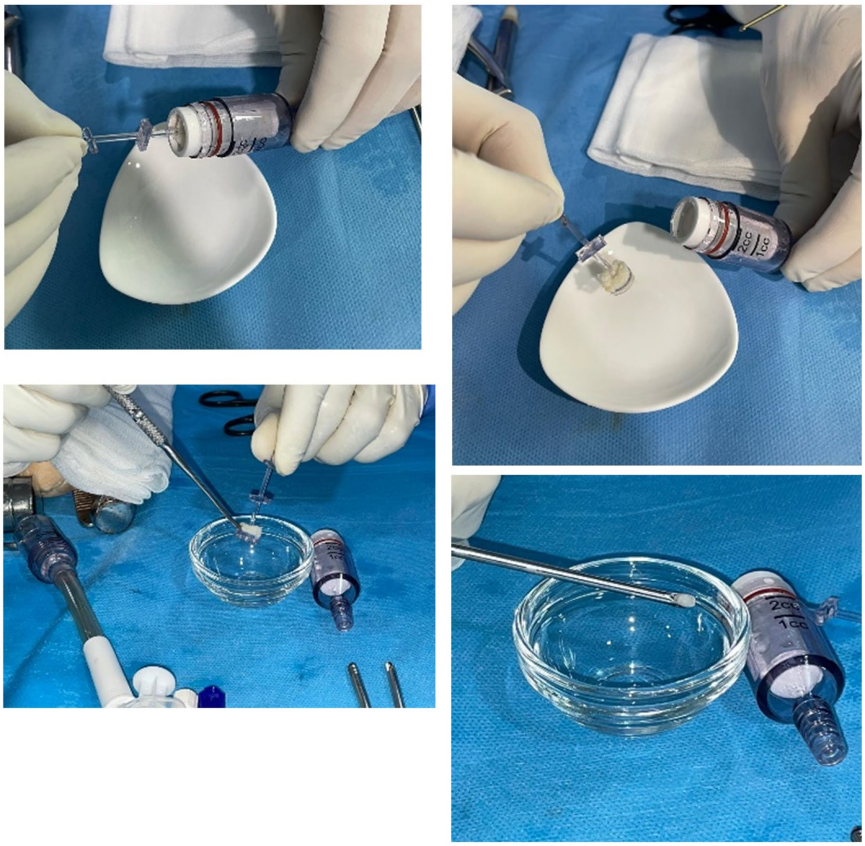


Figure 8. Arthroscopic Chondroplasty with minced cartilage technique with Arthrex graft net tissue collection device.

## 6. Results

Randomized studies described in various medical literature show that the functional status of patients improves even only after HTO procedure, even in studies lasting 10 - 15 years the results are positive. However, the results worsen over time. We have performed 50 surgical procedures of HTO with Chondroplasty in our institution. The work that we have provided there was presented not only the osteotomy procedure, but also the chondroplasty procedure in combination with HTO. Therefore, we believe it improves the functional result after the combined surgery. If we compare the results of the abovementioned procedure with the results of conservative treatment, the functional result of the HTO with chondroplasty (Figure 8) combined procedure according to the scoring system of WOMAC and KOOS prevails over the functional result of conservative treatment (Figure 9).

The primary goal of ongoing researches and newly published studies is to improve the methodology of chondroplasty procedure. In our work, the single staged chondroplasty method was used, however, long-term observation is required to say final positive conclusion. The microfracture procedure is gradually being replaced by two-stage and single stage chondroplasty methods. HTO implants are modified every year allowing to correct and fix cases causing deformations of tibia.

On this experience we have developed concept plate (Figure 10 and Figure 11) which has corrected puddu type and T shaped plate's drawbacks (Increased tibial slope, limited ROM, recurrence of varus deformity, Polyaxial locking possibility).

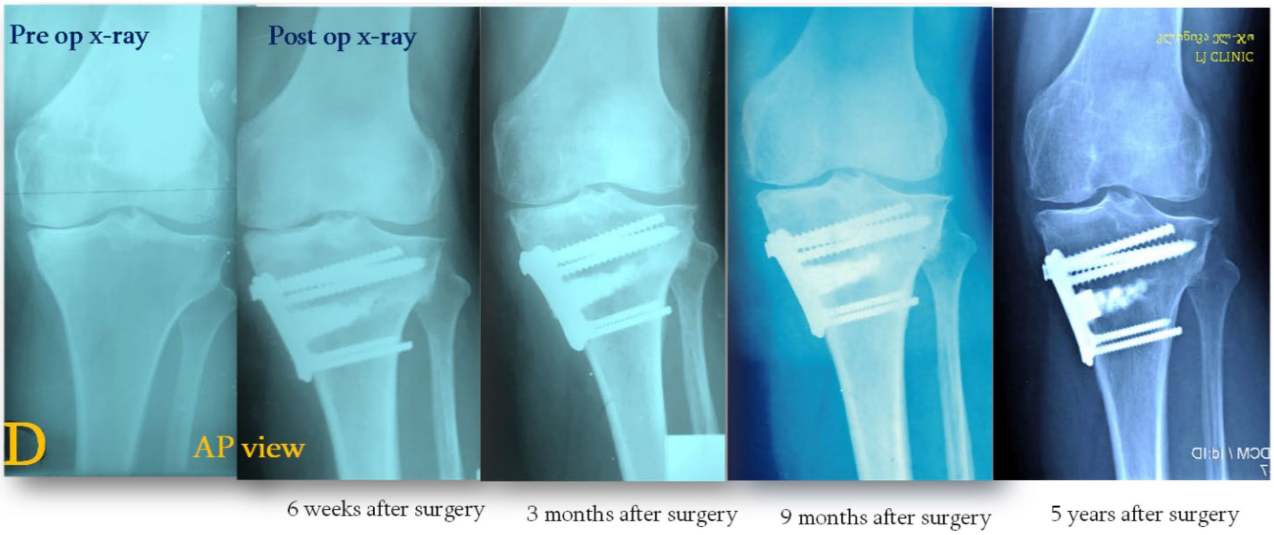



Figure 9. Serial radiographs of 65 year old woman. Serial X-ray films in the dynamics show 5 years postoperatively the preservation and slight increase of the medial compartment joint space compared to preop X-ray image.

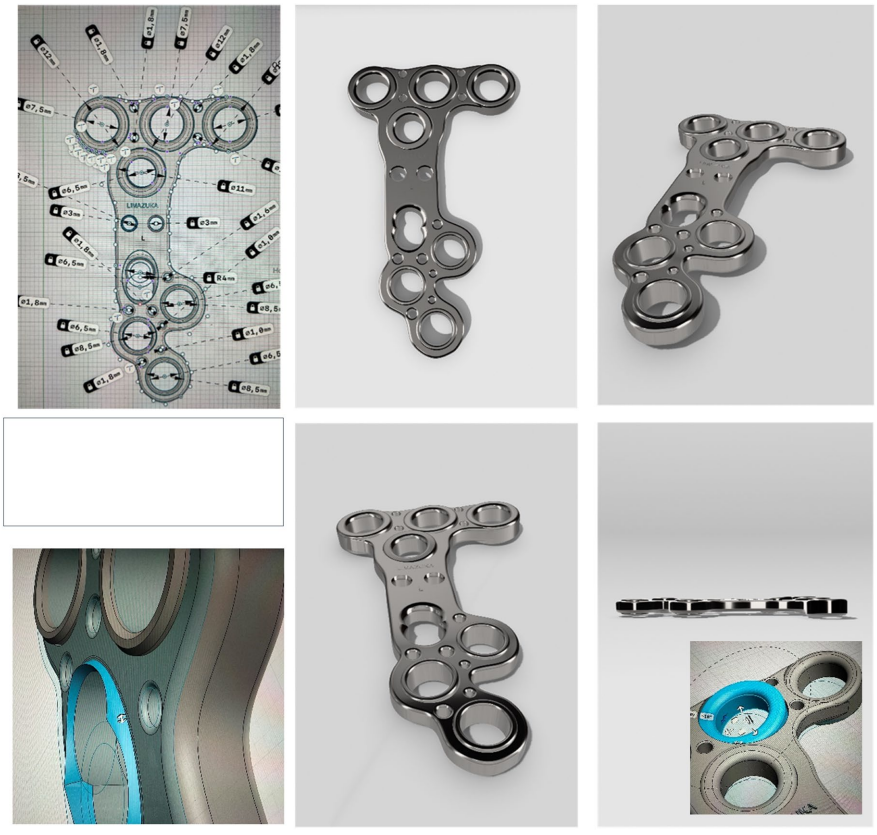


Figure 10. Concept HTO plate Limazuka. First modification.

**Figure 11.** First modification of Limazuka concept plate.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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