The Egyptian Journal of Hospital Medicine (July 2019) Vol. 76 (5), Page 4085-4091

Open Wedge High Tibial Osteotomy versus High Fibular Osteotomy in Management of Osteoarthritis Knee

Ahmed Shamma, Mohammed Elnahas, Loay Hassanin Mahmoud Ibrahim*
Orthopedic Surgery Department, Faculty of Medicine, Al-Azhar University
***Corresponding author:** Loay Hassanin Mahmoud Ibrahim , **Email:** loayyhusssen@gmail.com

ABSTRACT

Background: osteoarthritis is the most common inflammatory joint condition and is expected to have an increasing prevalence in middle-aged and elderly patients.

Objectives: to evaluate the functional outcome of open wedge High Tibial Osteotomy (HTO) versus High Fibular Osteotomy (HFO) with segment resection in management of medial compartment osteoarthritis of the knee.

Patients and Methods: we compared 10 cases of HTO and 10 cases of HFO complain with uni-compartment knee osteoarthritis.

Results: success in HTO depends on good technique. The determination of the exact localization of the osteotomy site, not to fracture lateral cortex, frequent assessment of the correction angle at every step of the operation, avoidance of overcorrection, the selection of an appropriate Puddu plate size fit for the osteotomy gap. During follow up, mean improvements obtained in KSS scores was 26.70. According to this assessment scale, preoperative score was deemed worse, and postoperative scores was good. HFO relieves pain and improves joint function in human knee osteoarthritis. This new surgery is simple, safe and affordable. Pain relief after surgery occurs in almost all patients. HFO may delay or replace TKA in a subpopulation of patients with knee osteoarthritis.

Conclusion: HFO is a simple, safe, fast and affordable surgery to relieve pain and improve joint function and the medial joint space in human knee osteoarthritis.

Keywords: High Tibial Osteotomy, High Fibular Osteotomy, Osteoarthritis Knee.

INTRODUCTION

Osteoarthritis is the most common inflammatory joint condition and is expected to have an increasing prevalence in middle-aged and elderly patients. Symptomatic disease in the knee occurs in approximately 6% of adults 30 years of age or older. From 1995 to 2005 number of people affected with symptomatic OA has grown from 21 million to nearly 27 million in the United States [(1)].

Osteoarthritis is the most common form of arthritis in the knee. It is a degenerative, "wear-and-tear" type of arthritis that occurs most often in people 50 years of age and older, but may occur in younger people, too [(2)].

OA diseases are a result of both mechanical and biological events that destabilize the normal coupling of degradation and synthesis of articular cartilage chondrocytes and extracellular matrix, and subchondral bone. Although they may be initiated by multiple factors, including genetic, developmental, metabolic, and traumatic, OA diseases involve all of the tissues of the diarthrodial joint [(2)].

Pathologically, the disease is characterized by irregularly distributed loss of cartilage more frequently in areas of increased load, sclerosis of subchondral bone, subchondral cysts, marginal osteophytes, increased metaphyseal blood flow, and variable synovial inflammation. Histologically, the disease is characterized early by fragmentation of the cartilage surface, cloning of chondrocytes vertical clefts in the cartilage, variable crystal deposition, remodeling, and eventual violation of the tidemark by blood vessels. It is also characterized by evidence of repair, particularly in osteophytes, and later by total loss of cartilage, sclerosis, and focal osteonecrosis of the subchondral bone. Biomechanically, the disease is characterized by alteration of the tensile, compressive and shear properties and hydraulic permeability of the cartilage [(3)].

Management of OA currently focuses on the relief of pain and the improvement of function through a comprehensive treatment plan that includes pharmacologic and non-pharmacological therapies. For most patients pharmacologic management begins with analgesia using acetaminophen or NSAIDs, Tramadol and narcotic medications can be useful adjunctive therapies. Topical NSAIDs, salicylates, and capsaicin can be useful as adjuncts or in patients for whom systemic medications are problematic. Intra-articular gluco-corticoids should be reserved for the short-term management of acute pain flares and used with caution, given their short duration of effect and potential for long-term harm. Glucosamine and chondroitin and intra-articular hyaluronic acid, there is controversies about their clinical benefits. The future of OA prevention and treatment may involve nutritional supplements such as vitamin D or selenium, but conclusive trials have not been completed. Likewise, numerous potential targets for therapy are under intense investigation [(4)].

Non pharmacologic Management relays upon Patient education, weight loss, Exercise (low-impact aerobic exercise program; walking, biking, or swimming or other aquatic exercise, Quadriceps-strengthening exercises), Heat modalities, modified activities of daily living, Knee braces and Orthotics [(5)].

Received:2/5/2019
Accepted:1/6/2019

Osteotomy offers an alternative surgical option to total knee replacement in reducing pain and improving function especially in younger and more physically active people with Osteoarthritis of the knee [5].

High Tibial Osteotomy (HTO) and High fibular osteotomy (HFO) are operations of proved value for relieving pain, restoring stability and improving function in osteoarthritic knee. HTO as a treatment option for varus deformity of the knee was developed during the 1960s in the United States [6].

Coventry was an early and influential supporter of the method. In the many years since its advent, the HTO has undergone many modifications. In spite of the many developments, the operation has retained its fundamental character from the early days. The angle of the leg is changed to a net valgus position to shift the force into the healthy lateral compartment and away from the diseased medial compartment [5].

High fibular osteotomy (HFO) relieves pain and improves joint function in human knee osteoarthritis [5]. This new surgery is simple, safe and affordable. Pain relief after surgery occurs in almost all patients. HFO may delay or replace TKA in a subpopulation of patients with knee osteoarthritis. In the present study, we carefully evaluated the short-term efficacy of HFO in terms of pain relief and improvement of joint function in a cohort of patients from our hospital [5].

AIM OF THE WORK

The aim of this study is to evaluate the functional outcome of open wedge High tibial osteotomy versus High fibular osteotomy with segment resection in management of medial compartment osteoarthritis of the knee.

PATIENTS AND METHODS

In this thesis study compared 10 cases of High tibial osteotomy and 10 cases of High fibular osteotomy complain with uni-compartment knee Osteoarthritis attending at El-Agouza Hospital.

Ethical and approval

The study was approved by the Ethics Broad of Al-Azhar University and an informed written consent was taken from each participant in the study between April 2017 and May 2019.

Inclusion criteria:

1. Age: patients between 35-59 years old.
2. Medial compartment osteoarthritis.
3. Patients with Genu varum associated with medial compartmental osteoarthritis.
4. Sex: male or female.

Exclusion criteria:

1. Age: more than 60 years old or less than 35 years old.
2. Trauma and pathological fracture.
3. Bi or tri compartments osteoarthritis.
4. Obese patients.
5. Consent form refusal.

Open wedge osteotomy

Hernigou et al. [6] described a medial opening wedge tibial osteotomy which they believe is more precise and allows more exact correction than does a lateral closing wedge osteotomy. The use of an osteotomy jig assembly to perform medial opening wedge osteotomy, a fixed-angle guide was used in the iliac crest to harvest grafts with precise angels for the opening wedge and the osteotomy was fixed with a compression plate device. They obtained an average of 13 degrees of correction with this technique and recommended it for younger patients.

Advantages of open wedge osteotomy

1. It is adjustable [6].
2. Allows concomitant rotational and translational correction [7].
3. It is indicated in patients with laxity of the medial collateral ligament or combined anterior cruciate ligament deficiency [7].

Disadvantages of open wedge osteotomy

1. It is relatively unstable due to minimal bone contact.
2. Creates a defect between the bone ends that must be either fill in or be filled with bone graft.

Surgical technique

After preoperative evaluation and preparation of the patients, the operation was done according to the following steps under general or spinal anesthesia:

- **Step 1:** patient position
- **Step 2:** arthroscopy
- **Step 3:** Incision and Exposure

Exposure to the anteromedial aspect of the tibia through a vertical skin incision centered between the medial border of the anterior tibial tubercle and the anterior edge of the medial collateral ligament (at line of medial border of patella) and extending 6–8 cm distally to the joint line. The investing fascia was incised and the pes anserinus was identified. Superficial medial ligament was dissected from the bone proximally up to the level of osteotomy. There was no risk of instability because the deepest and much more stabilizing tibio meniscal bundle of the ligament remains intact.

A blunt retractor is placed dorsally, deep to the collateral ligament, to protect the posterior vessels and expose the postero-medial corner of the tibia. Anteriorly, a second retractor is placed under the patellar tendon. The procedure is facilitated by

flexion of the knee. Then under the guidance of fluoroscopy, with the knee in extension, 2 K-wires (3 mm) were advanced medially from 1–2 cm distal to the level of the joint up to the lateral cortex and parallel to the joint line to ensure maintenance of the original tibial slope and prevent extention of the fracture to the tibial condyles. Afterwards other K-wire (2.4 mm) was introduced at an appropriate angle up to the lateral cortex.

The lower half of the tibial tuberosity was osteotomised to prevent its fracture during tibial osteotomy, then the osteotomy was performed, keeping the oscillating saw blade below and parallel to the guide pin to prevent an intra articular fracture. The saw was used to cut the medial cortex only. Then a sharp osteotome was used to finish the osteotomy, making certain that the all the cancellous metaphysis and especially the anterior and posterior cortices were completely interrupted, but preserving a lateral hinge of approximately 0.5 cm of intact bone. Fibular osteotomy was not necessary.

- **Step 4:** Plate Fixation

After adequate exposure of the osteotomy line, the osteotomy guide was removed, and an appropriate plate was placed inside the osteotomy line. The plate was placed just on the anterior aspect of the medial ligament to hold the proximal end of the tibia and the tibial shaft. Positioning a symmetrical plate anteromedially will increase the slope, using a tapered plate directly medially should have no effect on slope, and positioning a tapered plate posteromedially should decrease tibial slope. Before fixing the plate, checking to the mechanical axis must be done, under fluoroscopic guidance, by means of the special guide rod, long enough to extend from the center of the femoral head through the knee to the center of the talus. When the rod crosses the knee at a lateral point about two thirds (63%) of the tibial plateau, planning to know the angular correction corresponds to that knee must be performed pre-operative. But if the correction is under-or oversized, we can still change the plate with one having a thicker or thinner tooth as needed. The plate was fixed proximally with two 6.5mm cancellous screws parallel to osteotomy and distally with two 4.5-mm cortical screws or two 6.5mm cancellous screws.

High Fibular Osteotomy:

Surgical technique

After preoperative evaluation and preparation of the patients, the operation was done according to the following steps under general or spinal anesthesia:

- **Step 1: patient position**
- **Step 2: arthroscopy**
- **Step 3: Incision and Exposure**

The patients were placed in the supine position after administration of anesthesia. An approximately 5-cm longitudinal incision was made over the lateral skin of the proximal fibula. We can use fluoroscopy (c-arm) to make sure the right incision and mark the osteotomy or by putting four fingers from the head of fibula.

Then we make the incision up to muscle sheath making small incision and cutting the sheath and go blunt. The fibula was exposed between the peroneus muscle and soleus muscle. We make incision in periosteum of fibula one line and elevate it one layer.

HFO was performed by removing a 2- to 3-cm length of fibula at a site 6 to 10cm from the caput fibulae by use of saw or drilling then sharp osteotomies or sharp osteotomies from beginning.

We can assess the medial compartment of knee under c-arm before and after the osteotomy to see the opening of the joint space. Close the wound after suturing the sheath. Also, we can put drain if needed. Full weight bearing and free mobilization were allowed postoperatively. Postoperative x-ray applied.

Statistical Analysis

Data were collected, revised, coded and entered to the Statistical Package for Social Science version 23 (IBM SPSS Ver. 23).

The qualitative data were presented as numbers and percentages and compared between groups using Chi-square test and/or Fisher exact test only when the expected count in any cell found less than 5.

Also quantitative data were presented as means, standard deviations and ranges and compared between two independent groups by using ***Independent t-test*** while the comparison between two paired groups regarding quantitative data with parametric distribution was done by using ***Paired t-test.***

The comparison between the two studied groups regarding difference between preoperative and postoperative measures was done by using ***Mann-Whitney test.***

Data were collected, revised, coded and entered to the Statistical Package for Social Science version 23 (IBM SPSS Ver. 23). So, the p-value was considered significant as the following: $P > 0.05$: Non significant (NS), $P < 0.05$: Significant (S), $P < 0.01$: Highly significant (HS).

RESULTS

Table (1): Comparison between the two studied groups regarding demographic data

		High tibial osteotomy	High fibular osteotomy	Test value	P-value	Sig.
		No. = 10	No. = 10			
Side	Right Left	4 (40.0%) 6 (60.0%)	5 (50.0%) 5 (50.0%)	0.202*	0.653	NS
Age	Mean±SD Range	48.30 ± 4.55 40 – 55	49.27 ± 5.78 40 – 57	0.425•	0.675	NS
Sex	Female Male	2 (20.0%) 8 (80.0%)	6 (60.0%) 4 (40.0%)	3.333*	0.068	NS

•: Independent t-test; *: Chi-square test

P > 0.05: Non significant (NS); P < 0.05: Significant (S); P < 0.01: Highly significant (HS)

Table(1) shows that there was no statistically significant difference found between high tibial osteotomy and high fibular osteotomy groups regarding side, age and sex with p-value = 0.653, 0.675 and 0.068 respectively.

Table (2): Comparison between the two studied groups regarding preoperative assessment

Preoperative assessment		High tibial osteotomy	High fibular osteotomy	Test value*	P-value	Sig.
VAS	Mean±SD Range	7.80 ± 0.79 7 – 9	8.00 ± 0.67 7 – 9	0.612	0.548	NS
KSS	Mean±SD Range	58.70 ± 4.74 52 – 65	56.60 ± 3.98 52 – 65	1.073	0.297	NS
Radio	Mean±SD Range	2.59 ± 0.68 1.2 – 3.5	2.78 ± 0.67 1.6 – 3.7	0.632	0.535	NS

*: Independent t-test

The previous table(2) shows that there was no statistically significant difference found between high tibial osteotomy and high fibular osteotomy groups regarding VAS, KSS and Radio in the preoperative assessment with p-value = 0.548, 0.297 and 0.535 respectively.

Table (3): Comparison between the two studied groups regarding postoperative assessment

Postoperative assessment		High tibial osteotomy	High fibular osteotomy	Test value*	P-value	Sig.
VAS	Mean±SD Range	4.20 ± 1.14 3 – 6	3.00 ± 0.94 2 – 5	2.571	0.019	S
KSS	Mean±SD Range	85.40 ± 5.62 75 – 91	91.00 ± 4.16 81 – 95	2.532	0.021	S
Radio	Mean±SD Range	3.35 ± 0.67 1.9 – 4.1	3.80 ± 0.59 2.8 – 4.7	1.594	0.128	NS

*: Independent t-test

The previous table(3) shows that there was statistically significant difference found between high tibial osteotomy and high fibular osteotomy groups regarding VAS and KSS with p-value = 0.019 and 0.021 respectively while no statistically significant difference found between the two studied groups regarding radio with p-value = 0.128.

Table (4): Comparison between preoperative and postoperative assessment in high tibial osteotomy

High tibial osteotomy		Preoperative assessment	Postoperative assessment	Test value*	P-value	Sig.
VAS	Mean±SD Range	7.80 ± 0.79 7 – 9	4.20 ± 1.14 3 – 6	7.962	<0.001	HS
KSS	Mean±SD Range	58.70 ± 4.74 52 – 65	85.40 ± 5.62 75 – 91	10.499	<0.001	HS
Radio	Mean±SD Range	2.59 ± 0.68 1.2 – 3.5	3.35 ± 0.67 1.9 – 4.1	6.413	<0.001	HS

*: Paired t-test. The previous table (4) shows that there was highly statistically significant decrease in VAS at the postoperative assessment than preoperative assessment with p-value < 0.001 while there was highly statistically significant increase in KSS and radio postoperative assessment than preoperative assessment with p-value < 0.001 and < 0.001 respectively.

Table (5): Comparison between preoperative and postoperative assessment in high fibular osteotomy

High fibular osteotomy		Preoperative assessment	Postoperative assessment	Test value*	P-value	Sig.
VAS	Mean±SD Range	8.00 ± 0.67 7 – 9	3.00 ± 0.94 2 – 5	16.771	<0.001	HS
KSS	Mean±SD Range	56.60 ± 3.98 52 – 65	91.00 ± 4.16 81 – 95	17.534	<0.001	HS
Radio	Mean±SD Range	2.78 ± 0.67 1.6 – 3.7	3.80 ± 0.59 2.8 – 4.7	22.881	<0.001	HS

*: Paired t-test

The previous table(5) shows that there was highly statistically significant decrease in VAS at the postoperative assessment than preoperative assessment with p-value < 0.001 while there was highly statistically significant increase in KSS and radio postoperative assessment than preoperative assessment with p-value < 0.001 and < 0.001 respectively.

DISCUSSION

Osteotomy offers an alternative surgical option to total knee replacement in reducing pain and improving function especially in younger and more physically active people with Osteoarthritis of the knee [(6)].

Considering two type of osteotomy HTO and HFO are best option in treatment of early stages of medial compartment of OA knee [(7)].

Regarding the selection of which type of osteotomy we found that;

Medial opening wedge HTOs have become increasingly popular over the past 2 decades. The procedure is attractive because the peroneal nerve is not in jeopardy and disruption of the proximal tibiofibular joint and lateral ligaments is avoided [(8)]. The theoretical advantages of opening wedge over closing wedge include: restoration of anatomy with or without addition of bone to the diseased medial side, the ability to achieve predictable correction in both coronal and sagittal planes, the ability to adjust correction intraoperatively, the requirement for only one bone cut, avoidance of proximal tibiofibular joint disruption and invasion of the lateral compartment, and the relative ease of combining with other procedures such as ACL reconstruction. The disadvantages of this procedure include the creation of a defect that requires bone graft with attendant harvest morbidity, and a theoretical higher risk of non-union, as well as the longer period of restricted weight bearing postoperatively. Associated laxity of the ACL or posterolateral corner (PLC) is not uncommon in patients with medial OA, and disruption of the proximal tibiofibular joint as commonly performed during lateral closing wedge HTOs may effectively lengthen the PLC and lead to increased instability [(9)].

In a recent study by some of the current authors [(9)], posterior tibial slope PTS increased by 2 to 5 degrees after open-wedge HTO and decreased by 2 to 5 degrees after closed wedge HTO.

Besides, anterior cruciate ligament (ACL) reconstruction can be achieved using the same incision. Furthermore, this technique also reserves bone stock to be used for possible future total knee prosthesis and provides the desired degree of correction. In addition, it is perfectly comfortable for the patient [(6)] followed 93 cases with arthrosis of the medial compartment that had undergone open-wedge osteotomies for a median of 11.5 years, and reported that the results obtained were satisfactory up to 7 years postoperatively. Medial open-wedge osteotomy (25 knees) or close wedge osteotomy (25 knees) for 50 knees of 46 patients, and reported that after 2 years of follow-up, clinical scores had improved in both groups without a significant difference between groups [(9)].

Success in medial open-wedge osteotomy depends largely on sound application of the technique. The determination of the exact localization of the osteotomy site accurately under a good fluoroscopic control, meticulous care not to fracture lateral cortex during opening of the osteotomy site, frequent assessment of the correction angle at every step of the operation, avoidance of overcorrection, the selection of an appropriate Puddu plate size fit for the osteotomy gap are important details increasing the success rate of this procedure. Based on median 34 month follow-up of the patients, mean improvements obtained in KSS scores was 26.70. According to this assessment scale, preoperative score was deemed ‘‘worse’’, and postoperative scores was ‘‘good’’ [(9)].

In addition, the radiological examinations revealed that the mechanical axes on the average passed 5.09 mm laterally achieving an average of 5 genu valgum. I am in the opinion that early outcomes of the medial open-wedge osteotomies with **Puddu plates** are fairly successful and safe. Besides when compared with the results reported in the literature for high tibial osteotomies my success rates are found to be similar or slightly better.

On other hand HFO consider best opion of treatment early stage of medial OA of knee less complication early weight bearing [9].

HTO has been the surgical treatment of choice for young patients with osteoarthritis of the medial compartment of the knee, and it is aimed at correcting alignment and delaying the time until TKA is required [10, 11]. However, HTO also has some disadvantages, including a delayed time to full weight bearing and risks of nonunion or delayed union, peroneal nerve paralysis and wound infection [12, 13]. HFO has emerged as a new surgery to relieve pain and improve joint function in patients with knee osteoarthritis [14]. The most striking findings in the present study included medial pain relief and an increase in the medial joint space. The majority of patients in our study had significant pain relief immediately after HFO, although the mechanism was unclear and the follow-up was short. Interestingly, the pain relief continued to improve, and some patients even reported no pain at the last follow-up. Postoperative ambulation (i.e. walking) was also obviously improved when compared with the preoperative state. HFO also improved the axial alignment of the lower extremity in some patients, especially in those with severe genu varus. Compared with TKA or HTO, HFO is a simple, safe, fast and affordable surgery that does not require insertion of additional implants. As such, HFO is a suitable surgical option in most developing countries that lack financial and medical resources.

This novel surgery can potentially become an alternative treatment method for osteoarthritis of the medial compartment of the knee, especially for patients who cannot undergo TKA because of medical comorbidities. However, several limitations to this study must be noted. First, although the short-term results are encouraging, the follow-up time was relatively short, and whether these outcomes will remain unchanged at a longer follow-up time is unclear. Therefore, a longer follow-up study is warranted. In addition, the mechanism of the efficacy of HFO is unclear. One possible explanation of why HFO relieves pain and improves the joint space is that it removes the fibula support that may cause genu varus. The fibula supports one-sixth of the body weight; thus, HFO may rebalance or redistribute the load on the lateral and medial tibia plateau after surgery [15].

Another possible mechanism is nonuniform settlement as proposed by ***Yang et al.*** [16] They stated that the lateral support provided to the osteoporotic tibia by the fibula–soft tissue complex may lead to nonuniform settlement and degeneration of the plateau bilaterally, which may cause the load from the normal distribution to shift farther medially to the medial plateau, consequently leading to knee varus and aggravating the progression of medial compartment osteoarthritis of the knee joint. Because only eight patients in our study exhibited obvious correction of alignment, the reason for this phenomenon remains unclear. Furthermore, the longterm side effects of HFO on other joints of the lower extremity, such as the hip and ankle, remain unknown. Therefore, the biomechanics of pain relief, increases in the medial joint space, and correction of alignment in patients who have undergone HFO need further study. Finally, the absence of a control group is another main limitation; however, a placebo control is difficult to include when performing this surgery because of the inability to exclude a placebo effect [16].

CONCLUSION

Our preliminary data clearly demonstrate that HFO is a simple, safe, fast and affordable surgery to relieve pain and improve joint function and the medial joint space in human knee osteoarthritis.

HFO may be a promising alternative in most developing countries because of their financial and healthcare delivery limitations. It may also constitute a promising alternative surgery for osteoarthritis of the medial compartment of the knee, especially for patients who cannot undergo TKA because of certain medical comorbidities. Furthermore, these patients can still undergo TKA in the future if it becomes necessary.

HTO is the surgery of choice in medial compartment OA associated with high degree of genu varum. Our strong point that the operations of all patients was done in the same place by the same physician and same duration of follow up and being assessed by the same scoring system. Weak point is limited number of cases and no long period assessment.

REFERENCES

1. **Lawrence RC, Felson DT, Helmick CG *et al*. (2008):** Estimates of the prevalence of arthritis and other rheumatic conditions in the United States. Part II. Arthritis Rheum., 2008; 58(1):26–35.
2. **Brandt KD (2000):** Diagnosis and non surgical management of osteoarthritis. Professional Communications Inc., second edition.
3. **Hunter DJ and Lo GH (2008):** The Management of Osteoarthritis: An Overview and Call to Appropriate Conservative Treatment. Rheum Dis Clin N Am., 2008; 34:689-712
4. **Harvey WF and Hvnter DJ (2008):** The role of Analgesics and intrarticular injections in disease management. Rheum Dis Clin N. Am., 34: 777-788.
5. **Firestein GS, Budd RC, Harris ED *et al*. (2008):** Kelley's Textbook of Rheumatology,W.B. Saunders company, 8th ed., chapter 91.

6. **Hernigou P, Medevielle D, Debeyre J, Goutallier D (1987):** Proximal tibial osteotomy for osteoarthritis with varus deformity: a ten to thirteen-year follow-up study. J Bone Joint Surg Am., 69:332—54.
7. **Paley D, Maar DC, Herzenberg JE (1994):** New concepts in high tibial osteotomy for medial compartment osteoarthritis. Orthop Clin North Am., 25: 483.
8. **Spahn G (2004):** Complications in high tibial (medial opening wedge) osteotomy. Arch Orthop Trauma Surg., 124:649-653.
9. **Amendola A, Fowler PJ, Litchfield R, Kirkley S, Clatworthy M (2004):** Opening wedge high tibial osteotomy using a novel technique: early results and complications. J Knee Surg., 17:164-169.
10. **Duivenvoorden T, Brouwer RW, Baan A *et al*. (2014):** Comparison of closing-wedge and opening-wedge high tibialosteotomy for medial compartment osteoarthritis of the knee: a randomized controlled trial with a sixyear follow-up. J Bone Joint Surg Am., 96: 1425–1432.
11. **Laprade RF, Spiridonov SI, Nystrom LM *et al*. (2012):** Prospective outcomes of young and middle-aged adults with medial compartment osteoarthritis treated with a proximal tibial opening wedge osteotomy. Arthroscopy, 28: 354–364.
12. **Sprenger TR and Doerzbacher JF (2003):** Tibial osteotomy for the treatment of varus gonarthrosis. Survival and failure analysis to twenty-two years. J Bone Joint Surg Am., 85-A: 469–474.
13. **Dahl A, Robertsson O and Lidgren V (2010):** Surgery for knee osteoarthritis in younger patients. Acta Orthop., 81: 161–164.
14. **Zhang YZ (2015):** Innovations in Orthopedics and Traumatology in China. Chin Med J (Engl), 128: 2841–2842.
15. **Wei XC, Wang XH, Li PC *et al*. (2017):** Proximal Fibular Osteotomy, A New Surgery For Pain Relief and Improvement of Joint Function in Human Knee Osteoarthritis: a Short-Term Clinical Study. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5536585/
16. **Yang ZY, Chen W, Li CX *et al*. (2015):** Medial compartment decompression by fibular osteotomy to treat medial compartment knee osteoarthritis: a pilot study. Orthopedics, 38: e1110–e1114.