

SHORT COMMUNICATION

A Critical Review of Proximal Fibular Osteotomy for Knee Osteoarthritis

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Abstract

The surgical management of Knee Osteoarthritis (KOA), so far, mainly revolved around arthroscopic procedures, arthroplasty (total: TKA and unicompartmental: UKA) or high tibial osteotomy (HTO). Recently, another minimally invasive surgical treatment of proximal fibular osteotomy (PFO) has been proposed for the management of KOA. The PFO has been found to be useful in the management of pain in KOA. The success of PFO depends on the correct location of the osteotomy and the right surgical technique. However, the experience of this procedure is minimal. Still, many questions need to be answered about the PFO viz. selection of best candidates and likely duration of pain relief. More multicentric, comparative and prospective studies are needed on a more substantial number of patients, the overlong follow-up to confirm its validity and recommendation for routine use for KOA.

Level of evidence: IV

Keywords: Arthroplasty, Knee, Osteoarthritis, Pain, Proximal fibular osteotomy

Introduction

The surgical management of Knee Osteoarthritis (KOA), so far, mainly revolved around arthroscopic procedures, total and unicompartmental arthroplasty (TKA and UKA) or high tibial osteotomy (HTO). Recently, another minimally invasive surgical treatment of proximal fibular osteotomy (PFO) is proposed for the management of KOA. This procedure is becoming much more popular in the Eastern world (China and India) than elsewhere. Its popularity is perhaps due to the fact this procedure is more straightforward, less expensive and requires lesser rehabilitation than the alternative procedures like HTO, UKA, and TKA. The PFO helps in the correction of a varus deformity in KOA, which shift the loading force from the medial compartment more laterally. It, therefore, helps in decreasing the pain and satisfactory functional recovery. We have critically reviewed the existing literature to evaluate the usefulness of PFO.

Materials and Methods

We have searched the available publications in the literature, on proximal fibular osteotomy for the treatment of KOA, on PubMed, Scopus, and Google Scholar on 18th August 2018. We have used the keywords proximal fibular osteotomy, and knee osteoarthritis. We only included the original studies (both retrospective and prospective), in the present analysis. We also excluded the publications related to poster presentation, abstracts only and articles not published in the English language (1, 2). We found nine publications in PubMed, seven in Scopus, 10 in Google Scholar. All the duplicate articles from these databases were excluded. Thus the total number of eligible articles was found to be 11. The final number of publications on original studies related to proximal fibular osteotomy (PFO) was seven only. These seven publications were critically studied and analyzed and formed the basis of this review article. The

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authors in these studies diagnosed knee OA according to the American College of Rheumatology criteria, mainly involving the medial compartment of the knee joint. The radiological grading of knee OA was done as per Kellgren Lawrence's criteria. These authors excluded KOA with valgus deformities and posttraumatic, post-infective, and inflammatory arthritis, from their studies. They also excluded patients with medical comorbidities leading to osteoporosis (hepatic or renal disease) and with a history of intra-articular steroid injections (within six months).

Results

Our literature search found that all the seven included studies on PFO in this review were published in between 2015 to 2018, in the English literature and from Chinese authors only. The researchers of the Third Hospital of Hebei Medical University, Shijiazhuang (China) published a maximum number of three papers on PFO. These seven studies included a total number of 468 knees (range: 16 to 156). Most of these studies were on the lower hierarchy of evidence, with six studies (level 4) and one study (level 3) [Table 1]. The PFO was done in these studies for all grades

of symptomatic knee OA. In two out of seven studies (including 203 knees), the authors did not document the grade of KOA in their patients undergoing PFO. Whereas, in the remaining 265 knees, the KL grade of OA was grade I (61 knees), grade 2 (97 knees), grade 3 (60 knees) and grade 4 (47 knees). Hence, the PFO was done in early OA (59.63%), moderate OA (22.64%) and in advanced OA (17.73%). The cumulative mean age of the patients included in these studies was 60.8 years (range 59.2 – 63.0 years). Body Mass Index (BMI) of the patients was mentioned only in three out of seven studies, with a mean BMI of 26.26 (range 24.2 – 27.4). The follow-up duration of these patients was from 12 to 49 months (mean: 24.43 months). Only four out of seven studies reported their complications following PFO. Nerve palsy was the most frequent complication reported in 14 cases from 294 operated knees (4.76%). There were 12 SPN palsy and 2 CPN palsy. All of these nerve palsies were transient and were recovered in an average time of 11.6 months (range: 3 to 15 months). The reported outcomes in all seven studies showed significant improvement of postoperative value as compared to preoperative values of Visual Analogue Score

Table 1. A compiled data of various factors from a published article on proximal fibula osteotomy for medial compartment osteoarthritis of the knee

No.	Author of the Publication	Year of publication	Country of origin	Number of cases (joints)	Level of evidence	Grade of osteoarthritis	Mean Age	BMI	Follow up duration	Result / Outcome score	Complication	Remark
1	Wang et al, (1)	Journal of International Medical Research, 2017	China	47	2	Not mentioned	63	Not mentioned	12 Months	A significant difference in VAS score and medial joint pain and improvement in medial joint space	Not mentioned	
2	Qin et al, (2)	Journal of International Medical Research, 2018	China	52 (67 joints)	2	KL SCORE >2 with varus deformity	62.5	27 ± 4	36 Months	Knee symptoms and function were significantly improved during the 36-month follow-up period (P<0.001)	8 SPN PALSY resolved over 12 months in 6 and 24 months in rest 2 patients. One affected limb showed constrained dorsiflexion of the ipsilateral big toe after the surgery, with a muscle strength grade of 1; this was combined with lateral skin numbness of the ipsilateral leg. The big toe dorsiflexion function of this patient returned to normal six months later, and the muscle strength grade was 5.	Obesity is an adverse factor in OA treatment. Weight gain in patients with knee varus will increase the pressure applied to the medial knee compartment. After an osteotomy, the muscles of the proximal fibula need to produce a more considerable traction force to counteract knee varus deformities resulting from load bearing. Therefore, the BMI was negatively correlated with improvement in the postoperative results (P<0.05, regression coefficient¼_0.675).

Table 1 Continued.

3	Zou et al, (3)	Journal of Biomedical Research, 2017	China	92 40 = PFO 52 = HTO	2	30= GR 1,2 10= GR 3,4	62.3	Not mentioned	25 Months	<p>A) operation time, bleeding amount during operation and drainage volume after the operation significantly decreased while the full weight-bearing time significantly shortened in the PFO group compared with HTO group ($P<0.05$).</p> <p>B) the pain VAS and FTA significantly decreased and the JOA score of the knee joint significantly increased in the PFO group compared with the HTO group ($P<0.05$).</p> <p>C) A Significantly lower incidence of complications were found in the PFO group compared with the HTO group ($P<0.05$).</p>	<p>PFO group: NVI 1 Fracture 1 Recurrent deformity 1</p> <p>HTO group: NVI 3 Infection 1 DVT 2 Non-union 2</p>	<p>Blaimont et al. found that the surgical effects of HTO are superior, but the excessively high osteotomy plane increases the risk of tibial plateau fracture and proximal necrosis(19). Hence, HTO is not recommended for the elderly or patients with severe osteoporosis.</p>
4	Kai Lu et al, (4)	Journal of Clinical and Diagnostic Research January 2018	China	31	2	Ahlback grade 1	58.8	24.2	25 Months	<p>Patients exhibited significant improvements from baseline to more than 24 months after treatment according to the VAS and HSS scores During follow up, no patient had radiographic evidence of osteoarthritis progression according to the Ahlbäck classification or fibular bony union, and no patients required conversion to other surgeries.</p>	<p>1 SPN palsy resolved in 3 months</p>	<p>A cadaveric study showed that the pressure of the medial compartment decreased by 21.57% at most and the pressure of the lateral compartment increased by 12.92% at most after partial fibulectomy(23).</p>

Table 1 Continued.

5	Liu et al, (5)	PLOSE ONE journal May 2018	China	84 pts 111 knee	2	Gr 2 = 17 Gr 3= 47 Gr 4= 47	59.4	Not men- tioned	12 Months	Not mentioned	<p>A) The study results indicated that preoperative KSS clinical score was the sole independent factor associated with the clinical satisfaction of patients, hence for patients suffering less severe disease are likely to achieve satisfactory results.</p> <p>B) the odds for clinical satisfaction approximately increased by 13.4% for every point of KSS clinical score increase.</p> <p>C) HKA angle and settlement value were less affected by subjective factors and were easy to measure. Therefore, these two factors could be used as the main bases for patient selection.</p> <p>D) settlement value was taken as a factor to reflect the degree of non-uniform-settlement of the tibial plateau (7). The higher the settlement value, the more significant the effect of lateral fibula support and the better the outcome of PFO. Such findings suggested that PFO in the treatment of KOA was closely related to the non-uniform-settlement theory.</p>	<p>A) The odds for functional satisfaction approximately increased by 7.2% for every year of age increase.</p> <p>B) patients with obvious medial space narrowing and smaller CP angle were more likely to achieve significant improvements in clinical symptoms. HKA angle reflected the changes in limb alignment (21), and patients with nearly normal HKA angles showed better outcomes in joint function, which might be because PFO could only partially correct the varus deformity of the tibial plateau. Studies have shown that patients with severe KOA had varus deformity in the femoral condyle as well [22]. For these patients, PFO was unable to fully improve their varus deformity and prognosis.</p> <p>C) medial joint space, CP angle, HKA angle and settlement value were objective factors and could be measured directly on X-ray films. Therefore, these factors were not subject to subjective impact, and thus suitable for prediction of a patient's postoperative recovery.</p>
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Table 1 Continued.

6	Yang et al, (6)	SLACK journal December 2015	China	156	2	Not men- tioned	59.2	Not men- tioned	49 Months	<p>At final follow-up, the mean FTA and lateral joint space were $179.4^{\circ} \pm 1.8^{\circ}$ and 6.9 ± 0.7 mm, respectively, which were significantly lower than the data measured preoperatively ($P < .001$).</p> <p>The lateral joint space was narrower, and the medial joint space was wider than demonstrated on preoperative radiographs. Mean KSS at final follow-up was 92.3 ± 31.7, which was significantly larger than the preoperative score (45.0 ± 21.3; $P < .001$).</p> <p>Mean VAS score, and interquartile range at final follow-up were 2.0 and 2.0, respectively, which were significantly lower than the preoperative data (7 and 1.0, respectively; $P < .001$;</p>	<p>2 CPN PALSY 2 SPN PALSY All resolved in 3 to 10 months</p>
7	Nie et al, (7)	Journal of Biome- chanics December 2017	China	16	2	KL2 =3 KL3=13	60.4	27.2	12 Months	<p>VAS pain score significantly decreased ($P < .001$).</p> <p>The HSS score significantly increased ($P < .001$) meaning function improved.</p> <p>After PFO there is a significant difference in HKA angle ($P = 0.006$) with postoperative status changing a mean 0.90 degrees from a more varus to more neutral alignment.</p>	<p>Not mentioned</p> <p>Evaluation of the change in stress contours (preoperatively to postoperatively) of the tibial plateau in five regions (anterior, posterior, medial, lateral and posterior-lateral) revealed decreased stress in the medial and lateral region and increased stress in the posterior-lateral region after PFO.</p>

(VAS) and Knee Society Score (KSS).

Discussion

Medial compartment degeneration is the most prevalent form of KOA, seen in the clinical practice. Proximal Fibular Osteotomy (PFO) has been proposed as an attractive surgical option for pain relief in patients with medial compartment KOA. It is much more popular in the Eastern world (China and India etc.) than elsewhere. It is reflected by the fact that the majority of publications on PFO are from China (1-7). The popularity of PFO is perhaps due to the fact this procedure is simpler, less expensive and requires lesser rehabilitation than the alternative procedures like HTO, UKA, and TKA. The use of PFO for the management of KOA has been reported in the literature, only recently since 2015 and only seven significant publications have been found so far, on PFO. Hence, there is a lack of detailed information and knowledge about this procedure.

The principal of PFO (Non-uniform settlement or Stress imbalanced syndrome)

The fibula bone is mostly a non-weight bearing bone which takes 6.4% of the body weight and serves mainly as the attachment site for various muscles of the leg and foot (8). Hence, osteotomy and partial excision of the fibula is done commonly for the various Orthopaedic indications. The role of the fibula as a strut, in giving support to the lateral tibial condyle has been recently highlighted by some researchers. As a normal aging process, the bone mass decreases. A varying degree of the settlement of bone mass exists in the load-bearing joints, such as the knees, hips, ankles, and spine (9). In healthy individuals, the weight transmission from femoral condyle to the tibia is equal in both condyles, but

in case of osteoporosis, the subchondral bone of the tibia becomes weak. The support of fibula over lateral condyle helps lateral condyle tibia transmit weight, but medial condyle tibia has no such support which therefore leads to non-uniform settlement (10). This settlement in the medial tibial plateau is more evident than in the lateral plateau. This non-uniform settlement due to change in the slope of the tibial plateau, produces transverse shearing force, to cause a medial shift of the femoral condyle during walking and sports (11). Also, the side-slip aggravates the non-uniform settlement of the tibial plateau, especially on the medial side. Therefore, non-uniform settlement occurs, due to increasing the load distribution in the medial compartment and non-uniform settlement occurs (12). The lateral support of the fibula to the tibial plateau is considered as the crucial factor that leads to the non-uniform settlement. It results in a medial shift of the mechanical axis, which results in varus deformity and degeneration of the knee joint (13). Nie et al. observed that before surgery in medial compartment KOA, both the tibia and fibula are loaded, the tibia much more than the fibula (7). However, after PFO, only the tibia was loaded, and the area of high stress on the cortical bone of the tibial shaft was more significant, than before the PFO. An osteotomy of the proximal fibula weakens the lateral fibular support, and therefore the stresses are shifted from the medial compartment to the posterolateral compartment of the knee. Thus PFO leads to correction of a varus deformity, which subsequently shifts the loading force from the medial compartment more laterally, and therefore helps in decreasing the pain and satisfactory functional recovery [Figure 1]. Kai Lu et al. quoted a cadaveric study, where the medial compartment pressures of the knee were decreased by 21.57% after PFO (4).

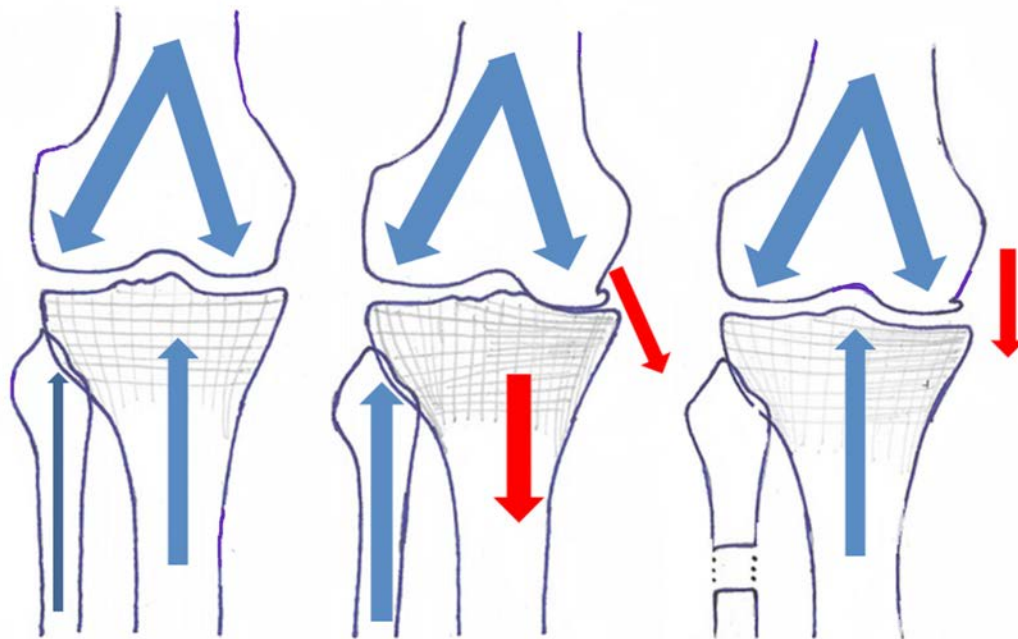


Figure 1. Mechanism of action of Proximal Fibular Osteotomy (PFO).



Figure 2. Pre and Postoperative Antero-Posterior radiographs after Proximal Fibular Osteotomy, showing good correction of knee deformities.

After PFO, the proximal fibular segment becomes free from the constraints of the from the TF syndesmosis and distal fibula, leading to a relative increase of ROM of the proximal tibiofibular joint (PTFJ) (2). The soleus and peroneus longus muscles attached to the proximal fibula, pull the fibular head distally and hence the tensile force is transmitted from the postero-lateral part of the fibular head to the lateral femoral condyle. The lateral joint space of the knee is therefore narrowed to counteract the varus deformity after weight bearing [Figure 2]. It helps in reducing the pressure on the medial compartment of the knee and relieving the medial knee pain (2). The greater displacement of the fibular head (as it is pulled distally) has several advantages like a) greater varus deformities correction, b) more medial compartment decompression, and c) significant clinical improvement in pain can be achieved.

The ideal site of fibulectomy

The success of PFO depends on the correct location of the osteotomy. It is known that the stability of the ankle joint complex depends on the integrity of the fibula and six centimeters of the distal fibula is essential for ankle stability (14). Hence, it seems preferable to perform partial fibulectomy more proximally, to avoid complications in the ankle. Also, the fibers of the interosseous membrane are oblique from tibia down to fibula, and during weight-bearing, the interosseous membrane pulls the fibula towards the tibia resulting in load sharing between the two bones (15, 16). When partial fibulectomy is performed more proximally, lesser loads are shared by the proximal fibular segment, and the support from the proximal fibular segment to the lateral tibial plateau is weaker.

The most commonly reported complication of PFO is related to the injury to peroneal nerve and its branches, due to its proximity and an anatomical course about the fibula (2, 6). Hence, it is mandatory to understand its

anatomical location and make all the efforts to prevent neurological injury, during the PFO. Common peroneal nerve (CPN) is formed by the bifurcation of the sciatic nerve in the popliteal fossa. It then enters the lateral compartment of the leg after wrapping around fibular head and neck, near the peroneus longus muscle and terminates in two branches known as superficial peroneal nerve and deep peroneal nerve. Superficial peroneus nerve runs over the anterolateral surface of fibula, and deep peroneal nerve runs in interosseus space [Figure 3]. It is imperative to remember that the muscular

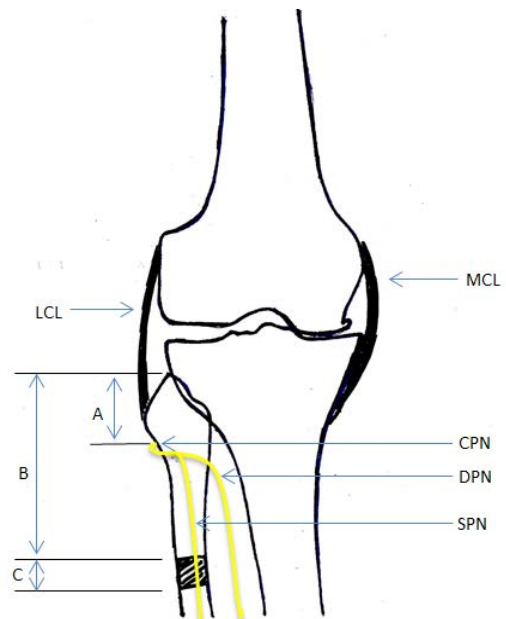


Figure 3. Anatomical representation of the peroneal nerve and its branches about the proximal fibula and osteotomy site.

and cutaneous nerve supply of the deep peroneal nerve (DPN) and Superficial Peroneal Nerve (SPN). The DPN supplies muscles of the anterior compartment of the leg, which include tibial anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius and gives cutaneous innervation to the web space between the first and second digit. Whereas, SPN supplies the muscles of the lateral compartment of the leg, which include peroneus longus and peroneus brevis and gives cutaneous innervation to the anterolateral aspect of the leg and dorsum of the foot.

At the proximal fibula, the region from 40 mm to 60 mm distal to the fibular tubercle is safe for motor branches of the deep peroneal nerve during proximal fibulectomy (17). However, the superficial peroneal nerve travels along the lateral border of the fibula, and the deep peroneal nerve is on the anterior border for almost the whole proximal one-third fibula (18, 19). Therefore, the incision of proximal fibulectomy should be made over the poster lateral surface of the fibula, and the soft tissue on the fibular surface should be detached immediately on the fibular cortex with caution [Figure 4]. Hence the ideal distance of fibula osteotomy site should be between 6 to 10 centimeters from the tip of the fibula, depending upon the height of the patient (6). Close attention is needed to avoid potential peroneal nerve injury during surgery. To reduce iatrogenic injury to the peroneal nerve postero-lateral approach is ideal, which passes between the Peroneus longus muscle and the soleus muscle to expose the proximal fibula (2-4). The use of a rolled sheet under the knee to keep it flexed in about 40 degrees, help in postero-lateral exposure [Figure 4]. Furthermore taking the mini-incision and vigorous use of retractors and bone spikes can also lead to neuropraxia of SPN by traction hence proper 4-5 centimeter incision should be taken with extra care while retracting the muscle flap. We suggest that the use of a bone saw for osteotomy of fibula should be smaller than the diameter of the fibula to avoid damage to the adjacent soft tissue and nerve [Figure 5].

Zou et al. compared HTO with PFO in the management of KOA (3). They preferred PFO to HTO, because of lower possibility of complications and early recovery. However, they emphasized the importance of an accurate fibular osteotomy site and protection of peroneal nerve during the surgery. Their recommended site of PFO was 4-7 centimeters away from the fibular head, to prevent the nerve injury and to achieve good pain relief after PFO. Compared to HTO, PFO offers several advantages [Table 2].

Factors influencing the outcomes of PFO

Several factors have been reported to influence the functional outcomes of PFO in KOA viz. severity of KOA, age, obesity, coexisting intra-articular pathology etc. The severity of KOA should dictate the indication for PFO. It is assumed that the PFO would be beneficial in cases with isolated medial compartment KOA. However, it has been used in patients with KL grade III and IV OA., with satisfactory outcomes (3, 5, 7). Qui et al. noticed that the obesity is an adverse factor, as it puts increased pressure on the medial compartment of the knee (2). They hypothesized it to be due to increased traction forces applied to the muscles of the proximal fibula after PFO, to counteract the knee varus deformity after load bearing. Liu et al. found that the odds for functional satisfaction after PFO were increased by 7.2% for every year of age increase (5). They also noted that the patients with more medial joint space narrowing were likely to achieve better clinical improvements after PFO. It was also reflected by improved limb alignment and Hip-Knee-Ankle angles. Kai Lu et al. reported a case series of 31 patients where arthroscopic meniscectomy was performed in addition to PFO and reported satisfactory results in 91.1% of their cases (4). They found it to be a safe and minimally invasive procedure. Hence, PFO can be done the additional arthroscopic procedure, if indicated.

Presence of Tibiofibular (TF) arthritis restricts the mobility of the TF joint. In a cadaveric study, Eichenblat



Figure 4. Surface making for proximal fibular osteotomy, with a flexed knee.



Figure 5. Small bone saw is being used for Proximal Fibular Osteotomy.

Table 2. Comparison of various factors between proximal fibula osteotomy (PFO) and high tibial osteotomy (HTO) for medial compartment osteoarthritis

Factors	High Tibial Osteotomy (HTO)	Proximal Fibular Osteotomy (PFO)
Surgical technique	Complex	Simple
Invasion	More invasive	Less invasive
Incision	Long	Small
Internal fixation	Required	Not necessary
Postoperative recovery period	Longer	Shorter
Weight-bearing	Delayed	Early
Complications	More	Less
Cost	High	Less

and Nathan found that the TF arthritis often coexists with KOA (20). An oblique orientation of the proximal TF joint was found to be more vulnerable to this joint degeneration (21). The presence of TF arthritis also correlates with the severity of KOA. Hence, an evaluation of the TF joint must be done before performing a PFO, because an arthritic TF joint would produce a lesser displacement of the fibular head after PFO, leading to lesser clinical benefit. Qui et al. noted that a larger inclination angle of the TF joint might lead to a relatively larger ROM, and therefore, after PFO, the fibular head can displace more distally (2). It may, therefore, assist the muscles attached to the proximal fibula in pulling the lateral femoral condyle, to counteract knee varus deformity.

Proximal Fibular Osteotomy (PFO) has been proposed as an attractive option for pain relief in patients with medial compartment Osteoarthritis of the knee. It is much more popular in the Eastern world (China and India etc.) than elsewhere. Its popularity is perhaps due to the fact this procedure is simpler, less expensive and requires lesser rehabilitation than the alternative procedures like HTO, UKA, and TKA. The most common complication of this

procedure includes transient neural injury to the braches of common peroneal nerve. However, there is an only a limited number of studies available in the literature on PFO, published recently. These publications are only from China and low in the hierarchy of evidence. Hence, the present knowledge about this procedure cannot be entirely relied upon. More controlled and multicentric trials are required from the other parts of the world on PFO, to reach to a reasonable conclusion about its role in the management of pain and reducing the progress of the disease process of OA.

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