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Original Article

Preliminary results of high fibular osteotomy (HFO) and cartilage regeneration procedure for medial compartment osteoarthritis of knee with varus deformity

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A B S T R A C T

Purpose: High fibular osteotomy (HFO) is a simple surgical technique to reduce pain and improve function in patients with osteoarthritis via fibular osteotomy. We report short-term results of HFO and mesenchymal cell induced chondrogenesis (MCIC) for the treatment of osteoarthritis of knee with varus deformity.

Patients and methods: 45 symptomatic patients with 14 males and 31 females age ranging from 40 to 75 years were treated by HFO and MCIC. Main lesions involved medial compartment of knee and lateral compartment with normal to mild lesions of lateral meniscus and articular cartilage, amenable to treatment via partial meniscectomy or observation.

Results: Knee injury and Osteoarthritis Outcome score and Lysholm showed a statistically significant increase and VAS, varus angle in X-ray showed a statistically significant decrease. A statistically significant difference between preoperative and postoperative scores was detected in male and female patients without any sexual differences.

Conclusion: High fibular osteotomy and mesenchymal cell induced chondrogenesis can be considered as a good treatment option for medial compartment osteoarthritis of knee with varus deformity.

1. Introduction

Osteoarthritis of knee is one of the most common joint diseases causing severe pain and limitation with activities of daily living [1]. Both high tibial osteotomy (HTO) and unicompartmental knee arthroplasty (UKA) are well-established treatments for medial knee osteoarthritis (OA) [2]. As arthroplasty is associated with serious postoperative challenges, joint preserving procedures have become popular and appropriate for young and active patients [3,18]. Therefore the ideal candidate for an HTO is a young patient (<60 years of age), with isolated medial osteoarthritis, with good range of motion and without ligamentous instability [4]. However, HTO is an excessive surgical action for mild varus deformity as the surgical procedure is technically demanding, needs long rehabilitation

Abbreviations: HFO, High fibular osteotomy; HTO, high tibial osteotomy; MCIC, mesenchymal cell induced chondrogenesis; BMAC, bone marrow aspirate concentrate; HA, hyaluronic acid; KOOS, Knee injury and Osteoarthritis Outcome score; VAS, visual analogue score.

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period, with serious potential complications including nerve and vascular injuries [5–8]. The clinical efficacy of arthroscopic surgery combined with HTO in patients diagnosed with varus osteoarthritic knee is disputed. However, arthroscopic surgery improves mechanical symptoms and quality of regenerative articular cartilage. High fibular osteotomy (HFO) is a simple surgical technique to reduce pain and improve function in patients with osteoarthritis via fibular osteotomy [9,10]. This procedure improves varus deformity by eliminating the force of fibula, which supports varus alignment. As the degree of correction with HFO is limited, arthroscopic cartilage regeneration for medial compartment osteoarthritis of knee may be combined to enhance the clinical outcomes. We report short-term results of HFO and mesenchyamal cell induced chondrogenesis (MCIC) for the treatment of osteoarthritis of knee with varus deformity.

2. Patients and Methods

This is a retrospective study of 45 symptomatic patients with 14 males and 31 females age ranging from 40 to 75 years, and conducted from June 2017 to November 2017. Arthritis with varus deformity was confirmed by weight-bearing knee X-ray and HFO were determined preoperatively. Main lesions involved medial compartment of knee and lateral compartment with normal to mild lesions of lateral meniscus and articular cartilage, amenable to treatment via partial meniscectomy or observation.

The inclusion and exclusion criteria were as follows:

2.1. Inclusion criteria

- Patients aged 18 years–75 years.
- Diagnosed with articular cartilage defect in the knee (ICRS/Outerbridge grade III/IV cartilage lesions as assessed on arthroscope).
- Weight-bearing x-ray of Kellgren–Lawrence grade III/IV.

2.2. Exclusion criteria

- Age below 18 years and above 75 years;
- Generalized and/or inflammatory arthritis;
- Active joint inflammation;
- More than 15° of varus or valgus deformity in anatomical axis and patellar maltracking;
- Ligament instability;
- Significant co-morbidities or classified as American Society of Anesthesiologists (ASA) grade 3/4.

2.3. High fibular osteotomy

An approximately 5-cm longitudinal incision was made along the lateral skin of the proximal fibula, and the fibula was exposed between the peroneus and soleus muscle. HFO was performed by removing a 1-cm length of fibula at a site 7–8 cm from the head of fibula. Gentle valgus stress was applied to the knee in order to open the medial joint space. The surgical wound was closed with sutures. The leg was covered with a compression bandage.

2.4. Preparation of BMAC, HA and fibrin gel mixture

After appropriate anesthesia, the patient's anterior superior iliac spine (ASIS) was marked, cleaned and draped. Bone marrow aspiration needle (T-Lok™, Angiotech, Gainesville, Florida, USA) and syringes pre-loaded with 2 ml Anticoagulant Citrate Dextrose solution A (ACD-A, Biomet, Massachusetts, USA) were used to aspirate 30 ml of bone-marrow from the iliac crest. The bone marrow aspirate was centrifuged twice in a BMC kit (Revmed, Seoul, Korea) (Fig. 1A). The first cycle lasted 6 min at 3500 rpm, followed by the second cycle for 5 min at 3600 rpm to obtain bone marrow aspirate concentrate (BMAC).

To address the chondral defect, two 2-ml syringes were connected to a Y-shaped mixing catheter. One syringe contained 0.8 ml of fibrinogen (Tisseel®, Baxter, Thetford, UK) and 0.2 ml of Hyaluronic acid (HA) (Highhyal, Huons, Seoul, Korea). The second syringe contained 0.8 ml of bone marrow concentrate and 0.2 ml of thrombin (Tisseel®, Baxter, Thetford, UK) (Fig. 1B).

2.5. Arthroscopic preparation of chondral defect

The knee was approached via antero-lateral and antero-medial arthroscopic portals and normal saline was infused under pressure (approximately systolic blood pressure). A Wolf cannula (Karl Storz GmbH, Tuttlingen, Germany) was inserted superolaterally as an outflow cannula. The articular cartilage lesions were carefully debrided using curettes and shavers; burrs were used if the subchondral bone was sclerotic. Micro-drilling was performed using a 3.0 mm-diameter drill to a depth of 5 mm at intervals of 3–5 mm in the lesion.

2.6. Application of BMAC, HA and fibrin gel mixture

The saline was drained from the knee joint and carbon dioxide (CO_2) was introduced at 20 mm Hg at a rate of 20 l/min using the Wolf cannula (Karl Storz GmbH, Tuttlingen, Germany) and disposable tubing with a filter (Insufflation tubing with Wolf adaptor, Leonhard Lang UK Ltd., Stroud, UK) through the superolateral portal (Fig. 2A). Residual saline was aspirated from the knee using a 20-ml syringe and an angled suction tube (Exmoor, Taunton, UK), with low pressure to avoid bleeding. The micro-drilled lesion(s) was dried with cotton buds.

A 20-gauge needle (inner diameter 0.9 mm, length 90 mm) (Spinal needle, Becton Dickinson, Madrid, Spain) was inserted into the joint via a suitable portal and connected to the double syringe. Under arthroscopic guidance, the BMAC, HA and fibrin gel mixture was gently applied, via the double syringe, uniformly over the lesion(s) (Fig. 2B). Due to the tamponade effect of the CO_2 and the adhesiveness of the gel, the graft adhered to the lesion(s), even against gravity. If necessary, a second layer was injected deep into the firm first layer. The graft was shaped *in situ* using a McDonalds dissector (Bolton Surgical, UK). The graft was attached firmly to the defect after 2 min and under arthroscopic vision, the knee was moved through its range of motion several times to anatomically sculpt the graft and test its stability. If satisfied, the CO_2 was switched off and all instruments were withdrawn.

2.7. Rehabilitation

All patients underwent the same rehabilitation procedure. The patients were instructed to partially bear weight on the operated leg for six weeks. Subsequently, free mobilization was allowed.

2.8. Clinical assessment

All participants were clinically assessed using three validated surgical scores: the Lysholm score, the Knee injury and Osteoarthritis Outcome score(KOOS) and a visual analogue score (VAS). Varus angle was determined by measuring the angle between the anatomic axis of femur, which is the mid-diaphyseal line and the anatomic axis of tibia in standing anteroposterior knee radiograph.

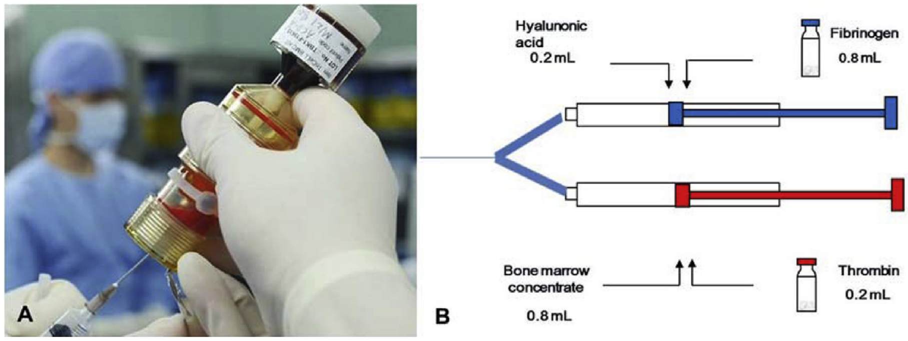

Fig. 1. A) Using BMAC(bone marrow aspirate concentrate) kit, BMAC is aspirated after centrifugation of bone marrow aspirate. B) 0.2 ml of hyaluronic acid and 0.8 ml of fibrinogen are loaded in 1 ml syringe and 0.8 ml of BMAC and 0.2 ml of thrombin are loaded in other 1 ml syringe. Two syringes are connected by Y-shape catheter for injection to the cartilage defect.

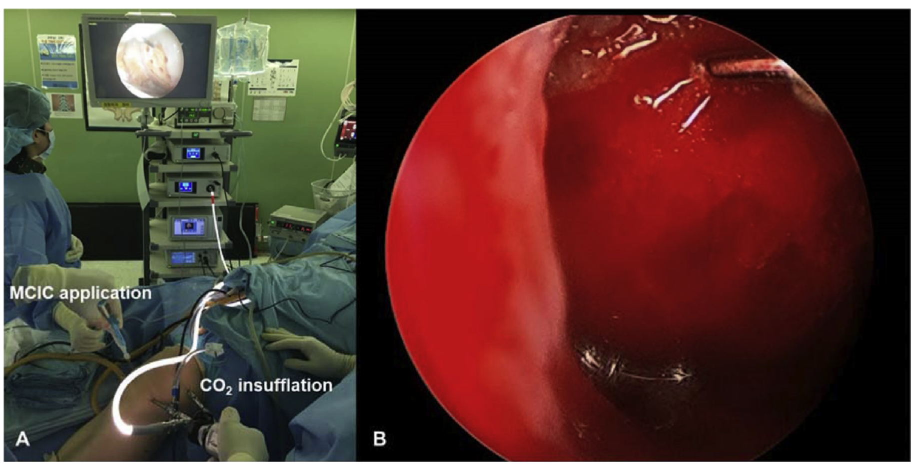

Fig. 2. A) Clinical photo of arthroscopy and CO_2 infusion setup for MCIC operation. B) BMAC mixed with hyaluronic acid and fibrinogen is injected to the cartilage defect under CO_2 insufflation.

The results between preoperative status and post-operative 6 months were compared.

2.9. Statistical analysis

Shapiro–Wilk test was used for normality analysis and non-parametric test was used for data which do not satisfy normality. KOOS, VAS, Lysholm, varus angle deference before and after surgery to evaluate the clinical status and radiological lower limb alignment were analysed using paired t-test and non-parametric test was used by Wilcoxon signed rank test. The difference of the average of variables according to gender was evaluated by t-test, Mann–Whitney test and the comparison of three groups according to age was analysed using ANOVA with Scheffe post hoc, Kruskal–Wallis test.

3. Results

A total of 45 patients were included in our study comprising 14 males and 31 females (68.9%) with a mean patient age of 61.9 years (range: 40–75). The chondral lesions were distributed in two compartments of the knee; 25 patients had one lesion, 12 patients carried two lesions and 3 patients had three lesions. All patients carried medial femoral condyle lesions, 11 patients had tibial lesion, 4 on the trochlea and 5 on the patella. The mean size of the lesions was 3.4 cm^2 (2–9 cm^2).

As the VAS did not meet normality in Kolmogorov–Smirnov test, a non-parametric statistical test was used. A significant difference between preoperative and postoperative scores was detected. KOOS and Lysholm showed a statistically significant increase and VAS, varus angle in X-ray showed a statistically significant decrease (Table 1).

A statistically significant difference between preoperative and postoperative scores was detected in male and female patients without any sexual differences (Table 2). There was no difference in preoperative KOOS, VAS, Lysholm, and varus angles across all age groups. The B group (age of 60–70 years) showed a statistically significant increase compared with Group C (age above 70 years) in KOOS (Table 3).

Two patients manifested paraesthesia over the dorsum of the foot which improved in 3 months, and one patient had great toe weakness (extensor halluces longus), which recovered fully in 5

Table 1
Comparison of the scores before and after surgery N=45.

Variables	Pre-OP	Post-OP	t or Z	*p*
	Mean (Standard Deviation, Min-Max)			
KOOS	30.2 (9.2, 7.7–50.6)	83.1 (8.3, 61.3–96.4)	−31.13	<0.001
VAS	9.0 (0.8, 7–10.0)	1.6 (0.8, 0–3.0)	−5.89	<0.001*
Lysholm	29.2 (7.0, 10.0–46.0)	81.9 (8.1, 64.0–94.0)	−33.72	<0.001
X-ray	10.5 (2.0, 8.0–15.0)	1.4 (0.9, 0–3.0)	26.52	<0.001

*Wilcoxon signed rank test.

Table 2
Comparison of the scores by gender N = 45.

Variables	Male (n = 14) M (SD, Min-Max)		t or Z	p	Female (n = 31) M (SD, Min-Max)		t or Z or U	p
	Pre-OP	Post-OP			Pre-OP	Post-OP		
KOOS	26.9(9.4, 7.7–42.3)	83.3(8.0, 70.1–94.6)	−17.50	<0.001	31.7 (8.8, 16.7–50.6)	83.1(8.5, 61.3–96.4)	−26.17	<0.001
VAS	9.3 (0.6, 8.0–10.0)	1.3 (0.9, 0.0–3.0)	−3.32	<0.001*	8.9 (0.8, 7.0–10.0)	1.7 (0.8, 0.0–3.0)	−4.91	<0.001*
Lysholm	30.2(9.1,10.0–46.0)	83.1(7.5, 71.0–94.0)	−14.37	<0.001	28.7 (5.9, 18.0–45.0)	81.4 (8.4, 64.0–93.0)	−32.93	<0.001
X-ray	10.4(1.9, 8.0–15.0)	1.3 (1.0, 0.0–3.0)	−3.32	<0.001*	10.6 (2.1, 8.0–15.0)	1.4 (0.8, 0.0–3.0)	−4.90	<0.001*
KOOS diff.	56.5 (12.1, 31.4–76.8)				51.4 (10.9, 27.0–69.2)		−1.41	0.167
VAS diff.	−8.0 (1.2, −10.0 to −6.0)				−7.2 (1.2, −9.0 to −4.0)		143.00	0.061†
Lysholm diff.	52.9 (13.8, 34.0–82.0)				52.6 (8.9, 38.0–71.0)		−0.07	0.943
X-ray diff.	−9.1 (2.5, −15.0 to −6.0)				−9.2(2.3, −15.0 to −6.0)		207.50	0.812†

*Wilcoxon signed rank test, diff: Differences in scores before and after surgery; †: Mann–Whitney test.

Table 3
Comparison of the scores by age group.

Variables	A group (n = 21)	B group (n = 15)	C group (n = 9)	F or χ2	P (Scheffe post hoc)
	M (SD, Min-Max)				
Pre OP					
KOOS	30.8 (9.7, 7.7–50.6)	28.8 (8.6, 16.1–48.8)	31.1 (9.9, 19.6–48.6)	0.24	0.785
VAS	9.0 (0.7, 8.0–10.0)	8.9 (0.9, 7.0–10.0)	9.1 (0.9, 7.0–10.0)	0.13	0.937*
Lysholm	31.0 (7.8, 10.0–46.0)	27.2 (6.3, 18.0–37.0)	28.4 (5.3, 22.0–37.0)	1.36	0.268
X-ray	10.5 (2.0, 8.0–15.0)	10.6 (2.1, 8.0–15.0)	10.4 (2.2, 8.0–15.0)	0.04	0.979*
Post OP					
KOOS	83.7 (8.2, 61.3–94.6)	86.4 (6.0, 78.0–96.4)	76.4 (8.6, 67.3–90.2)	4.91	0.012 (B > C)
VAS	1.5 (0.9, 0.0–3.0)	1.5 (0.8, 0.0–3.0)	1.9 (0.8, 1.0–3.0)	0.47	0.792*
Lysholm	82.9 (8.4, 64.0–94.0)	83.9 (5.8, 70.0–92.0)	76.2 (8.6, 66.0–92.0)	3.14	0.053
X-ray	1.6 (0.8, 0.0–3.0)	1.3 (1.0, 0.0–3.0)	1.1 (0.8, 0.0–2.0)	2.12	0.347*
Difference					
KOOS	52.9 (10.1, 36.9–76.8)	57.5 (8.5, 36.3–67.4)	45.3 (15.0, 27.0–67.3)	3.61	0.036 (B > C)
VAS	−7.6 (1.1, −10.0 to −6.0)	−7.5 (1.2, −9.0 to −5.0)	−7.2 (1.6, −9.0 to −4.0)	1.48	0.478*
Lysholm	51.9 (10.9, 34.0–82.0)	56.7 (9.4, 40.0–71.0)	47.8 (9.7, 34.0–64.0)	2.29	0.114
X-ray	−9.0 (2.3, −15.0 to −6.0)	−9.3 (2.3, −15.0 to −7.0)	−9.3(2.7, −14.0 to −6.0)	0.24	0.886*

A group: < 60 years of age; B group <70 years of age; C group > 71 years of age; *: Kruskal–Wallis test.

months. It may be due to the excessive retraction. All these patients were our initial patients.

4. Discussion

Biomechanically, osteoarthritis of knee occurs due to the imbalance between biological resistance and mechanical stress, and one of the important treatments is to reduce the stress to articular cartilage [11]. Osteotomy around the knee reverses the stress from the arthritic articular cartilage to normal or less arthritic articular cartilage [11,12]. Despite unclear reasons underlying pain reduction after osteotomy, we assumed that it was due to the correction of knee mal-alignment [10].

HTO is indicated for medial compartmental osteoarthritis of knee with varus deformity in young and active patients [2,3]. This operation transfers the joint reaction force from medial to lateral compartment of knee, which is normal or less arthritic. HTO can halt or delay the arthritis progression and improve joint pain and patient's activity [11]. However, the rehabilitation period is very long, and entails possible complications including nerve palsy, vascular injury, non-union of osteotomy site and infection [5–8]. Further, it is recommended for moderate varus deformity around 10°–15° of mechanical axis. HTO may be excessive for the correction of around 5° of mechanical varus deformity, considering the complexity of surgery and post-operative complications [7].

All patients in this study should have been ideally treated by HTO as the varus deformities are over 10° in mechanical axis. However due to economical constraints and reluctance of metal fixation in patients, possible treatment option was HFO [9,10].

HFO entails resection of a small fragment of proximal fibula. Weight bearing is initiated according to patient's condition and facilitates rapid recovery with rare post-operative complications. However, the fibular osteotomy site should be carefully determined, without going below 6 cm from the head of fibula to avoid nerve injury [13]. Incision should not be very small in order to prevent overstretching of the soft tissue structures to avoid transient neurological problems such as paresthesia and EHL weakness.

Wang et al. [10]. and others performed only proximal fibular osteotomy at 6–10 cm from the fibular head and resected 2–3 cm of bone fragment without cartilage regeneration arthroscopy. It attenuated knee joint pain and function. However, we treated patients using single-stage arthroscopic cartilage regeneration via mesenchymal cell-induced chondrogenesis (MCIC) and HFO. Even though HFO improved varus deformity of osteoarthritic knee, the correction for deformity was limited and the precise correction angle cannot be estimated. Therefore, for better clinical result, the pathology of medial compartment warranted arthroscopic intervention, to treat the biological and mechanical aspects of osteoarthritis [14–20].

We prefer to use the term “high fibular osteotomy” even though the osteotomy site of fibula was about 7 cm below the fibular head (Fig. 3), because this operation contrasted with HTO and was easily recognized by surgeons proficient with HTO procedure. We resected only 1 cm of bone fragment, which improved the varus deformity without risk of early union and hindering varus correction (Fig. 3). Therefore, the morbidity can be minimized compared with larger bone resection technique. We assumed that the correction of varus deformity occurred via release of the deforming force by cutting the string of bow. Therefore, HFO decreases the pressure in

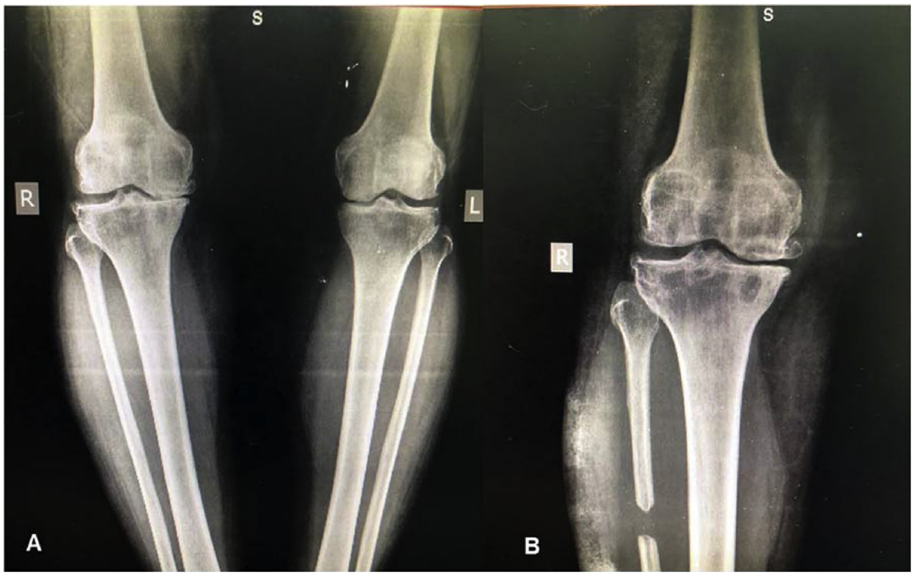

Fig. 3. Knee standing AP radiograph of 70 years old female with medial compartment osteoarthritis. A) 8 degree of varus deformity in anatomical axis of right knee, preoperatively, B) 1 degree of varus deformity in post-operative 6 months.

the medial compartment of the knee, reducing the knee pain and improving the function in patients with medial compartment knee osteoarthritis [10,13].

The excellent results in this study also can be attributed to the combined effect of MCIC and HFO. MCIC is an arthroscopic cartilage regeneration technique, which uses a mixture of bone marrow aspirate concentrate, hyaluronic acid and fibrin. Kim et al. showed excellent results of MCIC in the treatment of osteoarthritis of the knee without osteotomy [14]. MCIC is not indicated for correction of varus deformity, but only for cartilage regeneration from the lesion

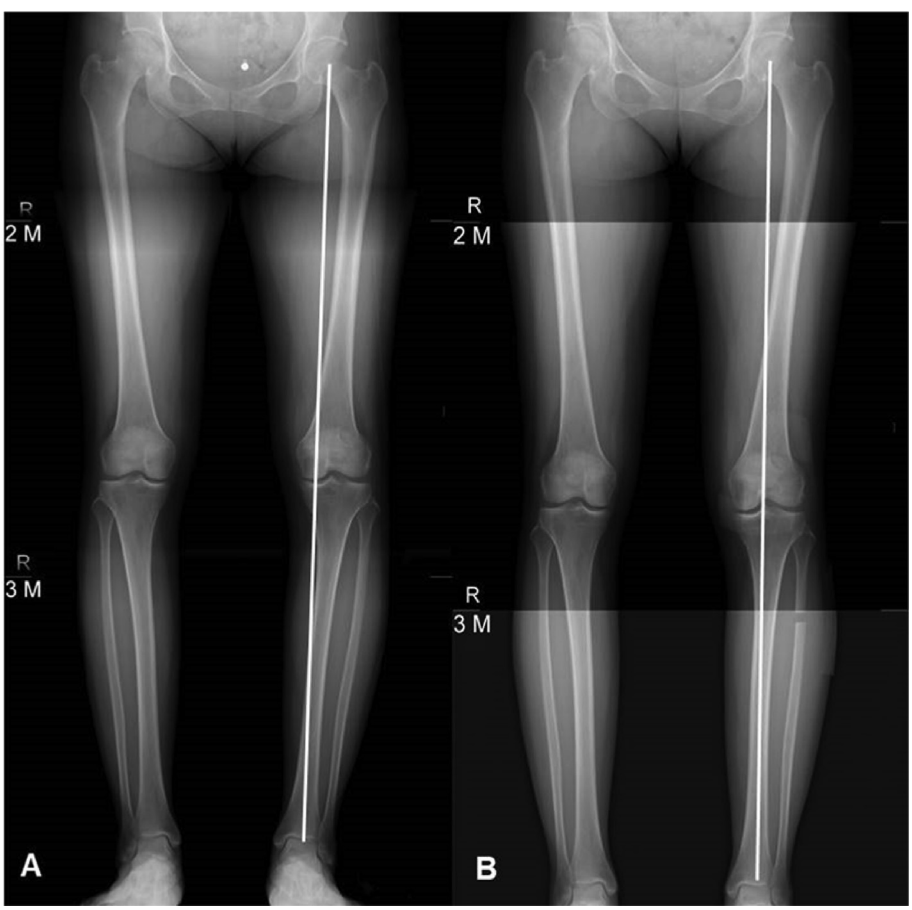

Fig. 4. Lower extremity standing AP radiograph of 54 years old female with medial compartment osteoarthritis. A) 7 degree of varus deformity in mechanical axis of left knee, B) 1 degree of varus deformity in post-operative 6 months.

and slight improvement of mal-alignment by restoring the joint space from articular cartilage regeneration.

As the HFO leads to limited improvement in varus deformity, the indications for operation can be suggested. Degenerative tear of medial meniscus, root tear of medial meniscus, focal cartilage defect involving medial femoral condyle or medial tibial plateau, with mild varus deformity around 5° may be ideal indications (Fig. 4). Serious pathologies of the medial compartment are an indication for HTO currently. However, following HTO for the correction of minor varus deformity, excessive valgus alignment of knee leads to cosmetic and functional challenges. In this scenario, HFO represents an ideal surgery for correction of small amounts of varus deformity spontaneously (Fig. 4).

There are several limitations in this study. The number of patients was small and the follow-up period was only 6 months. Therefore, additional number of patients and further long-term follow-up are necessary to determine the accuracy of results of HFO.

To the best of our knowledge, this is the first report of combined HFO and cartilage regeneration procedure to treat osteoarthritis of knee. We recommend HFO and cartilage regeneration procedure as a standard operation indicated for medial compartmental osteoarthritis of knee with mild varus deformity.

5. Conclusion

High fibular osteotomy with cartilage regeneration procedure can be a good treatment option for medial compartment osteoarthritis of knee with varus deformity.

Ethics approval

The study protocol was approved by the institutional Ethical Committee and Informed consent was confirmed by the institutional Ethical Committee.: Institutional Ethical Committee TOSH (Trauma & Orthopaedic Speciality Hospital EC Ref No: 004/2017); There are no animal experiments carried out for this article.

Availability of data

Access to data will be considered by authors upon request.

Consent for publication

Not applicable.

Funding

Not applicable.

Authors' contributions

JH was involved in reviewing the literature, and drafting the manuscript as the main author. AS, NC, KK and KK were involved in documentation and data preparation. TS, JS and YC were involved in the interpretation of the results and giving intellectual contributions. SK gave an original concept of this paper and was responsible for the final proofreading of the manuscript.

All authors read and approved the final manuscript.

Competing interest

The authors declare that they have no competing interests.

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