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Original Research Article

Prospective Comparative Analysis of Knee Preservation Techniques in Osteoarthritis of the Knee

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Abstract

Background: Knee osteoarthritis is a major cause of pain, disability, and reduced quality of life worldwide. In recent years, knee preservation techniques have gained importance as alternatives to joint replacement in appropriately selected patients. The present study compared the clinical, functional, and radiological outcomes of commonly employed knee preservation strategies in patients with osteoarthritis of the knee.

Methods: This prospective comparative study included 94 patients with Kellgren–Lawrence grade II–III knee osteoarthritis treated at a tertiary care center. Patients were allocated to High Tibial Osteotomy (HTO) (Group A, n=32), arthroscopic cartilage preservation procedures (Group B, n=31), or Platelet-Rich Plasma (PRP) therapy (Group C, n=31). Baseline demographic and clinical characteristics were recorded. Outcomes were assessed using Visual Analog Scale (VAS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Knee Society Score (KSS), range of motion (ROM), radiological progression, and complications over a 12-month follow-up period.

Results: Baseline demographic and clinical characteristics were comparable among the groups ($p>0.05$). At 12 months, all interventions resulted in significant clinical improvement; however, HTO demonstrated superior outcomes. Mean VAS scores improved from 7.6±1.0 to 2.1±0.9 in the HTO group compared with 3.1±1.2 following arthroscopy and 4.2±1.4 after PRP ($p<0.001$). HTO also achieved the greatest improvements in WOMAC (38.4±10.2), KSS (37.4±11.3), and ROM (15.6±8.7°) (all $p<0.001$). Radiological progression was absent in 81.3% of HTO patients compared with 64.5% and 48.4% of arthroscopy and PRP patients, respectively ($p=0.018$). Conversion to total knee arthroplasty was lowest following HTO (3.1%). Complication rates were low and comparable among groups.

Conclusion: All three knee preservation techniques were effective in improving symptoms and function in knee osteoarthritis. However, HTO provided the most favorable clinical, functional, and radiological outcomes, suggesting superior joint-preserving efficacy in appropriately selected patients. Arthroscopic procedures offered moderate benefits, while PRP provided symptomatic improvement with minimal invasiveness but less durable structural preservation.

Keywords: Knee osteoarthritis; High Tibial Osteotomy; Platelet-Rich Plasma; Arthroscopic cartilage preservation; Knee preservation surgery.

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Introduction

Osteoarthritis (OA) of the knee is one of the most prevalent chronic musculoskeletal disorders and a major cause of pain, disability, and impaired quality of life among adults worldwide [1]. It is characterized by progressive degeneration of articular cartilage, subchondral bone remodeling,

osteophyte formation, synovial inflammation, and gradual loss of joint function [2]. The global burden of knee OA has increased substantially over recent decades due to population aging, increasing obesity rates, sedentary lifestyles, and longer life expectancy [3]. Recent estimates suggest that more than 500 million people are affected by osteoarthritis globally, with the knee being the most commonly involved joint [3]. In India, the prevalence of knee OA has been reported to range from 22% to 39%, making it a significant public health concern, particularly among the elderly population [4].

The development of knee OA is multifactorial and involves a complex interaction of mechanical, biological, genetic, and metabolic factors. Advancing age, obesity, previous joint injury, malalignment, occupational stress, and muscle weakness are recognized risk factors contributing to disease onset and progression [5]. As the disease advances, patients experience chronic pain, stiffness, reduced mobility, and functional limitations that adversely affect daily activities and socioeconomic productivity [6].

Conservative management, including lifestyle modification, weight reduction, physiotherapy, analgesics, and intra-articular injections, forms the cornerstone of initial treatment [7]. However, these interventions often provide only temporary symptomatic relief and may not adequately address the underlying biomechanical abnormalities responsible for disease progression [7]. Total knee arthroplasty remains the definitive treatment for advanced OA, but concerns regarding implant longevity, revision surgery, and postoperative activity restrictions make it less suitable for younger and physically active patients [8].

Consequently, increasing attention has been directed toward knee preservation techniques aimed at delaying or avoiding joint replacement while maintaining native joint anatomy and function [9]. Procedures such as high tibial osteotomy, cartilage restoration techniques, meniscal preservation procedures, and biologic therapies seek to correct malalignment, redistribute load transmission, preserve joint structures, and slow degenerative changes [10]. Although these interventions have shown promising clinical outcomes, evidence comparing their effectiveness in different patient populations remains limited [10].Therefore, the present study was aimed to prospectively compare the outcomes of knee preservation techniques in patients with osteoarthritis of the knee and evaluate their role in improving functional outcomes and delaying disease progression.

Materials and Methods

Study Design and Setting: This prospective comparative observational study was conducted in the Department of Orthopaedics of a tertiary care teaching hospital over a period of 24 months from January 2023 to December 2024. Institutional Ethics Committee approval was obtained prior to commencement of the study, and written informed consent was obtained from all participants before enrollment.

Study Population: Patients presenting to the outpatient and inpatient services of the Department of Orthopaedics with symptomatic osteoarthritis of the knee and considered suitable candidates for knee preservation procedures were screened for eligibility. Adult patients aged between 40 and 65 years with radiologically confirmed osteoarthritis of the knee corresponding to Kellgren–Lawrence grade II or III, persistent symptoms despite at least six months of conservative treatment, and preserved range of motion were included in the study. Patients with advanced tricompartmental osteoarthritis (Kellgren–Lawrence grade IV), inflammatory arthritis, previous major knee surgery, active joint infection, severe flexion deformity (>15°), significant ligamentous instability, neuromuscular disorders affecting gait, or severe medical comorbidities precluding surgery were excluded.

Sample Size and Group Allocation: A total of 94 eligible patients were enrolled consecutively during the study period and allocated into three treatment groups according to the knee preservation procedure indicated based on clinical and radiological assessment. Group A (n=32) comprised patients undergoing High Tibial Osteotomy (HTO), Group B (n=31) included patients treated with arthroscopic cartilage preservation/restoration procedures, and Group C (n=31) consisted of patients receiving biologic knee preservation therapy in the form of Platelet-Rich Plasma (PRP) injections. Each group included 30 patients. Treatment allocation was based on established surgical indications, degree of deformity, cartilage status, age, activity level, and surgeon preference.

Preoperative Evaluation: All patients underwent a detailed clinical evaluation including history of pain, duration of symptoms, functional limitations, previous treatment history, and associated comorbidities. Physical examination included assessment of gait pattern, limb alignment, range of motion, ligament stability, joint line tenderness, crepitus, and deformity. Baseline demographic variables including age, sex, body mass index (BMI), occupation, and affected side were recorded. Radiological assessment included weight-bearing anteroposterior, lateral, skyline patellar, and long-leg alignment radiographs. Osteoarthritis severity was graded according to the Kellgren–Lawrence classification. Mechanical axis

deviation and lower limb alignment parameters were measured using standardized radiographic techniques.

Intervention Protocol: Patients in the HTO group underwent medial opening wedge high tibial osteotomy under regional or general anesthesia using standard operative techniques. Correction was planned preoperatively based on mechanical axis calculations, aiming to shift the weight-bearing line toward the lateral compartment. Internal fixation was performed using a locking plate system, and bone grafting was utilized whenever required. Patients in the arthroscopic preservation group underwent procedures such as microfracture, chondroplasty, debridement, or cartilage restoration according to intraoperative findings. Standard arthroscopic portals and techniques were employed to address focal cartilage defects and associated meniscal pathology whenever indicated.

Patients in the biologic therapy group received three intra-articular injections of autologous platelet-rich plasma at two-week intervals under strict aseptic precautions. PRP was prepared using a standardized double-spin centrifugation protocol yielding platelet concentrations approximately three to five times baseline blood levels.

Postoperative Rehabilitation and Follow-Up: All patients underwent a structured rehabilitation protocol tailored to the specific intervention performed. Physiotherapy focused on pain control, range-of-motion exercises, quadriceps strengthening, gait training, and progressive functional rehabilitation. Follow-up evaluations were conducted at 1 month, 3 months, 6 months, and 12 months after treatment.

Outcome Measures: Clinical and functional outcomes were assessed using the Visual Analog Scale (VAS) for pain, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Knee Society Score (KSS). Range of motion was measured using a standard goniometer. Radiological progression was evaluated using follow-up weight-bearing radiographs. Complications including infection, thrombosis, implant-related problems, persistent pain, or requirement for subsequent surgical intervention were documented.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.

Intergroup comparisons of continuous variables were performed using one-way analysis of variance (ANOVA) followed by post-hoc analysis where appropriate. Within-group changes over time were assessed using paired t-tests or repeated-measures ANOVA. Categorical variables were compared using the Chi-square test or Fisher's exact test. A p-value less than 0.05 was considered statistically significant.

Results

The study included 94 patients with osteoarthritis of the knee, comprising 32 patients in the High Tibial Osteotomy (HTO) group, 31 in the Arthroscopic Preservation group, and 31 in the Platelet-Rich Plasma (PRP) group. The mean age of participants ranged from 51.7±7.1 to 55.1±5.9 years, with no significant difference among the groups (p=0.118).

Male patients predominated in all groups, accounting for 59.4%, 54.8%, and 51.6% of patients in Groups A, B, and C, respectively (p=0.823). Baseline BMI, symptom duration, side of involvement, and radiographic severity according to Kellgren–Lawrence grading were comparable across the three groups (all p>0.05).

Similarly, baseline pain and functional status measured using VAS, WOMAC, and KSS showed no statistically significant intergroup differences, confirming homogeneity of the study population before intervention (Table 1).

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants.

Variable	Group A (HTO) n=32	Group B (Arthroscopy) n=31	Group C (PRP) n=31	p-value
	Frequency (%)/Mean ± SD			
Age (years),	53.8 ± 6.4	51.7 ± 7.1	55.1 ± 5.9	0.118
Gender				
Male	19 (59.4)	17 (54.8)	16 (51.6)	0.823
Female	13 (40.6)	14 (45.2)	15 (48.4)	
BMI (kg/m²)	28.7 ± 3.2	27.9 ± 3.5	29.1 ± 3.8	0.421
Symptom duration (months)	28.6 ± 11.4	25.9 ± 12.1	30.8 ± 13.6	0.289
Side involved				
Right knee	18 (56.3)	19 (61.3)	17 (54.8)	0.887
Left Knee	14 (43.7)	12 (48.7)	14 (45.2)	

KL Grade				
KL Grade II	11 (34.4)	15 (48.4)	14 (45.2)	0.472
KL Grade III	21 (65.6)	16 (51.6)	17 (54.8)	
Baseline VAS Score	7.6 ± 1.0	7.3 ± 1.1	7.5 ± 1.2	0.517
Baseline WOMAC Score	61.2 ± 8.6	58.8 ± 9.4	60.7 ± 8.9	0.541
Baseline KSS	49.1 ± 7.8	51.6 ± 8.1	50.4 ± 7.5	0.392

BMI: Body Mass Index; KL Grade: Kellgren–Lawrence Grade; VAS: Visual Analog Scale; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; KSS: Knee Society Score.

Significant differences were observed in procedure-related parameters among the three treatment groups. The mean procedure duration was highest in the HTO group (104.8±18.6 minutes), followed by the arthroscopy group (62.4±14.8 minutes), and lowest in the PRP group (18.5±4.3 minutes) ($p<0.001$). Patients undergoing HTO required a significantly longer hospital stay (4.9±1.3 days) compared with arthroscopy (1.8±0.6 days), whereas PRP was performed as a day-care procedure ($p<0.001$).Time to full weight-bearing and return to routine activities also differed significantly, with HTO requiring the longest rehabilitation period and PRP demonstrating the fastest recovery (both $p<0.001$) (Table 2).

Table 2: Procedure-Related Characteristics

Variable	Group A (HTO) n=32	Group B (Arthroscopy) n=31	Group C (PRP) n=31	p-value
	Mean ± SD			
Procedure duration (minutes)	104.8 ± 18.6	62.4 ± 14.8	18.5 ± 4.3	<0.001
Hospital stay (days)	4.9 ± 1.3	1.8 ± 0.6	-	<0.001
Time to full weight-bearing (weeks)	8.4 ± 1.7	3.1 ± 1.0	-	<0.001
Return to routine activities (weeks)	13.6 ± 3.4	7.9 ± 2.1	4.6 ± 1.4	<0.001

HTO: High Tibial Osteotomy; PRP: Platelet-Rich Plasma.

At baseline, VAS, WOMAC, KSS, and ROM values were comparable among the three groups (all $p>0.05$). At 12 months, all treatment modalities demonstrated substantial clinical improvement; however, the magnitude of improvement differed significantly. The HTO group achieved the lowest mean VAS score (2.1±0.9), followed by arthroscopy (3.1±1.2) and PRP (4.2±1.4) ($p<0.001$). Similarly, WOMAC scores at 12 months were significantly lower in the HTO group (22.8±7.1) compared with arthroscopy (31.4±8.5) and PRP (40.6±9.8) ($p<0.001$). Functional assessment using KSS revealed superior outcomes in the HTO group (86.5±8.2) relative to the arthroscopy (78.4±9.3) and PRP groups (69.8±10.7) ($p<0.001$). Range of motion improved in all groups, with the highest final ROM observed in the HTO group (117.0±9.4°) ($p=0.021$) (Table 3).

Table 3: Comparison of Functional Outcomes at 12-Month Follow-Up

Outcome Measure	Group A (HTO) n=32	Group B (Arthroscopy) n=31	Group C (PRP) n=31	p-value
	Mean ± SD			
VAS Score Baseline	7.6 ± 1.0	7.3 ± 1.1	7.5 ± 1.2	0.517
VAS Score 12 Months	2.1 ± 0.9	3.1 ± 1.2	4.2 ± 1.4	<0.001
WOMAC Baseline	61.2 ± 8.6	58.8 ± 9.4	60.7 ± 8.9	0.541
WOMAC 12 Months	22.8 ± 7.1	31.4 ± 8.5	40.6 ± 9.8	<0.001
KSS Baseline	49.1 ± 7.8	51.6 ± 8.1	50.4 ± 7.5	0.392
KSS 12 Months	86.5 ± 8.2	78.4 ± 9.3	69.8 ± 10.7	<0.001
ROM Baseline (°)	101.4 ± 11.2	104.3 ± 12.5	103.1 ± 10.9	0.563
ROM at 12 Months (°)	117.0 ± 9.4	114.5 ± 10.8	110.2 ± 11.6	0.021

VAS: Visual Analog Scale; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; KSS: Knee Society Score; ROM: Range of Motion.

Analysis of changes from baseline to 12 months demonstrated significant differences in treatment effectiveness among the three groups. The HTO group showed the greatest reduction in pain, with a mean VAS improvement of 5.5±1.4 points, compared with 4.2±1.3 points in the arthroscopy group and 3.3±1.5 points in the PRP group ($p<0.001$). Likewise, improvements in WOMAC score were greatest in the HTO group (38.4±10.2), followed by arthroscopy (27.4±9.6) and PRP (20.1±8.7) ($p<0.001$). The mean increase in KSS was also highest among HTO patients (37.4±11.3),

with significantly smaller gains in the arthroscopy and PRP groups (p<0.001). Improvement in knee range of motion followed a similar pattern, with HTO achieving the largest ROM gain (15.6±8.7°), followed by arthroscopy (10.2±7.1°) and PRP (7.1±6.4°) (p<0.001) (Table 4).

Table 4: Magnitude of Clinical Improvement from Baseline to 12 Months

Variable	Group A (HTO) n=32	Group B (Arthroscopy) n=31	Group C (PRP) n=31	p-value
	Mean ± SD			
Reduction in VAS Score	5.5 ± 1.4	4.2 ± 1.3	3.3 ± 1.5	<0.001
WOMAC Improvement	38.4 ± 10.2	27.4 ± 9.6	20.1 ± 8.7	<0.001
KSS Improvement	37.4 ± 11.3	26.8 ± 10.5	19.4 ± 9.9	<0.001
ROM Gain (degrees)	15.6 ± 8.7	10.2 ± 7.1	7.1 ± 6.4	<0.001

VAS: Visual Analog Scale; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; KSS: Knee Society Score; ROM: Range of Motion.

Radiological assessment at follow-up demonstrated significant differences among treatment groups. Absence of radiological progression was observed in 81.3% of HTO patients, compared with 64.5% in the arthroscopy group and 48.4% in the PRP group (p=0.018). Progression by at least one Kellgren–Lawrence grade occurred most frequently in the PRP group (51.6%) and least frequently in the HTO group (18.7%). Post-treatment complications were generally infrequent and comparable across groups. Infection rates were low, occurring in one patient each in the HTO and arthroscopy groups (p=0.609). Persistent pain requiring additional intervention was more common in the PRP group (22.6%) than in the arthroscopy (12.9%) and HTO groups (6.3%), although the difference did not reach statistical significance (p=0.094). Conversion to total knee arthroplasty was least common following HTO (3.1%) and highest in the PRP group (16.1%). Overall complication rates ranged from 12.5% to 25.8%, with no statistically significant intergroup difference (p=0.278). These findings suggest superior radiological preservation and lower rates of subsequent arthroplasty following HTO compared with the other knee preservation strategies (Table 5).

Table 5: Radiological Progression and Complications During Follow-Up

Variable	Group A (HTO) n=32	Group B (Arthroscopy) n=31	Group C (PRP) n=31	p-value
	Frequency (%)			
No radiological progression	26 (81.3%)	20 (64.5%)	15 (48.4%)	0.018
Progression by ≥1 KL Grade	6 (18.7%)	11 (35.5%)	16 (51.6%)	
Infection	1 (3.1%)	1 (3.2%)	0 (0.0%)	0.609
Persistent pain requiring intervention	2 (6.3%)	4 (12.9%)	7 (22.6%)	0.094
Conversion to Total Knee Arthroplasty	1 (3.1%)	3 (9.7%)	5 (16.1%)	0.118
Overall complications	4 (12.5%)	6 (19.4%)	8 (25.8%)	0.278

KL Grade: Kellgren–Lawrence Grade; TKA: Total Knee Arthroplasty.

Discussion

The present prospective comparative study evaluated the clinical, functional, radiological, and complication-related outcomes of three commonly employed knee preservation strategies—High Tibial Osteotomy (HTO), arthroscopic cartilage preservation procedures, and Platelet-Rich Plasma (PRP) therapy—in patients with osteoarthritis of the knee. The baseline demographic and clinical characteristics were comparable among the three groups, with no significant differences in age, sex distribution, BMI, symptom duration, radiographic severity, or baseline functional scores.

This homogeneity minimizes selection bias and strengthens the validity of subsequent comparisons. The mean age of participants ranged from 51.7 to 55.1 years, which is consistent with the typical age group targeted for knee preservation procedures. Previous studies by Bhushan et al., and Dong et al., similarly reported that patients undergoing joint-preserving interventions are generally younger and more active than those considered for arthroplasty, emphasizing the importance of preserving native joint biomechanics in this population [11,12].

Procedure-related outcomes revealed expected differences in invasiveness and rehabilitation requirements. HTO was associated with significantly longer operative time, hospital stay, and delayed return to full weight-bearing compared with arthroscopy and PRP therapy (p<0.001). Despite this greater initial treatment burden, HTO

provided superior long-term benefits. These findings support observations by Zhang et al., who reported that although medial opening-wedge HTO requires prolonged rehabilitation, it yields substantial improvement in pain and function by correcting underlying mechanical malalignment [13]. The prolonged recovery period observed in the present study likely reflects the biological time required for osteotomy healing and gradual adaptation of joint loading patterns [14].

Pain relief constituted one of the most clinically relevant outcomes. At 12 months, patients undergoing HTO achieved the lowest VAS score (2.1±0.9), compared with arthroscopy (3.1±1.2) and PRP therapy (4.2±1.4), with a corresponding mean pain reduction of 5.5 points. These findings are comparable to those reported by Liao et al., and Wen et al., who demonstrated significant pain reduction following HTO through redistribution of mechanical load away from the diseased medial compartment [15,16]. The biomechanical rationale underlying this improvement lies in correction of varus malalignment, which decreases focal cartilage stress and reduces nociceptive stimulation arising from subchondral bone overload [16]. In contrast, PRP primarily acts through biological modulation of inflammation and growth factor release, explaining its beneficial but comparatively less pronounced effect on pain [17].

Functional outcomes mirrored the pain findings. The HTO group achieved significantly better WOMAC and KSS scores at one year than both arthroscopy and PRP groups ($p<0.001$). The mean WOMAC improvement of 38.4 points and KSS improvement of 37.4 points observed after HTO indicate substantial restoration of knee function and quality of life.

Similar improvements have been reported by Bode et al., who found that appropriately selected patients undergoing HTO experienced sustained functional gains and delayed disease progression [18]. Arthroscopic procedures demonstrated intermediate outcomes, likely because they address focal cartilage defects and mechanical symptoms but do not fully correct the abnormal load distribution responsible for osteoarthritis progression [19]. This finding aligns with report from Srinivasan et al., who observed modest functional improvement following arthroscopic cartilage procedures in early-to-moderate osteoarthritis [20].

Range of motion improved significantly in all treatment groups, with the greatest gain observed following HTO (15.6°). Improved ROM likely reflects reduction in pain, correction of deformity, enhanced joint biomechanics, and structured postoperative rehabilitation [21]. Restoration of a more physiological mechanical axis may improve gait mechanics and facilitate greater knee excursion during daily activities [22].

An important finding of the present study was the superior radiological preservation achieved with HTO. More than four-fifths of HTO patients (81.3%) demonstrated no radiological progression during follow-up, compared with 64.5% in the arthroscopy group and only 48.4% in the PRP group ($p=0.018$). Furthermore, progression by at least one Kellgren–Lawrence grade occurred least frequently after HTO. These results are consistent with long-term studies by Park et al., Jansen et al., and Birmingham et al., which demonstrated that realignment osteotomy can slow structural deterioration by redistributing load away from damaged cartilage and reducing disease-driving biomechanical stress [24,25]. The comparatively higher progression rates observed after PRP suggest that while biologic therapies may improve symptoms, their ability to modify structural disease progression remains limited [24]. Complication rates were low and comparable across groups. Although persistent pain and conversion to total knee arthroplasty occurred more frequently in the PRP group, these differences did not reach statistical significance. Nevertheless, the lower arthroplasty conversion rate observed after HTO supports previous evidence by Hunter et al., Madry et al., and Geng et al., indicating that successful realignment procedures can delay the need for joint replacement by several years [26,27,28].

Limitations

The present study has certain limitations. The sample size was relatively modest and derived from a single tertiary care center, which may limit the generalizability of the findings. Treatment allocation was based on clinical indications rather than randomization, introducing the possibility of selection bias. Furthermore, the follow-up period was limited to 12 months, which may not fully capture long-term radiological progression, durability of functional outcomes, or eventual need for total knee arthroplasty.

Conclusion

All three knee preservation techniques—High Tibial Osteotomy (HTO), arthroscopic cartilage preservation procedures, and Platelet-Rich Plasma (PRP) therapy—resulted in significant improvements in pain, function, and knee mobility in patients with osteoarthritis of the knee.

However, HTO demonstrated superior outcomes with the greatest reduction in pain, highest improvement in WOMAC and Knee Society Scores, better range of motion, and lower rates of radiological progression and conversion to total knee arthroplasty. Arthroscopic procedures provided intermediate benefits, whereas PRP

offered symptomatic relief with minimal invasiveness but comparatively limited structural preservation. Appropriate patient selection remains crucial for optimizing outcomes of knee-preserving interventions.

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