A COMPARATIVE CLINICAL STUDY OF CRUCIATE-RETAINING TOTAL KNEE ARTHROPLASTY AND CRUCIATE-SUBSTITUTING TOTAL KNEE ARTHROPLASTY

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Abstract

Background: This prospective clinical study was performed to compare the clinical outcomes between patients with cruciate-retaining (CR) and cruciate-substituting (CS) total knee arthroplasty (TKA).

Methods: from July 2018 to June 2019, 52 patients (32 females and 20 males) with a total of 70 knees with a mean age of 61.11 years (range, 46 to 78 years) were enrolled in this study. Patients were randomly divided into two groups including group A (Cruciate-Retaining Total Knee Arthroplasty (CR-TKA) underwent 35 CR TKA, and group B (Cruciate-Substituting Total Knee Arthroplasty (CS-TKA) underwent 35 CS total knee Arthroplasty. The evaluation parameters included knee scores, pain score, functional scores, radiographs of the knees and ROM (Range of motion). Regular follow up done at 4 weeks, 12weeks and then every 6 months. All data were collected and analyzed with the help of suitable statistical parameters.

Results: Both designs give equal and good results. We preferred CR Knees in relatively young patients and patients with smaller knees as its bone conserving implant and CS knees in patients with Inflammatory arthritis, patient with severe Varus or flexion deformity, when tibia cut is more than 10 mm and when intra-operatively findings suggestive of non-functional posterior Cruciate ligament. However, in our short term randomized interventional study Posterior Cruciate substitution Total Knee Arthroplasty had a marginally better outcome than the posterior Cruciate retaining in terms of range of motion but it needs a long-term analysis.

Key words: Cruciate substitution Total Knee Arthroplasty, Cruciate-Retaining Total Knee Arthroplasty, Knee scores, Pain score

Introduction

Patients with severe osteoarthritis (OA) of the knee have difficulty with many of the normal activities of daily living. Total knee Arthroplasty has evolved over the past decades into a very much reliable surgical treatment for advanced arthritis of knee.

Total knee replacement has been shown to restore patient function and relieve pain and deformity that results from knee arthrosis. The success of a total knee replacement is determined by many factors including pain relief, functional outcome, and range of motion, radiographic loosening or component revision.¹

There have been numerous changes in the total condylar type of total knee Arthroplasty during the past 20 years. These modifications include alterations in component geometry, understanding of the rotational alignment of the components, sizing options and modularity, accurate instrumentation for correcting deformity and improved cementation techniques. The total condylar prosthesis which was developed in 1974 was subsequently modified to a posterior Cruciate substituting the posterior stabilized version in around 1978 for the purpose of improving stair climbing, better range of knee motion, prevention of posterior subluxation and more conforming knee kinematics.²

The best knee replacement is one, which reproduces the kinematics of the normal knee. Amongst several factors affecting the kinematics, variations in surface geometry and the retention or sacrificing the posterior Cruciate ligament is considered especially important. Yet, there is no clear evidence of how best to deal with the posterior Cruciate ligament at the time of knee replacement surgery. There are four options available to the surgeon. The first is to retain the ligament and to preserve as much as possible of the normal anatomy and function of the knee. Preservation of the ligament is thought to enhance stability, femoral rollback, mechanical advantage of the quadriceps muscle and proprioceptive properties.³,⁴

The second option is to excise the ligament in order to facilitate the correction of any fixed deformities. This
allows more accurate and reliable soft tissue balancing resulting in improved fixation of the components.

The third option is to substitute the ligament with a posterior stabilized tibial insert. These inserts have a central post, which can engage on a femoral cam during flexion, mimic femoral rollback and reproduce near normal kinematic profiles. The central post may also allow some stability in the anteroposterior plane and act as a secondary stabilizer to a Varus or valgus stress. The fourth option is to release the ligament; this offers a compromise between preservation and excision.\(^5\)\(^6\)\(^7\)\(^8\)

In modern orthopaedics most knees have been replaced with some form of PCL-substituting prosthesis when the PCL is excised. Several researchers have compared Cruciate-retaining (CR) TKA and CS TKA. Both posterior Cruciate-retaining (CR) and posterior Cruciate-substituting (PS) TKAs have at least 90% of patients obtaining good or excellent scores at long-term follow up. Controversy still continues concerning the role of the posterior Cruciate ligament (PCL) in TKA. Proponents of retaining the PCL have considered that the PCL produces normal knee kinematics, especially femoral rollback and that it improves joint proprioception. On the other hand, those in favour of sacrificing the PCL have argued that excision of the PCL makes ligament balance easier and that the cam–spine mechanism provides more reliable femoral rollback. Most previous clinical studies have reported short-term results.\(^7\)\(^8\)\(^9\)

Therefore, current study was organized to compare Cruciate retaining total knee Arthroplasty and cruciate substituting total knee Arthroplasty."

**Material and Methods**

**Study Area:** This study was conducted in the Department of Orthopaedics, S.M.S Medical College and attached group of hospitals, Jaipur with due permission from the institutional ethical committee and review board and after taking written informed consent from the patient

**Study Period:** Data collection for study started from July 2018 to June 2019 or till the sample size is achieved (whichever is earlier). Then it took another two months to process and analyse data.

**Study Type and Design:** Hospital based, prospective randomized, comparative interventional study.

**Sample Size:** Sample size was calculated to be 35 subjects in each groups (aged 46 years to 78 years) at alpha error-0.05 and study power- 80%, assuming mean difference of anteroposterior laxity 1 mm and standard deviation 1.5 mm. Total 52 patients (M/F=20/32) were taken and 16 Left, 18 Bilateral TKA were done. (70 knees)

**Randomisation Method:** The patients were randomized in 2 groups through chit box method.

**Group A** (\(n=35\))
Cruciate-Retaining Total Knee Arthroplasty (CR-TKA)

**Group B** – (\(n=35\))
Cruciate-Substituting Total Knee Arthroplasty (CS-TKA)

**Study Universe:** Patient who met the inclusion criteria and reported at department of Orthopaedics, SMS Hospital, Jaipur, included.

**Inclusion Criteria**
Patient with severe osteoarthritis (Kellgren and Lawrence score Grade 3 and 4) of knee joint. Patients who are fit for surgery and given written informed consent for study.

**Exclusion Criteria**
Patients with associated hip and ankle arthritis, Surgical and medical contraindication, Poor skin conditions, Post traumatic arthritis

**Ethics Statement**
The study protocol was approved by the institutional ethical committee. Informed consents were obtained in written form from patients and all clinical investigations were conducted according to the standard protocol. The patients gave consent for the publication of the clinical details.

**Data Analysis**- Data was recorded as per Performa. The data analysis was computer based; SPSS-22 was used for analysis. For categorical variables chi-square test was used. For continuous variables independent samples’\(t\)-test was used. \(p\)-value <0.05 was considered as significant.

**Method**

**Pre op evaluation:**

In this study all patients were evaluated Scoring system formulated by the American knee society used to evaluate the patients before and after surgery. Both knee scores and functional scores calculated with each mounting to a total of 100 points. Preoperative full length radiograph from the hip to ankle was taken in all the patients who underwent knee replacement surgery and pre op mechanical axis was drawn and the amount of Varus or valgus deformity was quantified. Radiological grading as advocated by Kellgren and Lawrence was used to evaluate the severity of the arthritis and graded from I to IV.

All the cases were investigated thoroughly and comorbid medical conditions brought under control before surgery. All the cases were done under tourniquet control using pneumatic tourniquet. Anaesthesia by either epidural or spinal as per the anaesthetist discretion. DVT prophylaxis not given to any of our patients

Standard postoperative protocol followed as advised by the American knee society. Patients discharged after suture removal on the 12th to 14th postoperative day.

Regular follow up done at 4 weeks, 12weeks and then every 6 months. Post operatively patients’ functional outcome studied using knee society scores.
Operative Procedures
For the varus knees, the soft tissue releases included superficial medial collateral ligament, portion of pes anserinus, and the direct head of semimembranosus tendon. For the valgus knees, the releases included the conjoined tendon of lateral collateral ligament and popliteus tendon, and the iliotibial band. The magnitude of soft tissue releases was determined according to the severity of the deformity. The bone resections were performed using the standard cutting jigs and guides. The distal femoral cut was made with an intramedullary guide at 5° to 7° valgus. Additional central recess was made with the housing device for CS prosthesis. The proximal tibia cut was made perpendicular to the axis of the tibia using an intramedullary rod or an external cutting guide at the surgeon’s preference. The patellar bone was cut using a cutting jig. The balance of flexion and extension gaps was performed with trial prosthesis.

Postoperatively, all patients received prophylactic antibiotic and anticoagulation. The same protocol for postoperative management was utilized in both groups. This included bedside continuous passive motion machine (CPM) and physical therapy with partial weight bearing, and quadriceps and hamstring strengthening exercises starting on the second postoperative day. Full weight bearing as tolerated was allowed after 1 week.

Follow-up examinations were scheduled at 1, 3, and 6 months after the operations. The evaluations of knee scores and functional scores were based on The Knee Society Clinical Rating System, (16) and The Knee Society Total Knee Arthroplasty Roentgenographic Evaluation and Scoring System was adapted for radiographic examinations.

A grading scale will be used to quantitate the anteroposterior and mediolateral laxities of the knee. For anterior laxity, 10 points will be assigned for knee with 0 to 5 mm, 5 points for 6 to 10 mm, and 0 points for over 10 mm laxity. For mediolateral laxity, 15 points will be assigned for knee with 0 to 5°, 10 points for 6° to 9°, 5 points for 10° to 14° and 0 points for greater than 15° laxity. In addition, functional assessments will be performed using the SF-12 functional survey.

Results

Table 1: Preoperative assessment of patient’s characteristics in CR & CS groups

| Parameters         | CR (N=35)     | CS (N=35)     | ‘p’ value* |
|--------------------|---------------|---------------|------------|
| Degree of deformity| 14.71 ±4.46   | 13.57 ±2.86   | 0.207      |
| Flexion deformity  | 12.29 ±3.01   | 11.43 ±2.59   | 0.204      |
| ROM/Pre op         | 98.43 ±6.27   | 96.71 ±8.31   | 0.332      |
| PAIN/PRE op        | 16.29 ±4.90   | 18.00 ±4.06   | 0.117      |
| KS/Pre op          | 44.77 ±7.24   | 46.51 ±7.37   | 0.323      |
| FS/Pre op          | 40.14 ±10.86  | 44.29 ±8.06   | 0.074      |

Pre op =preoperative, ROM=range of motion, KS=knee score, FS=functional score

Table 2: Comparison of ROM (Range of motion) under same group

| Parameters         | CR (N=35)     | ‘p’ value* | CS (N=35)     | ‘p’ value* |
|--------------------|---------------|------------|---------------|------------|
| ROM/Pre            | 98.43 ±6.27   | --         | 96.71 ±8.31   | --         |
| Pre v/s Post 4     | 100.57 ±6.74  | <0.001     | 105.66 ±8.80  | <0.001     |
| post 4 v/s Post 12 | 111.86 ±7.28  | <0.001     | 114.71 ±4.84  | <0.001     |
| Post 12 v/s Post 6m| 111.14 ±6.87  | 0.134      | 116.29 ±5.47  | 0.009      |

*Paired t-test Pre=preoperative, post 4=postoperative 4 weeks, post 12=postoperative weeks, post 6 m=postoperative 6 months.

Table 3: Comparison of pain score between CR and CS group

| Parameters         | CR (N=35)     | ‘p’ value* | CS (N=35)     | ‘p’ value* |
|--------------------|---------------|------------|---------------|------------|
| PAIN/PRE           | 16.29 ±4.90   | 0.117      | 18.00 ±4.06   | 0.074      |
| PAIN/POST 4        | 36.29 ±4.90   | 0.410      | 37.29 ±5.19   | 0.451      |
| PAIN/POST 12       | 44.71 ±3.42   | 0.828      | 44.14 ±2.84   | 0.074      |
| PAIN/POST 6 m      | 47.57 ±3.81   | 0.451      | 47.43 ±2.54   | 0.074      |

*Unpaired ‘t’ test Pre =preoperative, Post 4=postoperative 4 weeks, post 12=postoperative 12 weeks Post 6 m=postoperative 6 months.
**Pain score:** In our study there was no significant difference in pain score between CR and CS group at 4 weeks, 12 weeks and 6 months follow up. This concluded that both the procedures were equally good in their respective pain scores.

**Table 4: Comparison of knee score between CR and CS group**

| Parameters | CR (N=35) | CS (N=35) | ‘p’ value* |
|------------|-----------|-----------|------------|
| KS/Pre     | Mean ±SD  | Mean ±SD  |            |
|            | 44.77 ±7.24 | 46.51 ±7.37 | 0.323      |
| KS/Post 4  | 81.34 ±4.95 | 82.17 ±5.58 | 0.513      |
| KS/Post 12 | 92.03 ±3.65 | 91.94 ±2.78 | 0.908      |
| KS/Post 6 m| 94.74 ±3.01 | 95.74 ±2.65 | 0.145      |

*Unpaired ‘t’ test  
Ks =knee score, Pre =preoperative, Post 4=postoperative 4 weeks, post 12=postoperative 12 weeks, Post 6 m=postoperative 6 month

**Knee Score:** In this study, there was no significant difference (‘p’ value=0.513, 0.908, 0.145) in knee score between CR and CS groups at 4 weeks, 12 weeks and 6 months follow up. This concluded that both the procedures were equally good in their respective knee scores.

**Table 5: Comparison of functional score between CR and CS group**

| Parameters | CR (N=35) | CS (N=35) | ‘p’ value* |
|------------|-----------|-----------|------------|
| FS/Pre     | Mean ±SD  | Mean ±SD  |            |
|            | 40.14±10.86 | 44.29±8.06 | ---        |
| FS/Post 4 weeks | 41.57±5.04 | 41.71±4.69 | 0.074      |
| FS/Post 12 weeks | 74.14±6.60 | 74.00±6.28 |            |
| FS/Post 6 months | 86.14±7.75 | 84.57±6.57 |            |

*Unpaired ‘t’ test, FS=functional score. Pre =preoperative, post 4=postoperative 4 weeks, post 12=postoperative 12 weeks, Post 6 months=postoperative 6 month

**Functional score:** In this study, there was no significant difference (‘p’ value=0.074) in functional score between CR and CS groups at 4 weeks, 12 weeks and 6 months follow up. This concluded that both the procedures were equally good in their respective functional scores.

![Figure 1: Cruciate Retaining Prosthesis](image1)

![Figure 2: Cruciate Substitution Prosthesis](image2)
Discussion

Total knee Arthroplasty for arthritic patients in whom all the conservative measures are exhausted, is an excellent procedure if proper attention paid to the patient selection. As total knee Arthroplasty is a surface replacement within the existing soft tissue sleeve, it functions within normal anatomic and physiologic boundaries. Impaired functionality after total knee Arthroplasty attributed to sequelae of the arthritic disease, the surgical trauma and the design of the prosthesis. Recent information on the outcome of minimally invasive procedures suggests the reduction of the surgical trauma offers early improvement and faster rehabilitation. This effect levels off after 3 months to a result similar to that in patients who had a standard exposure. This means factors other than the exposure and extensor mechanism violation are involved in the reduced functionality after total knee Arthroplasty. Various factors are associated with the onset and progression of osteoarthritis. These include genetic factors, age, sex, obesity, occupation, abnormal loading of the joint in kneeling, squatting and cross-legged sitting. The mean age of this study that had osteoarthritis is lesser than the data available from the western population. The earlier onset of osteoarthritis in individuals with normal range of body mass index explained by the habit of kneeling, squatting, cross-legged sitting practiced by the population in this part of the world. Various studies have confirmed the abnormal loading of knee joint during heavy physical activity, particularly kneeling, squatting and cross-legged sitting.

It has been theorized that the PCL plays an important role in the femoral roll back mechanism, which is responsible for deep knee flexion. Furthermore, preserving the PCL may improve joint proprioception and thus the clinical outcome. In a study by Condit et al. CR knees were found to be more functional than PS knees in activities of daily living such as squatting, kneeling and gardening. However, in recent prospective studies, a lack of normal femoral roll back was shown in CR knees, no notable difference seen between the CR and PS knees in joint proprioception. Retention of posterior Cruciate ligament in total knee Arthroplasty, advocated as a way to transmit load through the ligament to the tibia, to encourage femoral component rollback to increase flexion, and to assist in maintaining the joint line. Retention of posterior cruciate ligament results in a central contact area of the femur on the tibia that helps to distribute load evenly on the tibial component. In our study flexion and standing view radiographs taken postoperatively for all patients. PCL retained cases exhibits femoral rollback when compared to the PCL sacrificed knees. In 99% of the virgin arthritic knees requiring Arthroplasty including rheumatoid posterior cruciate ligament was found to be intact. The intact PCL may have to sacrificed in rare instances.

In the knee with severe angular deformity requiring an extensive release on the concave side of the deformity, the intact posterior Cruciate ligament can act as a tether and hinder proper balancing of medial and lateral structures. In our experience, this has occurred twice. Each knee has presented with angular deformity of 30 degrees and required extensive medial and lateral release.

We have used the scoring system as advocated by the American knee society. According to this system only three main parameters pain, stability, range of motion judged. Flexion contracture, extension lag and misalignment dealt with as deductions. Thus, 100 points given to knee with no pain, 125 degrees of motion and less than 5mm of anteroposterior and 5 degrees of mediolateral instability. Functional score considers walking distance and stair climbing with deductions for walking aids. The maximum functional score 100 is given to patients who can walk unlimited distance and go up and down stairs normally.

Although some advocate retaining the posterior Cruciate ligament in all patients and others argue for posterior Cruciate ligament sacrifice and substitution in all patients Laksin et al. suggest a more appropriate approach in which implant design selection based on an individual’s pathologic criteria.

In our study, posterior Cruciate ligament sacrifice was done in patients who had severe end stage degenerative arthritis, valgus and Varus deformities of more than 25 degrees, where surgical exposure is challenging and balancing soft tissue is difficult.

All 52 patients evaluated preoperatively and postoperatively using knee society score and functional score. There was Statistically no significant differences in the mean pain score (‘p’value=0.410, 0.451, 0.828), mean knee score (‘p’value=0.513,0.908,0.145) and mean functional score (‘p’ value=0.074) observed 4weeks, 12weeks and 6months follow up between the cruciate retained and substitution group total knee Arthroplasty. In addition to this, there was significant improvement (‘p’value=<0.001) in pain score (16.29 to 47.57), knee score(44.77 to 94.74) and functional score(40.14 to 86.14) between preoperative and postoperatively observe under CR group TKA similarly pain score (18.00 to 47.43), knee score(46.51 to 95.74) and functional score(44.29 to 84.57 ) under CS group TKA at 6 month.

Significantly, greater improvement in range of movement from preoperative to most recent follow-up assessment seen in patients in the posterior cruciate substituting group TKA compared to the retaining group. There was postoperative improvement in the range of motion of CR and CS knee at 4weeks, 12weeks and 6 months.The respective ‘p’ value* were 0.003, 0.058, <0.001. A statistically significant difference (p= <0.001) was observed between mean range of motion of the CR and CS knee at 6 months follow-up. At six months, mean range of motion in CR group was 111.14 and in CS group was 116.29. (Table 2)

Several other studies have directly compared the two prosthetic designs, with mixed results. Maruyama et al.

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did prospective, randomized comparison of posterior cruicate-retaining (PCR) and posterior stabilized (PS) total knee arthroplasties (TKAs) conducted in 20 patients who underwent bilateral TKAs for osteoarthritis (One knee was implanted with a PCR TKA, and a contralateral knee with a PS TKA). Patients had a clinical and radiographic evaluation at a mean of 31.7 months for PCR TKAs and 30.6 months for PS TKAs postoperatively and there were no significant differences between the PCR and PS TKAs in postoperative knee scores. However, postoperative improvement in range of motion was significantly superior in the PS group (131° versus 122°, p<0.05).

Yoshiya et al performed in vivo kinematic analysis of 20 patients who underwent bilateral total knee arthroplasties with a posterior-stabilized implant in one knee and a cruciate-retaining implant in the other. In the PCR TKA, an anterior femoral translation from 30 degrees to 60 degrees of flexion was observed in the weight-bearing condition indicating that the PCL might not be functioning while flexion kinematics for the PS TKA was more stable characterized by the maintenance of a constant contact position under weight bearing conditions and posterior femoral rollback in passive flexion. They also found a greater range of motion of the knees that had posterior-stabilized implants (131°±12° versus 121°±16°).

Bolanos et al examined fourteen patients with a posterior-stabilized prosthesis in one knee and a cruciate-retaining prosthesis in the contralateral knee at mean 98 months follow-up time Hospital for Special Surgery (HSS) knee scale were evaluated by isokinetic muscle testing and comprehensive gait analysis. At mean 98 months time no significant differences were found between the cruciate-retaining and the posterior-stabilized knees with regard to gait parameters, knee range of motion, and electromyographic waveforms during level walking and stair climbing. Both knee prosthesis performed equally well.

Charles Engh has observed that before any technique is to be adopted or recommended there must be a minimum follow up of ten years. Our study is a small series with maximum follow up of only 6 months, we cannot draw any conclusion from our findings.

But the average age of our total knee Arthroplasty patients is less when compared to Western literature; the need of revision will be more. Hence, in posterior cruciate retaining Arthroplasty, less bone cut as compared to Cruciate substituting Arthroplasty and the bone stock was preserved. So that in subsequent Arthroplasty, revision will be easier in Cruciate substitution Arthroplasty.

Conclusion
Both designs give equal and good results. We preferred CR Knees in relatively young patients and patients with smaller knees as its bone conserving implant and CS knees in patients with Inflammatory arthritis, patient with severe Varus or flexion deformity, when tibia cut is more than 10 mm and when intra-operatively findings suggestive of non-functional posterior Cruciate ligament. However, in our short term randomized interventional study Posterior Cruciate substitution Total Knee Arthroplasty had a marginally better outcome than the posterior cruciate retaining in terms of range of motion but it needs a long-term analysis.

References
1. Merrill A, Ritter, Michael Berend, John B, Melding and Brain M. Cortes. Long term follow-up of anatomic graduated components posterior cruciate retaining total knee replacement. Clin Orthop. 2001; 388, pp.51-57
2. Scott RD, Volatile TB. Twelve years’ experience with posterior retaining total knee Arthroplasty. Clin Orthop 1986; 205:100-7.
3. Insall JN. presidential address to the knee society. Choices and compromises in total knee Arthroplasty. Clin Orthop 1998; 226: 43-8.
4. Kleinbert FA, Bryk E, Evangelista J, Scott WN, Vigorita VJ histological comparison of posterior cruciate ligaments from arthritic and age matched knee specimens. J Arthroplasty 1996; 11: 726-31.
5. Freeman MAR, Insall N, Besser W, Walker PS, Hallel T. Excision of the cruciate ligaments in total knee replacement. Clin Orthop 1977; 126:209-12.
6. Matuda S, Whiteside LA, White SE, McCarthy DS. Knee kinematics of posterior cruciate ligament sacrificed total knee Arthroplasty. Clin Orthop 1997; 341: 257-66.
7. Dennis DA, Komisteck RD, Hoff WA, Gabriel SM. In vivo knee kinematics derived using an inverse perspective technique. Clin Orthop 1996; 331: 107-17.
8. Scott RD, Thornhill TS. Posterior cruciate supplementing total knee replacement using conforming inserts and cruciate recession; effect on range of motion and radiolucent lines. Clin Orthop 1994; 309: 146-9
9. R. Straw, S. Kulkarni, S. Attfield, T.J. Wilton posterior cruciate ligament at total knee replacement J Bone Joint Surg 2003; 85-B: 671-4.
10. John N. Insall, Lawrence D. Dorr, Richard D. Scott, and W. Norman Scott: Rationale of the knee society clinical rating system. Clin Orthop1989; (248): 13-14.
11. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthrosis. Ann Rheum Dis 1957; 16: 494-502.
12. Ensen LK, Eenberg W: occupation as a risk factor for knee disorders. Scand J Work Environ Health. 1996 Jun; 22 (3): 165-75.
13. Coggan D, Croft P, Kellingray S, Barrett D, McLaren M, Cooper C: occupational physical activities and osteoarthritis of the knee. Arthritis Rheum. 2000 Jul; 43 (7): 1443-9.
14. Jensen LK. Knee-straining work activities, self-reported knee disorders and radiographically determined knee arthritis. Scand J Work Environ Health. 2005; 31 Suppl 2:68-74.

15. Manninen P, Heliovaara M, Riihimaki H, Suomilainen O. Physical work load and the risk of severe knee osteoarthritis. Scand J Work Environ Health 2002 Feb; 28(1): 25-32.

16. Kuster M, Wood GA, Sakurai S, Blatter G. Stress on the biomechanical femoral patellar joint in downhill walking: a biomechanical study. Z Unfallchir Versicherungsmed. 1993; 86(3): 178-83.

17. Kujala UM, Kettunen J, Paananen H, Aalto T, Battie MC, Impivaara O, Videman T, Sarna S. Knee osteoarthritis in former runners, soccer players, weight lifters, and shooters. Arthritis Rheum. 1995 Apr; 38 (4): 539-46.

18. Ritter MA, Faris PM, Keating EM. Posterior cruciate ligament balancing during total knee arthroplasty. J Arthroplasty. 1988; 3: 323-326.

19. Conditt MA, Noble PC, Bertolusso R, Woody J, Parsley BS. The PCL significantly affects the functional outcome of total knee arthroplasty. J Arthroplasty 2004; 19(7 suppl 2):107–12.

20. McMillan G, Nicholas L, osteoarthritis and meniscus disorders of the knee as occupational disease of Miners Occup. Environ. Med. 2005 Aug; 62 (8): 567-75.

21. Yoshiya S, Matsui N, Komistek RD, Dennis DA, Mahfouz M, Kurosaka M. In vivo kinematic comparison of posterior cruciate-retaining and posterior stabilized total knee arthroplasties under passive and weight-bearing conditions. J Arthroplasty. 2005; 20:777-83.

22. Frank R. Kolisek, and C. Lowry Barnes, Scorpio Posterior-Stabilized Knee System: 5-Year Clinical and Functional Results The Journal of Arthroplasty Vol. 21 No. 8 2006.

23. Laskin RS, O’Flynn HM. Total knee replacement with posterior cruciate ligament retention in rheumatoid arthritis. Problems and complications. Clin Orthop 1997;345: 24-8.

24. Maruyama S, Yoshiya S, Matsui N, Kuroda R, Kurosaka M. Functional comparison of posterior cruciate-retaining versus posterior stabilized total knee arthroplasty. J Arthroplasty. 2004;19:349-53.

25. Bolanos AA, Colizza WA, McCann PD, Gotlin RS, Wootten ME, Kahn BA, Insall JN. A comparison of isokinetic strength testing and gait analysis in patients with posterior cruciate-retaining and substituting knee arthroplasties. J Arthroplasty. 1998; 13:906–15.

26. Sofka CM, Potter HG, Adler RS, Pavlov H. Musculoskeletal imaging update: current applications of advanced imaging techniques to evaluate the early and long-term complications of patients with orthopedic implants. HSS J 2006;