Characterization of a Consistent Radiographic Finding in Chronic Anterior Cruciate Ligament Deficiency: The Posteromedial Osteophyte

Brian H. Mullis, MD, Spero G. Karas, MD, and Scott S. Kelley, MD

Abstract

Often found in patients undergoing total knee arthroplasty (TKA) is an osteophyte, at the posterior lateral corner of the medial tibial plateau, that prevents anterior translation. This osteophyte does not occur in the presence of an entirely normal anterior cruciate ligament (ACL) with normal vascularity. Although similar findings have been reported in animal studies, to our knowledge this has never been documented in humans. To determine the incidence of this finding in our patient population, anteroposterior and lateral x-rays of the affected knee of 90 patients undergoing TKA were reviewed. Forty-two percent (43/102 knees) had radiographic signs of this stabilizing osteophyte. This finding confirms previous animal research and may lead to a better understanding of how the knee adapts to improve stability in a chronic ACL-deficient state.

Dr. Mullis is Chief of Orthopaedic Trauma, Indiana University School of Medicine, Indianapolis, Indiana.
Dr. Karas is Assistant Professor of Orthopaedic Surgery, Emory University, Atlanta, Georgia.
Dr. Kelley is Clinical Professor of Orthopaedic Surgery, Duke University, Durham, North Carolina.

Requests for reprints: Scott S. Kelley, MD, North Carolina Orthopaedic Clinic, Duke University Medical Center, 4309 Medical Park Dr, Suite 100B, Durham, NC 27704 (tel, 919-471-9622; fax, 919-471-1929; e-mail, sk@ncorthoclinic.com).

Am J Orthop. 2007;36(9):494-497.

Studies have shown that the posterior horn of the medial meniscus resists anterior translation of the tibia after anterior cruciate ligament (ACL) transection.[1-3] This block to anterior tibial translation is lost when the medial meniscus is removed.

Animal studies have demonstrated adaptive responses to improve stability after ACL transection.[4-7] The medial meniscus, especially the posterior horn, thickens several months after the ACL is surgically transected. Others studies have shown radiographic evidence of osteophyte formation in this area several months after the ACL is sacrificed or ruptured.[4-6,8-10]

After the ACL is débrided during total knee arthroplasty (TKA) for osteoarthritis, there is often a block to anterior tibial translation. When this block is present, there is consistently a stabilizing osteophyte at the posterior lateral corner of the medial tibia plateau (Figure 1). After this osteophyte is removed, the tibia easily translates anteriorly. This osteophyte can also be seen on standard preoperative x-rays (Figures 2A, 2B). It is best viewed on the lateral x-ray as an extension off the posterior medial tibial plateau extending posteriorly and superiorly (Figure 2B). Intraoperatively, the ACL is often present, but it is consistently lax and has fibrosis and poor vascular markings.

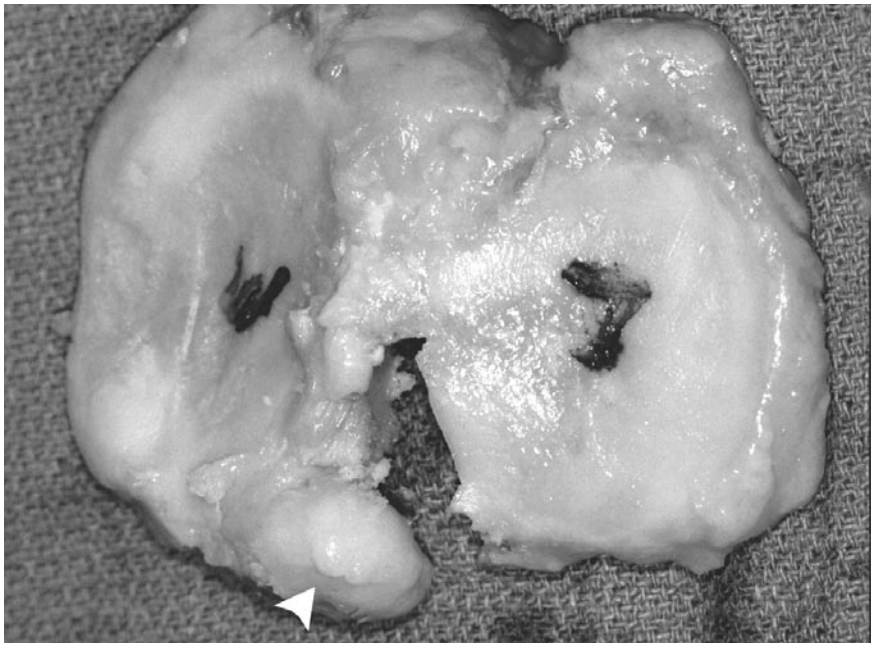

Figure 1. A typical osteophyte at the posterior lateral border of the medial tibial plateau.

Figure 2. Anteroposterior (A) and lateral (B) x-rays show a typical osteophyte at the posterior lateral border of the medial tibial plateau.

Biomechanical studies of human knees have shown very little AP motion in the medial compartment relative to the lateral compartment (Figure 3).[11-14] This suggests there may be a mechanical advantage to a stable medial compartment, which may explain why animals have developed a means to adapt to an unstable medial compartment after injury. In a comparison of Figures 1 and 3, the location of this osteophyte is well positioned to impede anterior translation without compromising rotation. The consistent location of this osteophyte is shown in Figure 3.

Materials and Methods

The study was performed at the University of North Carolina-Chapel Hill, where a database was kept of all patients undergoing TKA. From this database, we selected the last 132 patients who underwent primary TKA for osteoarthritis. Lateral x-rays for 40 patients were inadequate. Twelve of the remaining patients had bilateral TKA, so we had adequate x-rays for 102 knees (57 left, 45 right) in 90 patients (37 men, 53 women). These knees were the basis of our review. Mean age was 66 years at time of surgery.

Drs. Mullis and Kelley reviewed knee x-rays and at that time designated them either positive or negative based on presence of a typical osteophyte extending off the posterior lateral corner of the medial tibial plateau (Figure 2B). The osteophyte was considered a typical lesion when it was at least 5 mm in diameter and extended posteriorly and superiorly directly off the lateral edge of the medial plateau.

Dr. Kelley performed all the surgeries, and all operative notes were available for review. All patients were asked to complete a questionnaire regarding previous injury to the knee, with a separate form for each knee when both knees were operated on. These forms were mailed to patients, and a phone call was made within 1 week to answer questions regarding the form. The χ^2 test was used for statistical analysis. The study was approved by the Committee on the Protection of the Rights of Human Subjects, and all patients were informed and agreed to participate.

Results

Of 102 knees (90 patients), 43 (42%) were positive for the stabilizing osteophyte. In patients with this osteophyte, ACL status was assessed at time of surgery, and in all cases the ACL either was completely absent or showed evidence of attenuation, scarring, or decreased vascularity. Of these 43 knees, 22 (51%) were positive on the left, and 21 (49%) were positive on the right. There was

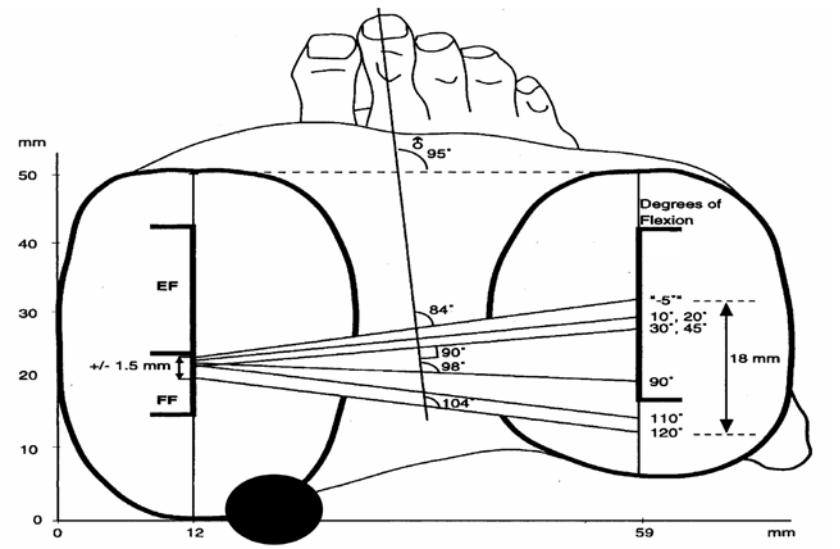

Figure 3. Lines have been drawn connecting the flexion facet (FF) centers of the medial and lateral femoral condyles as the knee is taken through –5° to 120° of flexion. Movement in the anteroposterior (AP) plane on the medial side is within the observer error (±1.5 mm); however, AP translation on the lateral side is 18 mm. Typical osteophyte location is represented by filled circle. EF represents extension facet. Reprinted and modified from Insall JN, Scott WN, eds., *Surgery of the Knee*, 3rd ed., Pinskerova V, Iwaki H, Freeman MA. The shapes and relative movements of the femur and tibia in the unloaded cadaveric knee: a study using MRI as an anatomic tool, page 275, copyright 2001, with permission from Elsevier.[26]

no statistically significant difference between the 2 sides. Questionnaires were received from 58 (64%) of the 90 patients for 67 (66%) of the 102 knees. There was no difference between the presence or absence of the stabilizing osteophyte with respect to recall of prior injury, prior medical treatment for the injury, or prior surgery for the injury (Table).

Table. History of Knee Injury Compared With Radiographic Presence of a Stabilizing Osteophyte

Osteophyte Present?	Yes	No
Questionnaire returned	29	38
Prior injury	13 (45%)	14 (37%)
Prior treatment for injury	12 (41%)	10 (26%)
Prior surgery for injury	8 (28%)	8 (21%)

Discussion

Traditionally, the femur has been thought to "roll back" on the tibia during flexion. Recent findings demonstrate almost 2 cm of AP translation in the lateral compartment of the knee but relatively little movement (≤2 mm) on the medial side.[11-14] This suggests there might be a mechanical advantage to translational stability of the medial compartment.

As many knees are found to be ACL-deficient at the time of TKA,[11] we suggest some stability might be gained by an osteophyte consistently found on the posterior lateral border of the medial tibial plateau.

Osteophytes are considered a "classic" finding in osteoarthritic knees.[15] It is still unclear why osteophytes form. Some authors have suggested that they arise in response to joint instability and help alleviate pain.[16] Pottenger and colleagues[17] reported finding, in osteoarthritic human knees, marginal osteophytes that provided varus and valgus stability. When osteophytes were removed, knees became unstable. The authors noted that femoral osteophytes could be distinguished from the femur, but tibial osteophytes blended with normal bone. Our radiographic finding of the posterior osteophyte extending off the medial tibial plateau is consistent with their findings.

Animal studies of ACL deficiency have consistently identified the formation of osteophytes similar to the posterior osteophyte described in this report. Studies of dogs, cats, and goats have shown that the knee gains stability as this osteophyte matures.[4-7] As early as 1971, Marshall and Olsson[6] demonstrated osteophyte formation as a response to ACL deficiency in a dog model: "Large osteophytes were found on the posterior aspect of the medial tibial condyle." Mechanical testing of the knees of the animals showed that they became stabler with time. Pournaras and colleagues[4] described osteophyte formation at the posterior edge of the medial tibial plateau in an ACL-deficient dog model. Suter and colleagues[5] sacrificed the ACL of cats in a study similar to that conducted by Marshall and Olsson.[6] Suter and colleagues noted, "Over time, osteophytes appeared on … the medio-dorsal border of the tibia." They found that, "16 weeks [after ACL transection], anterior tibial translation relative to the femur is reduced by about 50%." Jackson and colleagues[7] found that knee stability slowly improved after ACL transection in a goat model: "The meniscus developed a thickened attachment to the underlying posterior tibial plateau, with a suggestion of early osteophyte formation in that area."

The medial meniscus has been shown to play an important role in stability in human cadaver models. Multiple studies have shown that the medial meniscus reduces anterior translation of the tibia after the ACL is sacrificed.[1-3] Shoemaker and Markolf[3] found that the most important part of the medial meniscus was the posterior horn. Allen and colleagues[1] confirmed these results and showed that the lateral meniscus played no role in AP stability after ACL transection.

The only previously identified pattern unique to ACL deficiency is osteophyte formation in the femoral notch and tibial spine.[18] In retrospective clinical studies, osteophyte formation associated with early degenerative changes have been reported in ACL-deficient knees. Feagin and colleagues[10] noted "buttressing osteophytosis." Fetto and Marshall[9] likewise noted osteophyte formation "at the intercondylar and peripheral joint margins." Jacobsen[8] focused on the timing of osteophyte appearance, noting formation within 2 years of ACL rupture, followed years later by osteoarthrosis. Good and colleagues[18] measured osteophyte formation in the femoral notch and concluded that it was more likely to occur as a result of instability rather than lack of ACL substance.

Daniel and colleagues[19] conducted a prospective study of ACL-deficient knees. Consistently, osteophyte formation in the femoral notch and tibial spine was found, especially in ACL-reconstructed knees. The authors

"…we suggest some stability might be gained by an osteophyte consistently found on the posterior lateral border of the medial tibial plateau."

also found increased osteoarthrosis in patients with ACL injuries and even higher rates of osteoarthrosis in patients with ACL reconstruction.

Although the progression to end-stage osteoarthrosis caused by ACL deficiency has been well documented in animal studies, a significant association has not been shown in humans.[20] Loss of medial compartment stabilization may lead to increased rates of osteoarthritis. The evidence is clear that meniscal tear is associated with ACL injury when the ACL is not reconstructed.[1,19,21,22] There is also a good deal of literature to support the finding that loss of the medial meniscus leads to osteoarthrosis of the knee.[21,23]

This study is the first to characterize in humans the presence of a stabilizing osteophyte at the posterior lateral border of the medial tibial plateau. Approximately 43% of our patients having TKA for osteoarthritis had this radiographic finding. In all cases, this osteophyte was associated with anatomical evidence of ACL compromise. Unfortunately, there was no association of patient recall of injury, treatment history, and surgery with respect to developing the osteophyte (Table). A prospective cohort looking for the development of this particular osteophyte could give more data, as recall bias may be present in our retrospective review.

Further studies are needed to explore the presence and reproducibility of this finding in the general orthopedic population.

The incidence of this radiographic finding is not surprising, as ACL abnormalities are a common finding during TKA.[11,24,25] Cloutier and colleagues[24] reported abnormalities of the ACL in 41% of knees undergoing TKA. This finding is similar to ours with respect to incidence and description of ACL changes. As positive Lachman or anterior drawer tests are uncommon in these patients, the occurrence of this osteophyte provides insight into possible stabilizing adaptive changes. Recognition of this finding on x-rays may aid surgical exposure during TKA and shed light on the natural history of chronic ACL insufficiency in humans.

Authors' Disclosure Statement and Acknowledgments

The authors report no actual or potential conflict of interest in relation to this article.

"Approximately 43% of our patients having TKA for osteoarthritis had this radiographic finding [a posteromedial osteophyte]."

This investigation was conducted in the Department of Orthopaedics, University of North Carolina, Chapel Hill, North Carolina.

We thank Don Kirkendall, PhD, for his help with manuscript preparation.

References

1. Allen CR, Wong EK, Livesay GA, Sakane M, Fu FH, Woo SL-Y. Importance of the medial meniscus in the anterior cruciate ligament–deficient knee. *J Orthop Res*. 2000;18:109-115.
2. Levy IM, Torzilli PA, Warren RF. The effect of medial meniscectomy on anterior–posterior motion of the knee. *J Bone Joint Surg Am*. 1982;64:883-888.
3. Shoemaker SC, Markolf KL. The role of the meniscus in the anterior–posterior stability of the loaded anterior cruciate–deficient knee. Effects of partial versus total excision. *J Bone Joint Surg Am*. 1986;68:71-79.
4. Pournaras J, Symeonides PP, Karkavelas G. The significance of the posterior cruciate ligament in the stability of the knee. An experimental study in dogs. *J Bone Joint Surg Br*. 1983;65:204-209.
5. Suter E, Herzog W, Leonard TR, Nguyen H. One-year changes in hind limb kinematics, ground reaction forces and knee stability in an experimental model of osteoarthritis. *J Biomech*. 1998;31:511-517.
6. Marshall JL, Olsson SE. Instability of the knee. A long-term experimental study in dogs. *J Bone Joint Surg Am*. 1971;53:1561-1570.
7. Jackson DW, Schreck P, Jacobson S, Simon TM. Reduced anterior tibial translation associated with adaptive changes in the anterior cruciate ligament–deficient joint: goat model. *J Orthop Res*. 1999;17:810-816.
8. Jacobsen K. Osteoarthrosis following insufficiency of the cruciate ligaments in man. A clinical study. *Acta Orthop Scand*. 1977;48:520-526.
9. Fetto JF, Marshall JL. The natural history and diagnosis of anterior cruciate ligament insufficiency. *Clin Orthop*. 1980;147:29-38.
10. Feagin JA Jr, Cabaud HE, Curl WW. The anterior cruciate ligament: radiographic and clinical signs of successful and unsuccessful repairs. *Clin Orthop*. 1982;164:54-58.
11. Freeman MAR. Knee flexion: the cruciate ligaments and the posterior stability in the flexed knee. In: Rand JA, Dorr LD, eds. *Total Arthroplasty of the Knee: Proceedings of the Knee Society 1985–1986*. Rockville, Md: Aspen; 1987:3-22.
12. Hill PF, Vedi V, Williams A, Iwaki H, Pinskerova V, Freeman MA. Tibiofemoral movement 2: the loaded and unloaded living knee studied by MRI. *J Bone Joint Surg Br*. 2000;82:1196-1198.
13. Iwaki H, Pinskerova V, Freeman MA. Tibiofemoral movement 1: the shapes and relative movements of the femur and tibia in the unloaded cadaver knee. *J Bone Joint Surg Br*. 2000;82:1189-1195.
14. Pinskerova V, Maquet P, Freeman MA. Writings on the knee between 1836 and 1917. *J Bone Joint Surg Br*. 2000;82:1100-1102.
15. Pavlov H. Radiographic examination. In: Insall JN, Scott WN, eds. *Surgery of the Knee*. 3rd ed. New York, NY: Churchill Livingstone; 2001:83-110.
16. Mankin HJ, Brandt KD. Pathogenesis of osteoarthritis. In: Ruddy S, Harris ED Jr, Sledge CB, eds. *Kelley's Textbook of Rheumatology*. 6th ed. Philadelphia, Pa: Saunders; 2001:1398-1399.
17. Pottenger LA, Phillips FM, Draganich LF. The effect of marginal osteophytes on reduction of varus–valgus instability in osteoarthritic knees. *Arthritis Rheum*. 1990;33:853-858.
18. Good L, Odensten M, Gillquist J. Intercondylar notch measurements with special reference to anterior cruciate ligament surgery. *Clin Orthop*. 1991;263:185-189.
19. Daniel DM, Stone ML, Dobson BE, Fithian DC, Rossman DJ, Kaufman KR. Fate of the ACL-injured patient. *Am J Sports Med*. 1994;22:632-644.
20. Sherman MF, Warren RF, Marshall JL, Savatsky GJ. A clinical and radiographical analysis of 127 anterior cruciate insufficient knees. *Clin Orthop*. 1988;227:229-237.
21. McDaniel WJ Jr, Dameron TB Jr. Untreated ruptures of the anterior cruciate ligament. *J Bone Joint Surg Am*. 1980;62:696-705.
22. Oates KM, Van Eenenaam DP, Briggs K, Homa K, Sterett WI. Comparative injury rates of uninjured, anterior cruciate ligament–deficient, and reconstructed knees in a skiing population. *Am J Sports Med*. 1999;27:606-610.
23. Cox JS, Nye CE, Schaefer WW, Woodstein IJ. The degenerative effects of partial and total resection of the medial meniscus in dogs' knees. *Clin Orthop*. 1975;109:178-183.
24. Cloutier JM, Sabouret P, Deghrar A. Total knee arthroplasty with retention of both cruciate ligaments. A nine to eleven-year follow-up study. *J Bone Joint Surg Am*. 1999;81:697-702.
25. Harman MK, Markovich GD, Banks SA, Hodge WA. Wear patterns on tibial plateaus from varus and valgus osteoarthritic knees. *Clin Orthop*. 1998;352:149-158.
26. Pinskerova V, Iwaki H, Freeman MA. The shapes and relative movements of the femur and tibia in the unloaded cadaveric knee: a study using MRI as an anatomic tool. In: Insall JN, Scott WN, eds. *Surgery of the Knee*. 3rd ed. New York, NY: Churchill Livingstone; 2001:255-283.