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Correspondence should be sent to Warran Wignadasan warran.wignadasan@gmail.com

W. Wignadasan,[1] A. Fontalis,[1,2] M. Shaeir,[1,2] F. S. Haddad[1,2,3]

[1]Department of Trauma and Orthopaedic Surgery, University College Hospital, London, UK
[2]Department of Orthopaedic Surgery, The Princess Grace Hospital, London, UK
[3]*The Bone & Joint Journal*, London, UK

Knee osteoarthritis (OA) is a debilitating condition characterized by joint degeneration, resulting in pain, stiffness, and reduced function. It is the fastest-growing cause of physical disability globally, with the lifetime risk of developing symptomatic knee OA estimated at 50%.[1] When non-surgical and regenerative management options in knee OA have been exhausted, our offering has evolved to modern total knee arthroplasty (TKA) for the pain relief and durability that it affords our patients.[2]

There are nevertheless difficulties in achieving the kinematics and function of the native knee, regardless of the type of knee arthroplasty that is performed, or the technique used.[3,4] There has therefore been a renewed focus on anterior cruciate ligament (ACL)-preserving knee surgery, including partial arthroplasty, in order to retain sagittal and rotational stability for patients who are still very active.

As we increasingly use enhanced technologies, with 3D planning and computer- and robotic-assisted surgery, it is likely that we will be able to undertake more personalized knee arthroplasty surgery and more ACL-preserving implant surgery.[5,6] At present, the introduction of robotics has led to incremental improvements, with better planning and more accurate and precise execution of surgery.[7] It holds promise to potentially deliver much more personalized resurfacing type solutions in the future that can restore knee kinematics and preserve cruciate function. To that end, the evaluation of both anterior cruciate structure and function will be key.

ACL-preserving surgical techniques include unicompartmental knee arthroplasty (UKA), bi-unicondylar arthroplasty (BKA), and tricompartmental arthroplasty (TCA). Their cruciate-retaining characteristics conceptually facilitate the replication of native knee kinematics.[8] UKA is an effective treatment strategy for patients with OA confined to a single compartment, assuming that there is no substantial deformity or ligamentous instability. UKA has been reported as a more cost-effective option, associated with better functional outcomes, faster rehabilitation, superior restoration of natural knee function, and fewer complications compared to TKA in patients with single-compartment OA.[9] Similarly, BKA has been associated with reduced morbidity, blood loss, stability, and better functional results when compared to TKA.[10] Bicruciate-retaining TKA aims to preserve both the anterior and posterior cruciate ligaments, closely mimicking natural knee kinematics.[11] Although the first generation of these implants did not gain widespread popularity due to their challenging technique and poor survival,[12] the second-generation prostheses have seen renewed interest. Recent advances in implant design and surgeon-friendly instrumentation have improved outcomes,[13] potentially making cruciate-retaining arthroplasty an appealing option for younger, more active patients who may benefit from retaining the ACL. Different implant designs, such as mobile-bearing UKA, fixed-bearing UKA, BKA, and TCA, place varying stresses on the ACL.[14] Mobile bearings need stronger ACL function for stability, while fixed bearings rely less on ACL integrity. Understanding these biomechanical differences is key to tailoring surgical approaches and preserving the ligament effectively.

The future of knee arthroplasty may involve a more tailored approach, replacing less of the knee. This raises several important questions: is it better to preserve the ACL? If so, how can we reliably determine if the ACL is intact and functional? Addressing these questions is essential for guiding treatment strategies and improving outcomes for patients undergoing knee arthroplasty procedures. The integrity of the ACL can be compromised in the context of knee OA.[15] Evaluating its condition and function is crucial for selecting the most suitable type of knee arthroplasty.

A thorough clinical evaluation forms the foundation of ACL assessment, encompassing a detailed patient history that highlights previous knee injuries and surgical interventions, as these factors can accelerate the onset of osteoarthritic changes.[16] In the context of ACL assessment, it is also key to consider the type of OA, as different OA patterns may have different implications for ACL integrity and function. A patient with an intact ACL and anteromedial OA may benefit more from ACL-preserving techniques like UKA, while other phenotypes with greater ligamentous degeneration may not. Anteromedial OA is characterized by cartilage and bone erosion centred anteriorly on the medial tibial plateau, with the posterior cartilage remaining intact. If the varus deformity of the knee corrects upon flexion, it indicates an intact ACL and a medial collateral ligament that is not contracted. This correctable deformity suggests that in the presence of an intact cruciate mechanism, the medial femoral condyle rolls back onto the intact posterior cartilage, highlighting the functional status of the ACL. Thus, during clinical assessment, if a patient's varus deformity diminishes in knee flexion, it implies ACL competency.[17] However, this potentially diminutive coronal correction can be difficult to appreciate in the clinical setting. Furthermore, patients with knee OA often experience pain and restricted range of motion, which can make it challenging to clinically assess the ACL. Special tests such as the Lachman and the pivot shift tests have historically been regarded as the most sensitive and specific tests for detecting ACL insufficiency.[18,19] While these clinical tests are useful, their sensitivity and specificity can be reduced in the setting of OA due to pain, swelling, and limited range of motion.[20] Therefore, complementing clinical examination with imaging is essential for a comprehensive assessment.

Imaging plays a key role in the assessment of the ACL in knee OA. The pattern of initial anteromedial OA which progresses posteriorly has been well described in the context of an ACL-deficient knee.[17] Scott et al[1] reported in their study of 300 consecutive TKA patients that ACL status could be predicted by the point of maximal tibial bone loss on true lateral radiographs. The maximal point of tibial bone loss at > 55% of the anterior to posterior distance predicted ACL redundancy with 93% sensitivity and 91% specificity. Likewise, if posterior tibial erosion is not visualized on true lateral radiographs, there is a 95% chance that the ACL is functionally satisfactory.[21] In addition, MRI has long been the imaging modality of choice for soft-tissue assessment, including the cruciate ligaments.[22] Kim et al[23] recently described the correlation between mucoid degeneration of the ACL (MD-ACL) and a lower intercondylar notch width index (NWI) on coronal MRI slices, along with a larger posterior tibial slope (PTS) compared to patients with normal ACLs. Additionally, contrast-enhanced MRI can more accurately assess the vascular supply within the synovial membrane, which has been shown to correlate with ACL degeneration.[24,25]

Arthroscopic visualization is also useful for evaluating the integrity of the ACL. The Oxford ACL grading system, based on macroscopic findings,[26] ranges from Grade 1 (intact ACL) to Grade 5 (complete absence of the ACL). Intermediate grades reflect varying levels of damage, with Grade 2 showing exposed ACL due to synovial damage, Grade 3 featuring longitudinal fibre tears, and Grade 4 indicating a fragile structure with some remaining fibres.[26] Hiranaka et al[27] established a correlation between this grading system and OA changes in the tibial plateau, showing that higher ACL grades were associated with increasing posterior cartilage damage, increased defect length, and a more posteriorly located defect centre. Lee et al[28] also graded ACL status during TKA in their study of 107 patients, and found a positive correlation between ACL deficiency and arthritic changes as measured by the Outerbridge grading system. Moreover, Nakamura et al[29] found that the MRI signal ratio between the ACL and the gastrocnemius muscle correlated with histological findings of ACL collagen degeneration, demonstrating that the ACL/muscle signal intensity ratio on MRI positively correlated with the extent of MD-ACL. Similarly, Toyono et al[30] illustrated the positive correlation between MRI signal intensity of the ACL and histologically affirmed mucoid degeneration in arthritic knees. Degenerative changes of the ACL are not often appreciated macroscopically, and this has become evident at a histopathological level, which is considered to be the most reliable method for evaluating ACL degeneration.[31]

The ACL in the arthritic knee can also be evaluated through functional analysis. Ogawa et al[24] demonstrated that ACL function in individuals with OA, measured as the degree of anterior knee joint laxity, was significantly correlated with Kellgren-Lawrence grade[30] and osteophyte score.[24] This study found that ACL function did not correlate with MRI and arthroscopic ACL grades. Although gait analysis has been a useful tool in evaluating patients following ACL repair and reconstruction,[32] there is a gap in the literature on accessing ACL function in the arthritic knee using gait analysis. While patient-reported outcome measures offer valuable insights into patient satisfaction and functional status, their utility in isolating the functional role of the ACL within an arthritic knee is limited. This is largely attributable to the concurrent presence of other pathological changes associated with OA, which can confound the assessment of ACL-specific functionality.[33]

The use of artificial intelligence (AI) and machine learning (ML) is rapidly growing in orthopaedic surgery.[34] Kunze et al[35] published a systematic review of 11 studies, investigating the ability of AI to identify ACL tears and meniscal injuries on MRI. Authors reported a detection accuracy between 90% and 98% for ACL tears and 85% to 91% for meniscal tears. Liu et al[36] reported no significant difference between the diagnostic performance of a deep learning-based system and clinical radiologists for identifying ACL ruptures on MRI scans in a study of 350 subjects. While AI has shown comparable accuracy to clinical radiologists in diagnosing ACL tears, there is a paucity in the literature reporting on its effectiveness in identifying degenerative ACLs. However, the optimistic growth and evolution of AI holds promise for advancing the evaluation of the ACL in the arthritic knee, paving the way for improved diagnostic capabilities and patient outcomes.

ACL evaluation in the arthritic knee presents a relatedly unsolved challenge, as various investigative methods each reveal distinct aspects of ligament integrity. Given the increasing interest in ACL-preserving surgical techniques, a thorough evaluation of the ACL is crucial for optimizing treatment strategies. More work is needed to evaluate whether a degenerate ACL can still provide functionality, and if so, whether ACL-preserving techniques should be considered in such patients. Future research should focus on further elucidating the relationship between ACL integrity and knee function in OA, exploring advanced imaging techniques, and leveraging AI to enhance diagnostic accuracy and management approaches. By doing so, we can tailor interventions in the hope of improving patient outcomes.

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Author information

W. Wignadasan, MBBS, BSc (Hons), MRCS, Trauma and Orthopaedic Registrar,
Department of Trauma and Orthopaedic Surgery, University College Hospital, London, UK.

A. Fontalis, MD, MRCS, MSc(Dist), Trauma and Orthopaedic Registrar
M. Shaeir, MB ChB, MRCS, MSc, FRCS (Orth), Senior Clinical Fellow
Department of Trauma and Orthopaedic Surgery, University College Hospital, London, UK; Department of Orthopaedic Surgery, The Princess Grace Hospital, London, UK.

F. S. Haddad, BSc, MD (Res), MCh (Orth), FRCS (Orth), FFSEM, Editor-in-Chief, Professor of Orthopaedic and Sports Surgery, Department of Trauma and Orthopaedic Surgery, University College Hospital, London, UK; Department of Orthopaedic Surgery, The Princess Grace Hospital, London, UK; *The Bone & Joint Journal*, London, UK.

Author contributions

W. Wignadasan: Writing – original draft, Writing – review & editing.
A. Fontalis: Writing – original draft, Writing – review & editing.
M. Shaeir: Writing – review & editing.
F. S. Haddad: Conceptualization, Supervision, Writing – review & editing.

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