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Review Article

Constraints in total knee arthroplasty: current status and review of literature

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ABSTRACT

Appropriate selection of prosthesis is critical for success of total knee arthroplasty. It is a daunting task of arthroplasty surgeon to choose from a wide array of implant design for a given situation to confer optimal stability, which translates into satisfactory outcome. Contemporary evolution of prosthetic design with various levels of constraints has revolutionized the approach to total knee arthroplasty. This paper deals with the succinct review of the level of constrained prosthesis available for knee arthroplasty.

Keywords: Constraint, Constrained condylar knee, Cruciate retaining, Posterior stabilized, Rotating hinge knee, Total knee arthroplasty

INTRODUCTION

Primary total knee arthroplasty (TKA) has come a long way and proved to be a highly successful procedure achieving survivorship approaching 95% at 15 years.[1] This invariably has led to concomitant increase in revision procedures. TKA performed in young and active individuals also purported to increase the burden of revision arthroplasty further. Tibio-femoral stability is the fundamental factor governing long-term success of this procedure. However, bone loss, ligament instability, and poor soft tissue coverage pose a challenging situation for surgeons in revision as well as in difficult primary arthroplasty procedures. Instability following TKA can lead to catastrophic failure, and poor patient satisfaction. Correct degree of constraint selection is therefore is of paramount importance in this context. Surgeons confront a difficult situation during selection of proper constraint to provide adequate stability, thus ensuring longevity of construct and satisfactory clinical outcome.

The purpose of this paper is to review the current status of constraint in TKA to provide surgeons a guide for appropriate selection of implant for a given situation.

LEVEL OF CONSTRAINTS AND INDICATIONS

Constraint is the limitation of motion between two bodies linked by a joint. In TKA this constraint may be extrinsic to the implant - provided by soft tissues such as the capsule, ligaments and muscle pull, or intrinsic to the implant affected by factors such as conformity of articular surfaces and linkage between the components.[2] Constraint within an implant implies a restriction of rotational movement in the axial and coronal planes, which can be achieved with a linked or non-linked implant design.[3]

There is a spectrum of constraint options available during TKA. Evolution of contemporary implant design and instrumentation provides surgeons with ample choice for implant selection, which translate into better patient satisfaction. Cruciate retaining (CR) prosthesis provides the least amount of constraint. By retaining posterior cruciate ligament (PCL), it theoretically restore the near normal knee kinematics. Presence of PCL, most importantly functioning PCL is prerequisite for use of this kind of prosthesis. Meticulous surgical technique, proper soft tissue balancing is of paramount importance to create a stable and durable joint. Equally important is presence of intact collaterals, and other peripheral knee stabilizers, and good bone quality. Therefore, their use is limited, and therefore, prone to fail in complex primary and revision TKA where surgeons faces complex situation of bone loss, ligaments insufficiencies, and severe deformities.[4,5]

Posterior stabilized (PS) knee prosthesis comes at the next level of constraint. It sacrifices the PCL and provides posterior stability by virtue of a tibial polyethylene post which engages in the intercondylar cam of femoral component. However, it provides little varus-valgus and rotational stability. Therefore, good soft tissue envelope and well-functioning collaterals, and well balanced knee are important for optimal stability. Because, all the technical difficulties encountered during PCL balancing are eliminated, many surgeons consider PS prosthesis technically facile. One important consideration in this kind of prosthesis is that, in presence of flexion laxity it might lead to cam dissociation and posterior subluxation.[6] Therefore, PS implants can only be considered in presence of intact functioning ligaments and good quality bone.[7] They have been used successfully in case of conversion of unicompartmental knee arthroplasty (UKA) to TKA.[8]

Another development in case of absent or nonfunctioning PCL is ultracongruent (UC) insert. It has proved to be useful in both primary and revision situation.[9] UC insert can substitute for PS prosthesis and, thus eliminate all potential complication of post and cam mechanism. It provides posterior stability by virtue of highly conforming articular insert which increases surface contact area to femoral component, and anterior build-up of polyethylene of 12.5 mm. However, all technical consideration of good soft tissue balancing, adequate ligament stability also applies for UC insert.

Condylar constrained knee (CCK) is at the next level of constrained prostheses. It is a semiconstrained, non-linked implant which confers varus-valgus as well as some rotational stability. It incorporates a long and large tibial post which engages in large intercondylar cam of femoral component. CCK can be considered in presence of medial and/or lateral collateral ligament insufficiency, and bone loss.[10-12] However, in presence of severe flexion instability, it too has the potential for post-cam dissociation like PS implant.[13]

Hinge knee prosthesis is a linked constrained device which provides the highest level of component to component constraint, and therefore, confers coronal plane, sagittal plane, as well as rotational stability. High failure rate of first generation hinge knee implants and better understanding of bio-mechanics has prompted evolution of these implants, and introduction of rotating hinge knee (RHK). RHK is considered for grossly unstable knee due to complete absence of medial and lateral collateral ligaments, poor soft tissue envelope, severe bone loss, and severe varus-valgus and flexion contracture.[13-16] It is also considered utilitarian for extensor mechanism incompetency, distal femoral or proximal tibial defect resulting from a tumour lesion or mechanical problem, or a comminuted fracture or malunion of the distal femur in the elderly subjects.[17,18] Neuropathic joints, elderly people with poor soft tissue envelope are relative indications for their use. There is no denying the fact that RHK prosthesis provides the surgeon an indispensable tool for salvage of revision TKA.

DISCUSSION

The primary goal of total knee arthroplasty is to provide a pain free stable joint, to restore knee kinematics, and alignment with good component fixation, which translate into successful functional and clinical outcome. Instability is an important cause of failure following TKA. Most primary TKA with mild to moderate deformities can be addressed by CR or PS prostheses. Well balanced ligaments and inherently stable joint are the prerequisite for these prostheses, as they do not provide any varus-valgus stability. Revision TKA is a more complex procedure compared to primary TKA with poor outcome and high complication rate.[19] Ligament insufficiency, bone loss, and moderate to severe deformities pose a daunting challenge for treating surgeons. CR or PS prostheses in these scenarios are fraught with dangers of instability and early failure.[7] Adherence to good surgical technique, meticulous soft tissue handling, and use of an appropriate constrained prostheses can impact the success of revision procedure and tide over the complex problem.

CCK prosthesis gives varus-valgus constraint and good amount of rotational stability. However, severe flexion instability is still a limitation of CCK prosthesis because of risk of cam dissociation. Although, there is theoretical disadvantage of increase mechanical stresses leading to early osteolysis, loosening and failure; long term result of CCK in difficult primary and revision procedures are encouraging.[20-22] Cholewinski P et al reported on long-term follow-up of CCK in primary TKA.[21] Their indications were severe deformity, pre-operative laxity, and failure to achieve intra-operative balancing. 43 patients were studied with mean follow-up of 12.7 years. They reported significant improvement of knee function with 11-year prosthesis survival rate of 88.5% overall, and 97.7% after excluding cases of infections (n =2). Long-term functional gain after CCK TKA was found to be similar to those reported after PS TKA, with no cases of constraint-mechanism failure or osteolysis. Wilke BK et al in his retrospective review of 234 semi-constrained revision total knee arthroplasty with average follow-up of 9 year, showed 91% 5-year and 81% 10-year survival.[22] At 10 years the average range of motion, pain level, and knee society score improved significantly ($p< 0.001$). Hinged prostheses were first designed for knee reconstruction following tumour resection.[23] Early generation hinged prostheses were a fixed hinge which allow motion in only one plane of flexion-extension. They did not allow for axial rotation and distraction. Historically, they produced disappointing result with high failure rate due to transmission of abnormal forces to implant-bone interface leading to loosening and wear.[24-26]

Improvement of design of these prostheses and introduction of modular rotating hinged knee prostheses, which allow axial rotation between components, has led to decrease in wear and abnormal stresses to implant-bone interface. Encouraging results have been reported in literature with these modern hinged prostheses.[27-30] Yang JH et al retrospectively reviewed 50 cases who underwent primary TKA using rotating hinge prosthesis.[28] Their indications included severe primary osteoarthritis with ligament laxity, severe rheumatoid arthritis with extreme ligament instability, bone loss, supracondylar non-union, charcot arthropathy, and posttraumatic arthritis. Results showed substantial improvement of function and reduction of pain. However, all (100%) patients needed some form of assisted devices for walking, and high rate of deep infection (14%) were encountered. Barrack RL et al also reported satisfying clinical results in a study of twenty-three modern generation hinged TKA with average follow-up of fifty-eight months.[29] No progressive radiolucency appeared at short-term follow-up. Their observations were also supported by Jones RE.[27] Pour AE et al reported results of revision TKA with RHK in 43 patients with mean duration of follow-up of 4.2 years.[30] The rate of prosthesis survival was 79.6% at one year and 68.2% at five year. However, a relatively large number of complication and failures (including revision because of periprosthetic infection [3 knees], aseptic loosening [4 knees], and periprosthetic fracture [1 knee]) were encountered. In light of relatively high rate of complication, he contended that this salvage procedure should be used with caution, and should be reserved primarily for elderly and sedentary patients.

Fuchs S et al compared outcome after salvage revision TKA using hinge and semiconstrained designs.[31] All 26 patients had a salvage situation secondary to excessive bone loss, enlarged flexion gap, collateral ligament insufficiency, or extensor mechanism insufficiency. He concluded that, albeit, post-operative flexion range of motion was significantly better with nonhinged design, implant design does not significantly affect the overall functional outcome.

Hwang SC et al reviewed the clinical and radiological results of 36 revision TKAs with a cemented PS, CCK, and RHK prosthesis in 8, 25, and 13 cases respectively, with a mean follow-up period of 30 months.[32] In general, a cemented PS prosthesis was used if both collateral ligaments were felt to be competent, and a CCK or RHK prosthesis was used if both collateral ligaments were incompetent. RHK was considered in case of extensor mechanism failure, soft tissue incompetence, severe bony defects, and flexion gap imbalance. Improvement of knee function, and Good or excellent outcomes were obtained in 82% of knees. He concluded that revision TKA requires a more constrained prosthesis than a primary TKA, and a well-planned and precisely executed revision can reduce pain and improve knee function significantly.

Hossain F et al retrospectively reviewed 349 cases of revision TKAs in 343 patients.[33] Three implant types were used: PS, CCK, and RHK. Implant choice was dictated by the extent of integrity of surrounding soft tissue structures providing stability to the knee, and the extent of periarticular, metaphyseal, and even diaphyseal bone defects. In cases in which collateral ligaments were intact and functional, providing valgus-varus stability, a PS implant was used. In cases of partially intact or functioning collateral ligaments, cases with varus-valgus deformities of greater than 150 or with flexion extension gap mismatches that may predispose to cam dissociation of a standard modular PS design, a CCK implant was considered. They used RHK prosthesis in cases in which there was complete absence of collateral ligament support or in cases of very severe varus-valgus deformity and flexion contracture, which would necessitate the complete release of the collateral ligaments. RHK was also considered for cases with severe flexion gap laxity, which may predispose to cam dissociation and dislocation even in an unlinked constrained CCK prosthesis or with bone defects that was not be amenable to joint line restoration with metal augments. Overall 10-year survivorship was 90.6% with highest survivorship seen in the rotating hinge group (92.5%). The rotating hinge group had the highest satisfaction rates (88%). They concurred that functional outcome and range of motion improve irrespective of revision implant type. The rotating hinge prosthesis provides patient satisfaction and survivorship similar to that of other implant types.

Vasso M et al prospectively evaluated sixty consecutive revision knee arthroplasties in 57 patients.[34] Prostheses implanted at revision included PS, CCK and RHK. Constraint choice for the revision prosthesis depended on the state of the ligaments and on the severity of bone loss according to AORI (Anderson Orthopaedic Research Institute) classification.[35] They used a primary PS implant in 7 knees that presented with intact ligaments and type 1 bone loss. A semiconstrained CCK implant was used in 35 knees with ligament insufficiency and type 2 bone defects. A rotating hinged prosthesis was considered in 18 knees characterised by ligament absence/disruption and type 2 or 3 bone loss. Type 1 defects were managed with cement and morsellised autografts. Type 2 and 3 defects were treated with metal augmentations, tantalum cones, and modular cementless stems. The median follow-up was nine years (range, 4-12 years). At the latest follow-up, IKS (International Knee Society knee and function score) and HSS (Hospital for Special Surgery knee score) scores, and Range of motion (ROM) were significantly improved. No significant differences were found between the three different groups (PS, CCK and RHK) in terms of IKS and HSS scores, whereas PS designs only presented significantly higher ROM values. They recommended precise indications for the use of the three different constraint knee prostheses on the basis of the state of peripheral ligaments and the severity of bone loss according to AORI classification. A primary PS system can be used if the ligaments are intact and the bone stock is preserved (type 1 defects). CCK systems can be used in case of insufficiency (but not absence) of the collateral ligaments, and moderate (type 2) bone loss. Hinged prostheses are generally used in the presence of complete disruption/absence of the ligaments with moderate (type 2) or severe (type 3) bone loss.

Normally knee is subjected to enormous amount of load by body weight, muscle forces. In normal knee, these forces are dissipated by intact soft tissue envelope. The trade-off of constrained prostheses is that at the expense of increased stability, it substantially increase stresses across implant-cement-bone interface, which might lead to early loosening and failure.[16,36] Also increase stresses on constraint mechanism, i.e. hinge of RHK, cam and post of CCK, is of concern for their early mechanical failure.[2] This potential disadvantage must be considered during selection of proper constraint, and surgeons should endeavour to use least possible constraint whenever possible.

CONCLUSION

Revision knee arthroplasty requires more component to component constraints than primary procedure. Arthroplasty surgeons should be well versed with the principle of revision arthroplasty, pearls and pitfalls of available constraints options. Precise pre-operative clinic-radiologic evaluation and through intraoperative assessment play a crucial role in decision making, and appropriate constraint selection. Increasing demand of revision knee arthroplasty encourages more research works in this field to seek the best results.

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