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Systematic review

The utility of bicruciate-retaining total knee arthroplasty

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ABSTRACT

Background: We describe the features of modern and historical bicruciate-retaining (BCR) total knee arthroplasty (TKA) implants compared with other TKA implant designs, reviewing kinematics, proprioception, operative technique, and clinical results.

Methods: We performed a review based on PubMed, Embase, CINAHL Plus, and Cochrane databases from January 1990 to April 2016 using combinations of the following keywords: "bicruciate-retaining arthroplasty," "bicruciate-retaining total knee arthroplasty," "bicruciate-retaining TKA," "kinematics," "knee kinematics," and "TKA kinematics."

Results: Four studies have supported the notion that preservation of both cruciate ligaments in TKA preserves more "normal" knee kinematics. BCR implants provide greater proprioceptive performance when compared with posterior cruciate-retaining (CR) TKA implants. However, the operative implantation is more challenging with BCR TKAs, requiring the surgeon to take additional precautions. Overall, there did not seem to be a significant difference in short-term clinical outcomes between the BCR and CR implants.

Conclusions: The utility of BCR TKA is still debatable. The literature has not shown clear indications and guidelines for the value and use of this implant. Although kinematics have been shown to mirror the native knee more closely, the clinical outcomes of BCR vs CR TKAs do not differ significantly. Moreover, additional care must be taken when inserting a BCR implant. The anterior cruciate ligament exploration and preservation is more challenging and certain preparation and precautions must take place. Overall, we have not found that BCR implants are significantly superior to CR implants with regards to short term clinical outcomes despite the BCR TKA having improved kinematics and proprioception.

Introduction and Background

Total knee arthroplasty (TKA) is one of the most effective orthopaedic procedures for pain relief and functional restoration in patients with an arthritic knee. Historically indicated in the elderly population, a demographic shift to the younger more active patient has recently been seen [1]. In conjunction with this change, numerous reports have demonstrated that approximately 20% of patients who undergo TKA procedures are still unsatisfied [2]. This dissatisfaction may potentially be explained by the abnormal kinematics of posterior cruciate-retaining (CR) and cruciate-sacrificing/substituting implant designs, which may affect the muscle moment arms, ligament tension, and proprioceptive instability during knee motion when sacrificing the anterior cruciate ligament (ACL) during TKA [3] (Table 1).

Variations of TKA implants have been designed based on patient demand and activity levels. The different variations include bicruciate-retaining (BCR), posterior CR, posterior-cruciate substituting (CS), and posterior stabilized (PS). BCR TKA is a specialized prosthetic implant that preserves both the ACL and posterior cruciate ligament (PCL). In the CR implant, the ACL is

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Table 1
List of studies reviewed categorized by parameters reviewed.

Studies reviewed	References
Kinematics	[3]
	[4]
	[5]
	[6]
Proprioception	[7]
	[8]
	[9]
	[10]
	[11]
	[12]
	[13]
	[14]
	[15]
	[16]
	[17]
	[18]
Operative technique	[19]
Clinical results	[20]
	[12]
	[21]
	[22]
	[23]

sacrificed, but the PCL is preserved, and the CS and PS implants involve removal of both cruciates. However, the CS implant has a more congruent polyethylene, which adds stability to the joint, whereas the PS implant has a central post that engages the femoral cam to replace the PCL function.

Innovative implants are being developed to simulate the native knee kinematics to potentially improve return to high activity levels, and to allow for better satisfaction. ACL retention may theoretically generate superior proprioception and knee kinematics, thereby improving postoperative function and stability [4]. Theoretically, by lessening the stress transmitted through the prosthesis, BCR TKA has the potential to improve implant longevity.

The literature has not yet provided clear guidelines for the application of BCR TKA implants. In this systematic review, we describe the features of BCR implants compared with other TKA implant designs, review kinematics, proprioception, operative technique, and clinical results.

Material and methods

Twenty-two studies were identified for this systematic review based on electronic searches through the PubMed, Embase, CINAHL Plus, and Cochrane databases from January 1990 to April 2016 using combinations of the following keywords: "bicruciate-retaining arthroplasty," "bicruciate-retaining total knee arthroplasty," "bicruciate-retaining TKA," "kinematics," "knee kinematics," and "TKA kinematics." The inclusion criteria were English language studies that reported on BCR TKA—both cadaveric and actual patient studies focused on implant design features, kinematics, operative techniques, proprioceptive performance, and patient outcomes. The exclusion criteria were studies in other languages, which are not focused on BCR TKA. Each study was reviewed individually by the following authors: SCT, KC, RS for appropriateness. Any disagreements were initially resolved by SCT and KC, until a unified decision about the study design and data was made. All further issues were discussed with the senior author RS for final clarification. Data extraction and assessment were performed by the following authors: FO, SCT, and KC. The data of each study reviewed were extracted for comparison and was not statistically reanalyzed. The parameters we assessed for the BCR TKA included kinematics, proprioception, operative techniques, and clinical outcomes, with each metric being compared with "historical implants" predating the year 2000 and "modern implants" after the year 2000. There are no violations of human or animal rights.

Results

Kinematics

Four studies have supported the notion that preservation of the cruciate ligaments in TKA preserves more "normal" knee kinematics, all using modern implants [3-6]. Stiehl et al [3] performed an in vivo weight-bearing fluoroscopic kinematic analysis reviewing 16 BCR knees (Ceraver Osteal, Paris, France) and comparing them with 6 CR knees (Advantim, Wright Medical Technology, Arlington, TN). The authors reported that in CR TKAs, medial and lateral contact points were significantly posterior at 0 degrees of flexion ($P < .01$, $P < .001$, respectively), and at 60 degrees of flexion, the lateral femoral condyle was significantly posterior ($P < .05$) compared with the bicruciate design. The authors stated that this posterior contact point in extension and posterior translation in deep flexion could potentially lead to increased posterior wear of the polyethylene insert. CR TKAs also demonstrated more anteroposterior translation during the motion arc compared with the BCR TKA, which demonstrated gradual posterior femoral rollback with limited anteroposterior translation. The CR TKA demonstrated abnormal kinematics with anterior translation during flexion. However, limitations of this study include the fact that no other TKA designs were studied such as CS, which has more constraint due to the conforming design, which may have potentially reduced anteroposterior translation. Also, functional activities were not assessed by the authors and this would potentially impact patient satisfaction with one implant design vs the other. Despite these limitations and differences in the kinematics of BCR and CR knees, all patients in this study had similar clinical outcomes at 12-month follow-up.

Similarly, Moro-oka et al [4] compared the kinematic differences between modern BCR and CR knees. More functional activities such as treadmill gait, stair stepping, and maximum flexion activities were assessed in BCR TKA (N2C, Zimmer GmbH, Winterthur, Switzerland) vs CR TKA (Natural-Knee, Zimmer GmbH, Winterthur, Switzerland). Dynamic fluoroscopy and shape matching were used as kinematic assessment tools [4]. Normal knee kinematics were better maintained with BCR as compared with CR knees. In contrast to the Stiehl et al [3] study, the authors in the present study found that CR knees were associated with less anteroposterior translation than BCR knees and that at 72-month follow-up, both TKA designs had similar range of motion (ROM) and Knee Society Scores. The BCR TKA showed greater posterior translation of the lateral femoral condyle than CR knees during kneeling and lunge activities. In addition, the BCR TKA showed greater tibial internal rotation and posterior translations during the maximum flexion activities. Hence, theoretically, BCR knees should have more ROM, but that was not observed at 5 years postoperatively.

Halewood et al [5] investigated the anteroposterior (AP) laxity of a modern BCR implant (Unity Knee, Corin Ltd., Cirencester, UK) to determine whether it was closer to the native knee than a CR implant (Unity Knee, Corin Ltd., Cirencester, UK). The BCR implants did not show a significant difference compared with the native knee, with the difference in AP laxity being 2.5 mm ($P = .039$) [5]. However, CR implants were shown to have significantly greater AP laxity, of 10 mm, than the native knee ($P = .006$) [5]. This was not an uncommon finding, although similar studies concluded the same result [2-5]. Neither prosthesis showed internal/external and valgus/varus rotational laxity differences from the native knee [1]. BCR knees, along with other knee designs also lack the

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