What factors determine the necessity of tibial and/or femoral stem use in primary total knee arthroplasty?

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Recommendation: A stem extension on the tibial tray should be considered in patients with obesity (BMI of > 35), patients with severe preoperative deformity (varus deformity of > 8 degrees), uncontained defects of > 10mm, severe osteoporosis, where a prosthesis with increased constraint is utilised or where a tibial stress fracture is present.

Level of Evidence: Moderate

Rationale:

Aseptic loosening remains one of the most common causes of revision surgery after primary total knee arthroplasty (TKA) [1-3]. The cause of aseptic loosening following TKA is multifactorial and associated with patient demographics, implant design, and surgical technique [4]. One strategy to mitigate this outcome in primary TKA, particularly in high-risk patients, is the use of a stem extension. Biomechanical advantages of a stem extension include additional fixation with a reduction in micromotion by limiting tibial lift-off and shear stress [5,6]. Data from the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) demonstrate that TKA prostheses augmented with tibial stems have lower rates of tibial component-only revision overall and specifically revision for aseptic loosening [7]. Hinman et al examined the effect of a stem extension on aseptic loosening [8]. They analyzed 111,937 primary TKAs in a US healthcare registry between 2009 and 2019. Propensity score matching was used for 10,476 stemmed TKA and 10,476 non-stemmed TKA. They also found a stem extension was less likely to be revised for aseptic loosening compared to those without a stem. This data, however, is not able to account for all variables that may increase the risk of aseptic loosening including obesity, osteoporosis/osteopenia, severe deformities, stress fractures, or ligament laxity requiring a prosthesis with increased constraint. Furthermore, the primary stem design of the prosthesis may have an impact on the outcomes of adding a stem extension.

Length of stem

Shorter stem designs have been identified as potentially being associated with higher rates of aseptic loosening. A low-profile keel of < 20 mm has been found to be associated with a significantly higher incidence of aseptic loosening [9]. This finding of shorter keels being associated with higher rates of aseptic loosening has been noted across a number of prosthesis designs [10,11]. This finding gives weight to the notion that stems in primary joint arthroplasty may reduce the risk of aseptic loosening, however, the optimal length for stems is still debated.

Obesity

An increased incidence of aseptic loosening following primary TKA was noted by Abdel et al in patients with a BMI of > 35 as compared to those with a BMI of <35 [12]. Of 5,088 stemless primary TKAs assessed at a mean 7-year follow-up, there was a nearly two-fold increase in the rate of aseptic loosening in patients with BMI >35 (HR = 1.9; P<0.05). Similarly, Fehring et al reported catastrophic failure due to varus collapse following TKA [13]. The average BMI for these patients was 40.5 with a high proportion of these patients having small tibial base plate sizes. The authors of this article proposed that in patients with a BMI > 40 and small tibial sizes, a stem should be considered to mitigate the risk of varus collapse. In a retrospective review of a prospectively collected database, 180 patients, with BMI > 30 were divided into 3 groups (a short cemented 30 mm, a 100 mm uncemented stem, and a no stems) and matched on the basis of age and type of stem. At two years follow-up, the cohort with short cemented stems showed better functional outcomes, and lesser failure rates compared to longer stems [14]. The Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) has recorded the BMI of patients undergoing TKA since 2015. An analysis of the AOANJRR data found no statistically significant difference in the rate of revision for loosening with or without the use of tibial stems when stratified by BMI [15]. However, according to the AOANJRR data, the rate of aseptic loosening significantly increases after 10 years since the index procedure [7]. The data presented in this paper relates to a follow-up period of 6 years and as such the conclusions that can be drawn from this study are limited by shorter follow-up periods. Furthermore, given the observational nature of a registry study, there are a large number of confounders that may have influenced the result. A recent systemic review and meta-analysis examining the use of stem extensions in patients with obesity undergoing TKA found a protective effect on aseptic loosening. This report identified 7 publications, 3 randomized controlled trials (RCT), and 4 retrospective cohort studies comprising a total of 934 procedures from 882 patients [16]. In the analyzed studies, there was heterogeneity in the classification of obesity with a cut-off of >30 to >35 utilized in the included studies. Stemmed tibial implants were found to reduce the risk of revision for aseptic loosening in obese patients (RR 0.25, 95% CI 0.07 to 0.92). Furthermore, when zero-event studies were excluded from this analysis, stemmed tibial implants were associated with an even greater reduction in risk of revision (relative risk: 0.15, 95% CI 0.03 to 0.64). When applying the results of this study, it is important to consider the potential confounding effect of the differences in tibial stem length among various implants. In obese patients undergoing TKA, the native stem design of differing implants may result in differing thresholds for using a stem extension. In addition, this systematic review highlights a significant deficiency of high-quality studies in the current literature with low risk of bias, sufficient sample sizes, and adequate follow-up, and this indicates that a definitive conclusion on the use of tibial stem extension in the obese patient population cannot be drawn from this systematic review alone.

Osteoporosis

Osteoporosis is a common comorbidity in patients undergoing TKA with up to 26% of patients carrying this diagnosis [17-19]. Patients with a diagnosis of osteoporosis have a higher risk of aseptic loosening (HR: 1.2; 95% CI: 1.1 to 1.3; $P < .001$) as well as all-cause revision at 5 years following TKA [19]. Biomechanical models have shown that in osteoporotic bone, the micromotion following surface cementation is increased which can be mitigated with the use of a stem extension [20]. Furthermore, a recent finite elements analysis described the effect of a stem on compression fatigue of host bone. This showed that where the underlying bone is abnormal, compression fatigue is reduced by the use of a tibial stem extension [21]. Clinical outcomes of the use of a stem extension in the setting of osteoporosis are limited. Samy et al reported on patients with a pre-operative DEXA diagnosis of osteoporosis who received either a stemmed or non-stemmed cemented tibial implant [22]. They found that in osteoporotic patients that received a stem extension, there was a significant reduction in visual analogue pain scores with a minimum follow-up at 2 years. This finding was not shown in the group of patients in this study without osteoporosis. The authors of this study suggested the improvement of pain occurs through the ability of the stem to transfer load from the weak osteoporotic metaphysis to the stronger diaphysis. The findings of this study are limited by the small cohort numbers and the retrospective nature of the study, however, the findings are suggestive of a beneficial effect of stem extension in patients with osteoporosis undergoing TKA.

Preoperative Deformity

Patients with severe pre-operative deformity are reported to be at higher risk of failure due to aseptic loosening or varus collapse following TKA [13, 23]. One potential solution for preventing this mode of failure is to add supplemental tibial fixation with the use of a stem extension [22,24-27]. Samy et al reported a statistically significant improvement in Knee Society Scores for patients who received a stem extension as compared to those who did not with a preoperative severe varus malalignment [22]. Park et al reported on a cohort of patients with a preoperative hip knee angle (HKA) of > 8 degrees of varus and found an estimated 10-year implant survival rate of 95.3% (95% CI: 92.6%- 98.1%) in the non-stemmed group and 100% in the stem extension group [24]. This data set was retrospective in nature and skewed towards the non-stemmed group with a total of 602 patients without a stem and 99 with a stem extension thereby limiting the conclusions that can be drawn from this study. Fournier et al reported on a 1:3 matched cohort of patients that underwent TKA with a stem extension as compared to no stem extension with a preoperative HKA <170 degrees (10 degrees of varus) [25]. No patients were found to have aseptic loosening in the stem extension group as compared to 3% in the stemless group (p = 0.04). In a further similar study by Hedge et al, patients with a preoperative varus deformity of >8 degrees and 2-year minimum follow-up with a stemmed tibial component (67 patients) were matched 1:2 to patients with a similar preoperative varus deformity with a standard tibial component (134 patients) [26]. Subsequent rates of radiographic lucent lines as well as aseptic loosening were lower in the stem group (0% vs 5.15%, P = 0.05).

Bone loss

A recent finite analysis, examining the effect of bone loss on the stress exerted at the bone prosthesis interface, showed that compared with intact medial bone, a defect model of 10mm led to an increase in stress of 84%. This was mitigated by the use of a stem. [28] Component loosening in the setting of tibial bone loss has long been recognised as a concern. Bone defects can be classified into contained and uncontained (peripheral) defects [29]. Contained defects may be managed with autologous grafting or cementoplasty. Uncontained defects may require structural augmentation [30]. In 1983, Scott et al recommended the use of a prosthetic augment in conjunction with a 70mm stem to overcome uncontained tibial bone loss [31]. Since this time, a variety of methods to accommodate uncontained defects have been described including prosthetic augments as well as structural bone grafting techniques [32 - 37]. Regardless of the choice of augment (prosthetic or structural bone graft), these reports all advocated for using a stem to improve load sharing and limit the micromotion at the bone prosthesis interface. There are no prospective comparative studies on the use of stems in the setting of uncontained bone defects, however, this practice is supported by biomechanical and finite element analysis[28,30].

Prosthesis constraint

In the setting of incompetent collateral ligaments, severe preoperative deformity, and/or inability to achieve intraoperative balance, a TKA prosthesis with increased constraint may be used. An example of this is varus-valgus constraint knee implants (VVC) which provide increased coronal stability through a long tibial post that articulates with a deep femoral box [38]. Stem extensions have been recommended to help transfer loads away from the epiphyseal zone to the metaphyseal and diaphyseal zones in order to distribute the increased stresses of a constrained articulation [39]. Moussa et al. retrospectively reported on 85 stemmed primary VVC implants compared with 354 stemless primary VVC implants. They reported a higher revision rate in stemless VVC implants at a 2-year follow-up (2.4% VS 1.1%), with most failures being aseptic loosening [40]. Mancino et al conducted a systemic review of outcomes in the use of primary VVC implants with a subanalysis on aseptic loosening rates in stemless or stemmed prostheses and found a similar outcome [41]. When considering only studies with a follow-up equal to or longer than 5 years the revision rate for aseptic loosening was 0.5% in the stemmed group and 2.3% in the stemless group. Conversely, a recent publication reported that stemless primary VVC implants were found to have a reliable midterm follow-up as compared to primary PS knees (0.6% for the PS group and 2.1% for stemless VVC) [42]. The majority of the reported literature supports the use of a stem to improve durable fixation when using a prosthesis with an increased level of constraint.

Tibial Stress Fracture

Severe arthritis of the knee may be complicated by a stress fracture of the proximal tibia[43,44]. Obesity, osteoporosis, severe deformity, and metabolic bone diseases are predisposing factors [45,46]. Whilst limited to small case series, a recent systemic review found the use of TKA with a stem extension which bypassed the stress fracture, provided good functional outcomes with low rates of failure. Given the length of stems required to bypass the fracture, all stems utilised were uncemented. The largest series of 34 knees reported a 100% union rate of stress fracture with no failures at a mean follow-up of 36 months [47]. Whilst limited to level 1 evidence, the use of a stem extension may be a viable option in managing tibial stress fractures associated with knee arthritis.

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