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Original Article

Correlation of tibial bone defect shape with patient demographics following total knee revision

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ABSTRACT

Background: Bone defects of the proximal tibia following revision total knee arthroplasty (TKA) are challenging to manage, but must be addressed to provide lasting stability. This paper will categorize tibial bone defects into shape groups and correlate resulting groups to patient demographic data.

Methods: Retrospective analysis of four hundred and four patients post revision TKA between January 2005 and February 2014 was conducted. One hundred and eighteen met the inclusion criteria and were subcategorized by defect shape on their post-operative lateral and anterior-posterior (AP) radiographs. The subgroups of defect shape were subsequently analyzed with Fisher's exact test and one way ANOVA.

Results: Trapezoidal shaped defects were the most common in both radiographic views, and the magnitude of the defect at the top joint line varied significantly amongst shape groups in both AP and lateral views. Trapezoid shaped defects were correlated with smaller defect top lengths in both views. There was no statistical correlation between defect shape BMI, TIV and reason for revision in lateral view. However, T-bilateral defect shapes were correlated with higher BMIs in AP view.

Conclusion: A volumetric classification system of tibial defects is necessary for preoperative planning in revision TKA. Common tibial bone defect shape groups were identified and analyzed in AP and lateral radiographs after revision TKA. Trapezoidal defects were the most common, and all other shapes followed a pattern of proximal enlargement tapering distally. Trapezoidal defects were smaller than other shapes and AP T-bilateral shaped defects were correlated with higher BMIs.

1. Introduction

With the demand for primary total knee arthroplasties (TKA) in the United States expected to increase to over 3 million procedures by 2030 and the revision burden (the ratio of primary to revision arthroplasties) remaining constant at just over 8%, there will be an exponential increase in the demand for revision TKAs which provide better outcomes than their predecessors.[1]

The reasons for failure of primary TKAs are numerous: infection, instability, implant failure, periprosthetic fracture, osteolysis, dislocation, bearing surface wear, and mechanical loosening.[2–4] Despite the many possible causes, generally the most common indication for revision TKA is aseptic loosening.[4–6] To restore joint line and potentiate implant stability, bone defects present after removal of primary TKAs must be addressed in revision TKAs.

Although primary TKA is a successful procedure and provides good patient satisfaction,[7,8] revision TKA is less successful in longevity and patient satisfaction.[4,9,10] The reasons for this discrepancy in outcomes between primary and revision arthroplasties are likely multifactorial: technical challenges, extensile exposure requirements, ligamentous laxity, bone stock deficits, stress shielding due to longer stems, and increased constraint.[10]

Tibial cemented intramedullary long stems have been in use for over two decades in revision and have generally been competent in the case of poor bone stock,[11,12] but there is still a clear need for improvement. To deal with bone loss, revision knee arthroplasty augments such as sleeves and cones have been introduced, with a variety of augment geometry, porosity, and implant interfaces. However, how to plan for their use pre-operatively, understanding which system to use, and how to correlate intra-operative findings with pre-operative imagining is unclear. To that end, a better understanding of the common morphology of bone defects following revision TKA is an important first step in using augments in revision knee arthroplasty surgery.

Currently, various classification systems for tibial bone defects exist. However, each has its own drawbacks. The Dorr system does not take into account the size of the defect, the Rand assessment and the

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Anderson Orthopedic Research Institute classifications both require intraoperative assessment[13] and the University of Pennsylvania classification system, though quantitative and reproducible, has not been adopted widely due to its complexity.[14]

Thus, this study aims to classify tibial bone defects in revision TKA radiographs into discrete shape groups and subsequently identify correlations between those groups and cohort demographics.

2. Materials and methods

The study protocol was approved by institutional ethics review board. Prospectively collected data on 404 patients requiring primary and knee revision surgery was identified using an institutional joint database as well as the retrieved implant database. Patients who underwent revision total knee arthroplasty from January 1, 2005 to February 28, 2014 were considered for inclusion within the study. Reasons for exclusion included amputations, fusions, lack of a suitable radiograph, previous revisions on the same knee and polyethylene exchange revisions. Patients were included if they had undergone revision surgery for aseptic loosening, polyethylene wear, osteolysis, instability, periprosthetic fracture, implant fracture, infection, malpositioning, pain, stiffness, and arthrofibrosis.

Surgeries were conducted by one of six fellowship trained, high volume surgeons and both fully cemented and metaphyseal cemented techniques were used.

Patient charts were retrospectively analyzed to record age at time of surgery, body mass index (BMI), gender, specific knee, weight, height, indications for revision and complications.

For each revision TKA, tibial defect size was assessed based on the radiographs taken six weeks after surgery. Measurements of defects in the radiographs were taken using ImageJ (National Institutes of Health, Bethesda, MD) in anteroposterior (AP) and lateral views by two experienced, fellowship trained, high volume arthroplasty orthopedic surgeons. All defect shape measurements were independently calibrated using the known tibial component implant size. These shapes were then categorized into shape groups in both lateral and AP views for each patient. Observers were blinded to all patient information and analyzed the presence of bone defects independently. The tibial components used were Smith & Nephew ® (Andover, MA) Genesis 2 ™ and Legion Revision ™; DePuy ® (Warsaw, IN) Sigma ®; Zimmer ® (Warsaw, IN) NexGen ® and Stryker ® (Kalamazoo, MI) Triathlon ® Total Knee Universal.

2.1. Statistical analysis

The cohort was subdivided by defect shape to analyze for a correlation between defect shape in AP and lateral views and TIV, BMI and indication for surgery. Statistical analysis was completed using SPSS Statistics version 23 (Armok, NY). Categorical data were analyzed using chi square or Fisher's exact test. One-way ANOVA analysis was utilized for examining variance of demographical factors within categorized groups. P values less than 0.05 were considered significant.

3. Results

One hundred and eighteen patients were included, 76 females (average BMI: 33.1st d. dev.: 7.1) and 42 males (average BMI: 34.1st d. dev. 12.6). Sixty-one operations were done on the right knee (51.7%) and 57 on the left (49.3%). Average demographics included a height of 163.7 cm, a weight of 89.7 kg and a BMI of 33.4 kg/m^2 (Table 1). Aseptic loosening was the most common reason for revision, followed by polyethylene wear (Table 2).

On analysis, six distinct shape groups were found for both AP and lateral views (Fig. 1).

On analysis of anterior-posterior and lateral radiographs, trapezoidal shaped defects were the most common, 55.1% and 45.8% respectively, while t-bilateral, flashlight and cone made up significant portions as well (Table 3).

Table 1
Demographics of study cohort, range in parentheses.

Demographic Variable	Average (Range)
Gender (F/M)	76/42
Knees	118 (118 patients)
(Right/Left)	61/57
Height (cm)	163.7 (140.2–186)
Weight (kg)	89.7 (50–173)
BMI (kg/m^2)	34.3 (17.9–54.4)
Time in vivo (years)	8.5 (0.8–27.2)

Table 2
Reason for revision. Percent of patients experiencing each in parentheses.

Reason for Revision	Counts
Aseptic Loosening	55 (46.6%)
Polyethylene Wear	27 (22.9%)
Osteolysis	11 (9.3%)
Instability	32 (27.1%)
Periprosthetic Fracture	1 (.01%)
Pain/Stiffness	34 (28.8%)

Secondly, defect size along prescribed measurements in both lateral and AP fell within the range of tibial implant sizes (see Appendix Table A in Supplementary material) used for the patients in this sample (Tables 4 and 5). ANOVA of defect top length showed significance ($p = 0.00001$) between shape groups in AP view. Subsequent Tukey's test showed trapezoid top length to be significantly smaller than that of flashlight ($p = 0.0004$) and T-bilateral ($p = 0.00001$). In lateral view, ANOVA of top length showed significance as well ($p = 0.0004$). Subsequent Tukey's showed T-bilateral top length to be significantly larger than cone ($p = 0.048$) and trapezoid ($p = 0.003$) and trapezoid to be significantly smaller than trapezoid-anterior t-posterior ($p = 0.04$).

Defect shape in each patient was also compared to the reason for revision TKA in both AP and ML views (Tables 6 and 7). No significance was found between the reasons for revision and subsequent defect shape (Tables 6 and 7).

Mean time in vivo (TIV) and BMI were also compared to the various shapes in AP and lateral views, with ANOVA showing significance in AP BMI ($p = 0.034$) between shape groups (Table 8). Subsequent Tukey's analysis showed the BMI for the AP T-bilateral shape group to be significantly larger than that of the flashlight group ($p = 0.048$).

4. Discussion

The factors affecting bone loss are varied and the method of reconstruction depends on defect size and location, presence of a cortical rim of bone around the defect and the etiology of the bone loss.[15] Current techniques used to cope with massive bone loss in revision TKA include autografts, allografts and metal augments.[16,17] Metal augments are increasingly being utilized, and can be broadly categorized into sleeve and cone designs. Fully cemented to highly porous augments, differences in symmetry, specific reamers or other preparation techniques and other features are all reflected in the fact that each industry partner has unique metal augment features and philosophies. Going forward, the increasing demand for revision TKAs will multiply the complexity of available techniques and materials. However, despite the many surgical methods of addressing bone loss, there isn't a systemized volumetric approach to classifying tibial bone defects themselves. This makes pre-operative decision making challenging and understanding the presentation of these bone defects an asset.

In this study's analysis of defect shape, we have found trapezoidal