Morsellized bone grafting compensates for femoral bone loss in revision total knee arthroplasty. An experimental study

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Abstract

This study was undertaken to examine the contribution of uncontained morsellized bone graft to the structural properties of a femoral reconstruction in total knee arthroplasty and to serve as a basis for an in vivo animal study. Ten human distal femora with a standard unicondylar uncontained medial bone defect were prepared to fit a femoral component of a cruciate sacrificing TKA. A cyclic axial load of 750 N was applied to the medial part of the femoral component in the presence of impacted morsellized bone graft. After removal of the bone graft, the cyclic loading was repeated for the unsupported situation. None of the grafts collapsed and all cement mantles stayed intact during the experiments. Elastic deformation during cyclic loading was significantly less when graft was added while time-dependent deformation was not affected. We conclude that impacted morsellized bone graft, used for reconstruction of uncontained femoral bone loss in revision knee arthroplasty, may improve the structural resistance against loading. Further animal experimentation for in vivo application is warranted. © 1998 Published by Elsevier Science Ltd. All rights reserved

Keywords: Total knee arthroplasty; Morsellized bone graft; Revision; Bone defect

1. Introduction

Uncontained femoral bone loss is often encountered in revision total knee arthroplasty (TKA) due to bone remodeling, wear and removal of the implant [1–3]. Massive bone graft, cement and metal augmentation have been used to reconstruct these defects. Massive bone grafts are liable to clinical failure [4]. In view of the very good long-term results of impacted morsellized bone grafts in revision total hip arthroplasty (THA) [5], we propose impacted morsellized bone grafting for femoral bone defects in combination with a cemented TKA. Unlike revision THA, however, femoral bone defects in revision TKA are often uncontained, creating the problem of lack of support. In cases of uncontained acetabular and femoral bone loss in THA, metal meshes are often used to create containment for the impacted morsellized bone graft. These meshes are less applicable in TKA, since the mandatory soft tissue coverage is often absent or insufficient. Hence, the morsellized bone graft may collapse under loading conditions.

The present study was undertaken to examine the contribution of the uncontained morsellized graft to the structural properties of the reconstruction and to serve as a basis for an in vivo animal study. For this purpose, the stiffness of the reconstruction and the deformational behavior with and without grafts under cyclic loading was measured.

2. Materials and methods

Ten fresh frozen human distal femoral bones were prepared to fit the femoral component of a cruciate sacrificing TKA (Press-Fit Condylar, Johnson and Johnson, Raynham, MA, USA). After trial fitting of the component, a standard uncontained unicondylar bone defect was created by removing 1 cm of the distal medial condyle. The defect was reconstructed with morsellized bone graft, manually impacted in a mould (Fig. 1). After removal of the mould the femoral component was cemented on the distal femur with the graft in place. The proximal end of the femoral shaft was potted in cement and clamped in an upside down position in a testing
machine (MTS, model 458020, Systems Corporation Minneapolis Minnesota). Zero measurements without loading were performed during 152 s. A cyclic axial load ranging from zero to 750 N with a 1 Hz frequency was then applied to the medial part of the femoral component (without a tibial component) for approximately one hour (3321 cycles, test A, Fig. 2). The loading peg had freedom of movement in the anterior/posterior and medial/lateral directions during axial loading. The same test was repeated after manual removal of the impacted graft to create a situation where no graft support for the femoral component was present (test B, Fig. 3). Graft collapse or cement failure was monitored by measuring the elastic and time-dependent deformation between prosthesis and bone at the medial and lateral side by two extensometers, with a resolution of 8 μm. The extensometers were aligned in the axial direction, where maximal deformations were expected. Elastic deformation was defined as the local displacement between the distal femur and the prosthesis, measured by the extensometers, during each loading cycle. Hence, elastic deformation may include bony deformation and displacement at the interfaces. Time-dependent deformation was defined as the ongoing change in local displacement, measured by the extensometers in time.

Statistical analysis of the test data was performed with the paired Wilcoxon signed rank test, comparing the difference in elastic and time-dependent deformation for tests A and B. P-values less than 0.05 were considered significant.

3. Results

Cyclic deformation between distal femur and prosthesis was observed in tests A and B. None of the impacted morsellized grafts collapsed during the loading experi-

ments. All cement mantles remained intact on visual inspection during and after the tests. Elastic and time-dependent deformations differed considerably from specimen to specimen (Figs. 4 and 5, Tables 1 and 2). Hence,
the inter-specimen variation was rather high. However, the intra-specimen results, analyzing purely the effect of the presence of the graft material in a particular specimen, indicated a significant effect of the presence of the graft on the stability of the reconstruction. The elastic deformation between the cement and the bone measured in test A was significantly less at the medial (Fig. 4, $P = 0.002$) and lateral ($P = 0.0039$) condyles, when compared to test B. The differences in time-dependent deformation between tests A and B were not significant for the medial (Fig. 5, $P = 0.7$) or lateral ($P = 0.63$) condyles. Time-dependent measurements at the lateral condyle gave negative values, indicating that the prosthesis was subject to tilting.

4. Discussion

The treatment of bone loss in revision TKA is a challenge. Surgeons often underestimate the amount of...
femoral bone loss preoperatively, and may be surprised by large defects that require reconstruction [3, 6]. In the case of uncontained femoral bone loss, Engh et al. [7] recommended the use of a stemmed femoral component to protect structural grafts. However, the application of a femoral stem extension may lead to increased femoral bone resorption, due to the stress shielding effect of the stem [8]. Therefore, a solution to uncontained femoral bone loss without a stemmed component seems advantageous. The present study addressed the question whether impacted morsellized bone graft, used in cemented revision TKA with unicondylar uncontained femoral bone loss, would remain stable and would contribute to reduction of elastic and time-dependent deformation under the loading conditions, comparable to a patient’s full body weight. This unicondylar load of the grafted condyle in cadaver bones exceeded the clinical situation. Both femoral condyles normally share the patient’s body-weight when post-operative alignment is correct. A delay in full weightbearing of about 3 months is commonly advised in revision TKA with bone grafting, until the graft is incorporated. Our results show that collapse of the impacted morsellized bone graft does not occur under the present loading conditions. The support from the intact lateral condyle, the inter-condylar box and the impacted morsellized bone graft to the cemented femoral component is adequate to prevent early mechanical failure.

Our results showed similar patterns for elastic deformation for all femora at the end of the test. The high-standard deviations in the values of the deformations were caused by differences in individual bone quality and geometry of the cadaver specimens. Elastic deformations, an indicator for strength, at the medial and lateral condyles were about 20% less in test A. Although this did not suggest a dramatic increase in stability, the paired differences were significant. This implies that reconstruction with impacted morsellized bone graft does reduce deformation to some extent. The lack of reduction in time-dependent deformation from tests A–B, however, remains a matter of concern. The absence of cortical support may cause early failure of the reconstruction of large bone defects if direct postoperative loading with full body weight is allowed. Our study only simulates the direct post-operative situation and does not investigate stability during the bone remodeling process. However, initial laboratory tests are essential in the process of stepwise introduction of new implant fixation methods, to monitor safety and efficacy [9]. By offering a scaffold for bone ingrowth, this technique may enable restoration of bone mass in the longer term. Further mechanical and biological tests of this new method will be conducted in an animal experiment.

We conclude that impacted morsellized bone graft used for uncontained unicondylar femoral bone defects in vivo cemented TKA may not collapse under dynamic loading. The structural resistance against load may be improved relative to the unsupported situation, although time-dependent deformation is not reduced.

References


