PEEKPower High Tibial Osteotomy Plate

Introduction

The medial opening wedge technique for high tibial osteotomies (HTO) is now a well-established method for the treatment of medial unicompartimental osteoarthritis of the knee (1). Compared to the traditional lateral closed-wedge technique, which is accompanied with a removing bone wedge procedure at the proximal tibia, the popularity of the HTO can be ascribed to advantages of maintaining bone stock and no necessity to perform a fibular osteotomy. The success of the HTO outcome relies on the preservation of the appropriate correction angle and bony consolidation postoperatively. Thus a stable osteotomy fixation is mandatory during the time frame of bone healing in order to minimize the risk of non-union and loss of correction. In recent studies the biomechanical behavior of different implant designs for HTO fixation has been assessed within distinct study designs (2; 3; 4; 5; 6). Due to varying load application, specimen preparation and the large range of dissimilar used osteosynthesis systems a directly biomechanical comparison with regard to fixation stability is difficult.

Within a preclinical experimental study the peek-carbon composite PEEKPower High Tibial Osteotomy Plate (Arthrex, München, Germany) was tested using a composite tibia sawbone model under static as well as dynamic loading and compared to a titan plate (TomoFix™, Synthes Medical., Bettlach, Switzerland). The purpose of this study was to evaluate the biomechanical behavior of these two plate systems in a comparable worst case compression bending test design.

Material & Methods

Two different HTO plates were tested in preclinical static and dynamic (each n=5) compression bending tests. Therefore a peek-carbon composite system (PEEKPower HTO-Plate®) as well as titanium plates (TomoFix Plate™) were used (Fig. 1b). All tests were performed at EndoLab® Mechanical Engineering GmbH (Rosenheim, Germany). The plate was mounted onto an artificial bone (large left tibia, Sawbone) 15 mm below the medial rim of the tibia plateau (Fig. 1a). A gap of 10 mm was applied between 40 and 50 mm below the medial rim of the tibial plateau. The plate was hand-tight fixed with four proximal and three distal bicortical screws, each with a diameter of 4 mm. Maximum loads for the endurance tests ranged overall from 80 to 220 N and were applied in the centre of the tibia plateau along the shaft axis (Fig 1c). The minimum dynamic load was set to 10 % of the maximum load. The tests were performed dry in ambient air at room temperature with a test frequency of 5 Hz for dynamic tests. The static load was applied with a loading rate of 5 mm/min. Dynamic tests have been stopped after attainment of 3 million load cycles or functional implant failure.

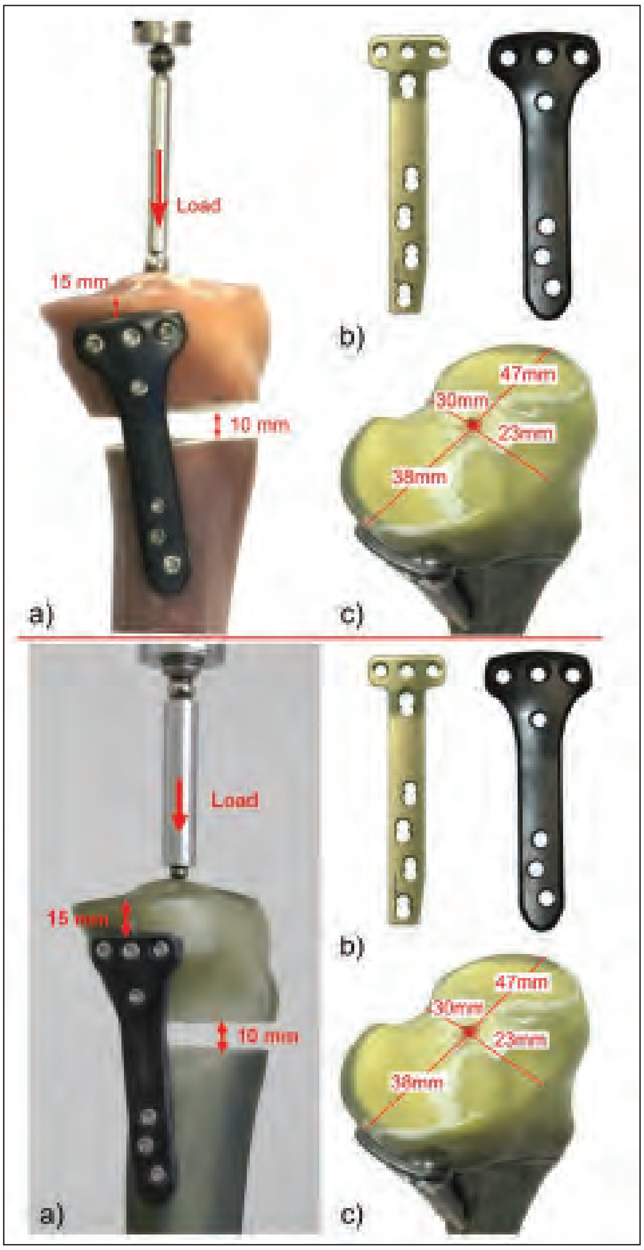

Fig. 1 Experimental set-up with load application and bone gap definition (a, c) for both HTO plates (b)

Results

The static compression bending tests revealed a distinct elastic-plastic deformation behavior between both plate constructs. Thereby higher construct stiffness, with decreased ultimate load as well as decreased ultimate displacement was assessed for the peek-carbon composite plates (Tab.1). While the titan plate test was terminated before tibial bone contact, failed the peek plate due to distal screw backout.

Specimen	Ultimate load [N]	Ultimate displacement [mm]	Stiffness [N/mm]	Plate material
1	230	7.53	77.0	Titanium
2	200	6.54	87.3	PEEK-carbon

Tab. 1:Results for the static compression bending tests

A relationship between applied dynamic loads and reached cycles until test stop were obtained in a lifetime diagram (Fig. 2). The lifetime curves are functional derived with power laws, which are shown in a semi-logarithmic manner. For both specimen groups lifetimes decrease with increasing loads. Compared to the peek carbon composite test results the titanium results reveal decreased lifetimes at lower load levels, but show a tendency to compensate this mismatch at higher load levels. Within the same test set up the titanium plate reached run out level at a maximum applied dynamic load of 80 N, while the peek-carbon composite system revealed a higher load with 160 N. All titanium plate specimens, with an early functional failure exhibit fracturing of the plate at the superior screw hole close to the resection line, whereas the peek-carbon composite plate specimens failed due to distal screw backouts.

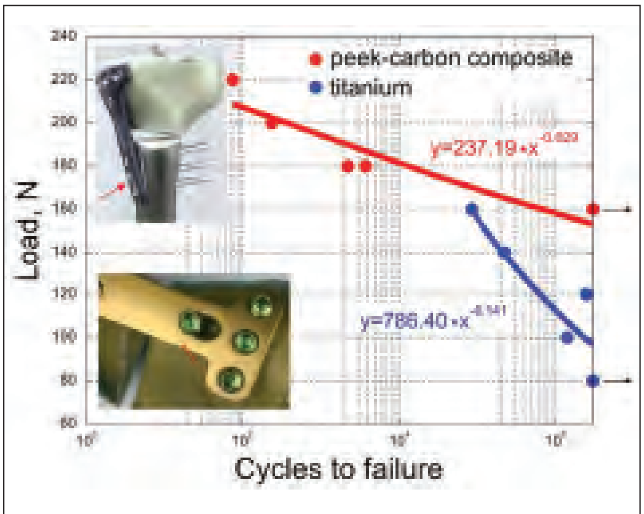

Fig. 2: Endurace curves for peek-carbon composite and titanium plates with mode of failure. Black arrows represent run out level specimen without failure (n=1).

Discussion

In this biomechanical comparative experiment the mechanical behavior of two different HTO plates was studied in a static and dynamic compression bending test. Bone substitute material was used to eliminate the effects of the variability of native bone. In order to simulate worst case conditions and avoid composite bone influences on the lateral side a fully bone gap was created, thus a direct comparison of the mechanical bending strength of the plate systems was guaranteed. The distinct static as well as long time stabilities of the two plate systems can be ascribed to design and material specific differences. While the peek-carbon composite plates resist higher dynamic loadings and showed a higher static flexural rigidity, the titanium plates evidenced a more elastic construct behavior with increased deformations.

The increased flexural strength of the peek-carbon plate is liable for the observed screw backouts at the distal plate side, where tensile forces arises due to an induced bending moment with the upper distal bone edge as pivot. Due to the fact that only functional plate failure determines early stop in this study and no additional failure parameter regarding loss of angle correction or flexural deviation was established, especially the dynamic test results of the higher loaded titanium plates approximate to the results of the peek-carbon plates. Also material specific differences in the damage mechanisms of both implant types may contribute to both distinct observed mechanical failures. The carbon fiber reinforced peek material exhibits a brittle material characteristic with deformations predominantly in the elastic regime of its stress-strain cure, whereas titan possess a more elastic material behavior with material weakening effects during cyclic loading. These effects evoke fracture initiation, propagation and final global implant failure as seen within all dynamic tests.

Within this comparable worst case compression bending test design the peek-carbon composite plate exhibit an increased static flexural strength compared to a titanium plate and an increased lifetime curve at higher load levels. Increased plate deformation may lead to the possibility of non-union and failure of fracture fixation. An appropriate ratio between rigidity and load bearing over a defined number of cycles are required for a successful long term function of the implant.

Literature

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