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Primary stability of different plate positions and the role of bone substitute in open wedge high tibial osteotomy

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A B S T R A C T

Background: The purpose of this study was to compare the mechanical fixation strengths of anteromedial and medial plate positions in osteotomy, and clarify the effects of bone substitute placement into the osteotomy site.

Methods: Twenty-eight sawbone tibia models were used. Four different models were prepared: Group A, the osteotomy site was open and the plate position was anteromedial; Group B, bone substitutes were inserted into the osteotomy site and the plate position was anteromedial; Group C, the osteotomy site was open and the plate position was medial; and Group D, bone substitutes were inserted into the osteotomy site and the plate position was medial. The loading condition ranged from 0 to 800 N and one hertz cycles were applied. Changes of the tibial posterior slope angle (TPS), stress on the plate and lateral hinge were measured.

Results: The changes in the TPS and the stress on the plate were significantly larger in Group A than in Group C. These were significantly larger in Group A than in Group B, and in Group C than in Group D. There was no significant difference between Group B and Group D, and no significant difference between knee flexion angles of 0° and 10°. Stress on the lateral hinge was significantly smaller when bone substitute was used.

Conclusions: A medial plate position was biomechanically superior to an anteromedial position if bone substitute was not used. Bone substitute distributed the stress concentration around the osteotomy gap and prevented an increase in TPS angle regardless of the plate position.

1. Introduction

Medial open wedge high tibial osteotomy (OWHTO) is an effective surgical intervention for medial compartmental osteoarthritis (OA) of the knee. The internal fixator TomoFix™ (Depuy-Synthes, Johnson & Johnson, New Brunswick, NJ, USA) was developed for OWHTO by the AO Joint Preservation Expert Group to achieve optimal stability, allow early initiation of rehabilitation programs, and maintain the attained correction [1,2]. Schröter et al. reported high plate-related complication rates using a short spacer plate without bone wedges after biplanar OWHTO, and mentioned the important role of bone substitutes [3].

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Optimal postoperative rehabilitation after OWHTO enables the patient to walk full weight-bearing as soon as possible without any support, which in turn prevents deep vein thrombosis, loss of function in the lower extremities, and osteoporosis aggravation, and may prolong the average life span. The present study established that an early and active rehabilitation program can help patients to walk with full weight-bearing within two weeks of surgery [4]. This program was realized by TomoFix in combination with beta-tricalcium phosphate blocks (OSferion 60; Olympus Terumo Biomaterials Co., Tokyo, Japan) inserted into the osteotomy gap [5].

Considerable stress is typically placed on the plate and lateral cortical hinge when full weight-bearing walking begins in the early stages after OWHTO. Taylor et al. reported that tibiofemoral forces during stair climbing are greater than those during walking, and that the shear force during stair climbing is more than double that experienced during walking [6]. This increases the chances of a greater tibial posterior slope (TPS) and plate and screw breakage. Plate positioning and wedge insertion into the osteotomy gap may play important roles in improving the structural stability of the osteotomy from a biomechanical point of view. Their relative position is expected to lead to greater stress distribution and reduced micro-motion magnitude at the posterior portion of the tibial plateau. Blecha et al. studied which plate position – medial or anteromedial – more effectively distributes stress around the osteotomy site after OWHTO, using finite element analysis, and concluded that medial plate positioning better achieved structural stability and safety than anteromedial plate positioning [7].

One hypothesis is that instability of the tibial plateau posterior slant and stress concentration on the plate screw system may vary biomechanically according to the plate position, and that bone substitutes into the osteotomy gap may protect against these problems. Thus, the objective of the present study was to use a composite tibia sawbone model under axial loading to evaluate the changes of the TPS, the stress on the plate, and lateral hinge according to the difference in the plate fixation position, with or without bone substitutes, and to clarify the role of bone substitutes.

2. Materials and method

2.1. Bone models

Twenty-eight of fourth-generation sawbone tibia models and one femur model were used in the present biomechanical study (Pacific Research Laboratories, Inc., Vashon Island, WA, USA) [8,9]. The mechanical properties of the tibia and femur model have been reported to reproduce those of a healthy young adult. To increase the contact area between the tibial and femoral joint surfaces, a sheet-shaped latex meniscus was attached to the tibial plateau. Consequently, the axial load was anatomically transmitted from the femur to the tibia. All tibiae underwent OWHTO with normal surgical procedures. The osteotomy was started from the medial side, 3.5 cm distal to the medial tibial plateau, to the upper position of the proximal tibiofibular joint. The osteotomy was incomplete, leaving five millimeters of lateral cortex intact, referred to as the bone bridge, which served as a hinge point during the opening of the osteotomy. The opening at the osteotomy site was performed slowly and carefully using special opening equipment to avoid fracture of the lateral cortex. The opening distance was 10 mm in all tested sawbones.

After the opening of the osteotomy site, a small TomoFix was attached to the medial side of the proximal tibia. The proximal fragment was fixed with four locking mono-cortical screws and the distal fragment was fixed with four bicortical screws. Four different types of experimental models were prepared: Group A ($n = 8$), where the osteotomy site was left open and the plate position was anteromedial; Group B ($n = 8$), where two OSferion 60 wedges were inserted into the osteotomy site and the plate position was anteromedial; Group C ($n = 6$), where the osteotomy site was left open and the plate position was medial; and Group D ($n = 6$), where two OSferion 60 wedges were inserted into the osteotomy site and the plate position was medial. First, an OSferion 60 wedge was fixed at the posterior portion of the osteotomy site and the second wedge was placed anterior to the first one. An anteromedial or medial position of the plate indicated that each plate was fixed to the medial site of the tibia with a screw direction of the B hole of 20° (anteromedial position) or 10° (medial position) from the transverse diameter of the tibial plateau, respectively

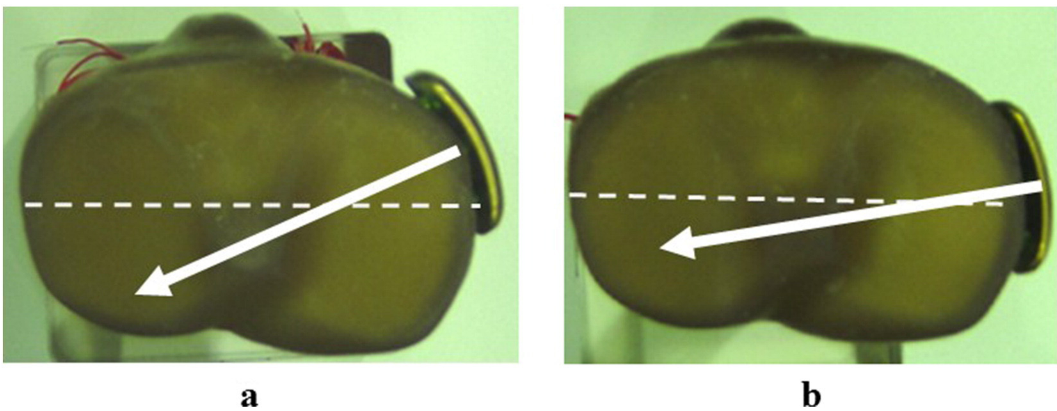

Figure 1. Plate positioning. a. Anteromedial plate position: The screw direction of the B hole (white arrow) is 20° from the transverse diameter of the tibial plateau (dotted line). b. Medial plate position: The screw direction of the B hole (white arrow) is 10° from the transverse diameter of the tibial plateau (dotted line).

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