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Technical note

Intraprosthetic screw fixation increases primary fixation stability in periprosthetic fractures of the femur—A biomechanical study

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ABSTRACT

Background: The purpose of this study was to develop a new fixation technique for the treatment of periprosthetic fractures using intraprosthetic screw fixation. The goal was to biomechanically evaluate the increase in primary fixation stability compared to unicortical locked-screw plating.
Methods: A Vancouver C periprosthetic fracture was simulated in femur prosthesis constructs. Fixation was then performed with either unicortical locked-screw plating using the LISS-plate or with intraprosthetic screw fixation. Fixation stability was compared in an axial load-to-failure model.
Results: The intraprosthetic fixation model was superior to the unicortical locked-screw fixation in all tested devices. The intraprosthetic fixation model required 11,807 N ± 1596 N for failure and the unicortical locked-screw plating required 7649 N ± 653 N ($p = 0.002$).
Conclusion: Intraprosthetic screw anchorage with a special prosthesis drill enhances the primary stability in treating periprosthetic fractures by internal fixation.

1. Introduction

The number of implanted hip prosthesis is still increasing all over the world [1]. This increase and the growth in life expectancy will rise the incidence of periprosthetic fractures [2,3]. Today, the risk of a periprosthetic fracture is about 0.3–2 percent in the first years after implantation [3–7].

Operative treatment is the first choice and non-operative treatment is reserved only for special situations. The best method of operative stabilization is still controversial and depends on different factors [8]. The Vancouver-classification is very useful in choosing the right treatment of these fractures. No doubt, fractures with unstable stems (B2) should be treated by revision arthroplasty [9–15]. Fractures with a stable stem can be treated by osteosynthesis.

However, the best way of stabilization is still controversial. Plate fixation [16–21], cerclages [22–24], and even external fixation [25,26] are described in the literature. Several studies have emphasized the advantage of locking screws. But the screw anchorage in the proximal fragment might be limited due to a mismatch between a big stem and thin cortical shell.

The strongest part in the proximal part is the prosthesis itself. Thus, the idea of an intraprosthetic screw fixation arises to enhance stability in the proximal part. This paper deals with a short insight in the development process of a "prosthesis drill". A biomechanical study compares the stability of intraprosthetic screw fixation and locked plating in a simulated fracture model (Vancouver C). We hypothesized higher fixation strength by intraprosthetic screw fixation than by locked-screw plating.

2. Materials and methods

2.1. Drill-machine

The requirement profile for intraprosthetic drilling includes the development of a drill-machine strong enough to drill metallic implant materials. After testing multiple different types of drills the decision was to use HPC-drills (High performance cutting) which are strong and stable enough to provide optimal intraprosthetic drilling and connectivity to commonly used manual drilling machines in trauma surgery [27]. Second, we had to deal with the rapid temperature increase during drilling solid materials within vital bone tissue and the amount of bore chips being produced during drilling procedure [28]. The temperatures during drilling with

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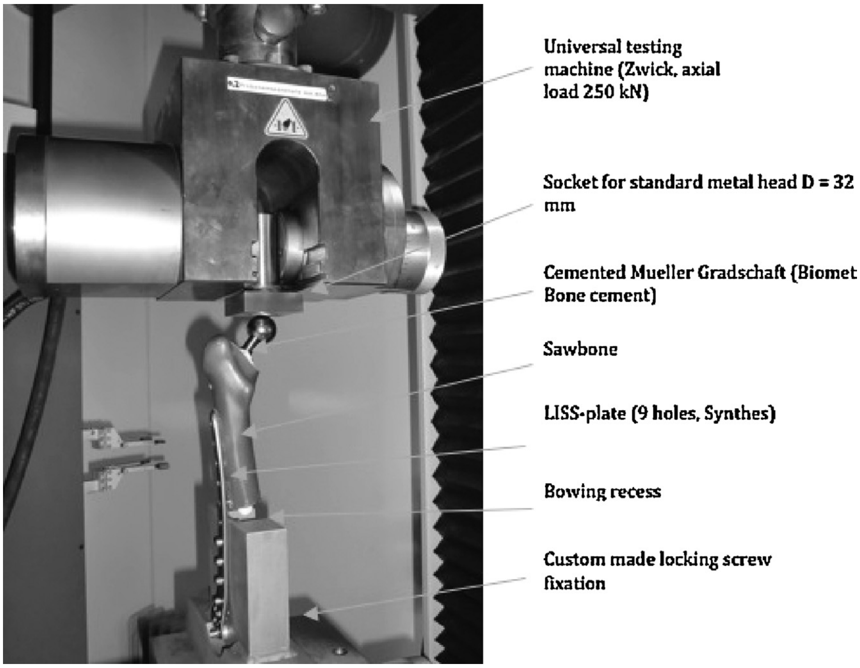

Fig. 1. Illustration of testing model for axial load.

externally applied cooling immediately reached tissue-damaging levels. So, we developed a new, custom-made internal cooling system connectable to HPC-drills and a special transportation channel to remove the produced chips.

The bore chips were removed during the drilling procedure using a separate two-channel suction system mounted around the drilling unit (Fig. 4). The application of the saline cooling solution was made through two spiral channels through the tip of the drill using a systematic pressure of 6 bars to secure permanent volume flow. A pressure vessel was used in which sterile packed saline solution was inserted. The opening of the inserted bottle was pressed into a flat seal using a pressure spring. This pressure vessel was filled with compressed air using the standard compressed air connection in an operating room.

Using continuously applied internal cooling a decrease of drilling temperature to tissue preserving levels was achieved [29].

Third, we had to develop a custom made steel tapping device for thread cutting. Because of the increased rigidity and stiffness of prostheses made from chrome-molybdenum alloys thread cutting is only usable for prostheses made of titanium alloys.

Furthermore, the control of feed forces and the development of a specially designed holding device were point of interest to avoid drilling failure in human bone material.

2.2. *Specimen preparation*

Eight synthetic femurs (four in each group) (Sawbone Composite medium third generation®, Pacific Research Labs Vashon Island, Washington, USA) were used instead of donor bones because of their availability and their equal shape and mechanical characteristics. A conventional hip stem (Ecofit, Implantcast®, Buxtehude, Germany) was implanted in each femur. A cemented implantation to provide an equal primary stability of the stems among all femurs was performed. Differences in thermal conductivity in comparing cemented to cementless implanted prostheses have already been described earlier [30].

The femurs were osteotomized 15 mm below the tip of the stem to create a Vancouver type C periprosthetic fracture. The screw fixation in the proximal part of the femur was our point of interest. The distal femur was abandoned and not involved in the study. We chose a commercial titanium locking plate (LISS = Less Invasive Stabilization System, Synthes®, West Chester, USA) with 9 holes for the fixation. This locking plate is recommended for periprosthetic fractures of the femur and was tested in different studies [17,31,32]. Specially designed periprosthetic screws with the diameter of 5 mm (Periprosthetic Locking Screws, Synthes®, West Chester, USA) are available to increase the number of threads within the unicortical fixation

In the control group, the locking plate was fixed with three unicortical locking screws implanted at the level of the prosthesis and one solid bicortical locking screw below the tip of the cemented stem. In the second group, the locking plate was fixed with the same bicortical screw configuration beneath the tip of the prosthesis. Two intraprosthetic screws were implanted instead of the three unicortical screws. After drilling two holes at the level of the prosthesis (insertion depth 10 mm), a thread was cut into the drill hole using a custom made tapping device. The company (Synthes®, West Chester, USA) provided us with screw blanks, which had the threaded locking head but a non-manufactured shaft. We customized threads that fitted the tapped threads within the prosthesis. The screws were inserted with the commercial torque wrench.

The distal plate end was fixed in a specially designed cup with locking screws to provide the maximum stability during testing. An insertion angle of 6° valgus direction was chosen following the mechanical axis of the femur of the leg (Fig. 3).

2.3. *Mechanical testing*

Tests were performed with the prepared specimen mounted in a universal testing machine using a custom made locking screw device for the LISS-plate fixation (Zwick Z250®, Ulm, Germany, Fig. 1). A standard commercially available metal head (32 mm) was placed at the top of the implanted prosthesis. A constantly increasing load was applied to the metal head in the anatomical axis of the femur with a starting force of 0 N (Newton). The applied force