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Original article

# A pilot trial comparing the tear-out behavior in screw-sockets and cemented polyethylene acetabular components – a cadaveric study

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ABSTRACT

*Background:* The removal of well-fixed acetabular components following THA (total hip arthroplasty) is a difficult operation and could be accompanied by the loss of acetabular bone stock. The optimal method for fixation is still under debate. The aim of this pilot study was to compare the tear-out resistance and failure behavior between osseo-integrated and non-integrated screw cups. Furthermore, we examined whether there are differences in the properties mentioned between screw sockets and cemented polyethylene cups.

*Hypothesis:* Tear-out resistance and related mechanical work required for the tear-out of osseo-integrated screw sockets are higher than in non-integrated screw sockets.

*Patients and methods:* Ten human coxal bones from six cadavers with osseo-integrated screw sockets ($n=4$), non-integrated (implanted post-mortem, $n=3$) screw sockets and cemented polyethylene cups ($n=3$) were used for tear-out testing. The parameters axial failure load and mechanical work for tear-out were introduced as measures for determining the stability of acetabular components following THA.

*Results:* The osseo-integrated screw sockets yielded slightly higher tear-out resistance ($1.61 \pm 0.26$ kN) and related mechanical work compared to the non-integrated screw sockets ($1.23 \pm 0.39$ kN, $P=0.4$). The cemented polyethylene cups yielded the lowest tear-out resistance with a failure load of $1.18 \pm 0.24$ kN. Compared to the screw cups implanted while alive, they also differ on a non-significant level ($P=0.1$). Osseous failure patterns differed especially for the screw sockets compared to the cemented polyethylene cups.

*Discussion:* Osseo-integration did not greatly influence the tear-out stability in cementless screw sockets following axial loading. Furthermore, the strength of the bone-implant-interface of cementless screw sockets appears to be similar to cemented polyethylene cups. However, given the high failure load, high mechanical load and because of the related bone failure patterns, removal should not be performed by means of tear-out but rather by osteotomes or other curved cutting devices to preserve the acetabular bone stock.

*Level of evidence:* Level III, case-control-study.



## 1. Introduction

Total hip arthroplasty (THA) is one of the most frequently performed orthopedic procedures with very high success rates [1]. Regarding the acetabular component, there are various methods for fixation into the coxal bone. Cemented polyethylene cups, screw sockets or press-fit systems are frequently used [2,3]. The optimal method for the fixation of the acetabular component still remains controversial [4–7]. The cemented fixation method shows a high primary stability in the early postoperative phase [8]. It is also well established that the surface porosity of cementless implants allows for sufficient osseo-integration into the pelvis [9–11].

Nevertheless, one of the most common complications in clinical practice is aseptic loosening of the acetabular component [12–16].

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Furthermore, there are indications for the revision of a well-fixed acetabular component, including malpositioning, infection or polyethylene wear [17]. The removal of the acetabular component can be demanding and requires patience and caution. It should therefore be performed by experienced surgeons only [17–19]. The reason for this is, because removal is often associated with extensive bone loss and fracturing, especially in osteoporotic bone [18,20–22]. Therefore, during revision of acetabular components, one of the priorities must be the preservation of the remaining bone stock at the acetabulum. Many techniques have been documented for the removal of the acetabular component, which can be achieved with the use of drills, screws, reamers, curved blades, chisels or osteotomes [23–27]. However, there is no optimal removal tool as a "gold standard" in current practice. Possibly, this is due to missing mechanical data such as tear-out resistance or mechanical work necessary to explant an acetabular component of different types and fixation methods. These data could possibly provide a basis for the development of new surgical methods and devices for a less invasive removal of the acetabular component. Given the lack of mechanical data, the aim of the current study was to compare the mechanical parameters axial failure load and mechanical work as well as the failure characteristics between osseo-integrated and non-integrated screw sockets following a tear-out. Furthermore, we examined whether there were differences in the properties mentioned between screw sockets and cemented polyethylene cups. The following hypothesis was addressed with the tests on human cadavers: the mechanical parameters axial failure load and mechanical work required for the tear-out of osseo-integrated screw sockets are significantly higher than in non-integrated screw sockets.

## 2. Patients and methods

### 2.1. Human tissues and anatomical preparation

Ten coxal bones were removed from six human cadavers (bilateral: 4 cadavers, unilateral: 2 cadavers) (Table 1). While alive, all body donors gave their informed and written consent to the donation of their bodies for teaching and research purposes. Being part of the body donor program regulated by the Saxonian Death and Funeral Act of 1994 (third section, paragraph 18 item 8), institutional approval for the use of the post-mortem tissues of human body donors was obtained from the Institute of Anatomy, University of Leipzig.

Recruitment of the cadaveric tissues took place between 1 January 2014 and 31 December 2014. All cadavers underwent X-ray imaging of the pelvis to clarify the presence of implanted total hip arthroplasties and to rule out additional pathologies or fractures before mechanical testing. Seven cadaveric coxal bones contained ingrown THA acetabular components with screw sockets ($n = 4$, 3rd generation, type biconical, manufacturer unknown) or cemented PE cups ($n = 3$, type and manufacturer unknown). The specimens with ingrown implants all showed macroscopic signs of osseo-integration into the coxal bone and were defined as osseointegrated for the investigations. Three native cadaveric coxal bones were held as a control group for implanting screw sockets post-mortem. None of the acetabula without an implant showed excessive signs of osteoarthritis. Immediately after removing the innominate bones from soft tissues, the anatomically unfixed tissues were precooled and then shock frozen at −80 °C.

### 2.2. Mechanical testing

In preparation for the mechanical tests, the coxal bone specimens were thawed carefully and embedded in a custom-made form by means of polyurethane foam (Götz Service GmbH, Premium TEC Hartschaum, Göppingen, Germany). The socket entrance level was grossly aligned perpendicular to the horizontal plane and fine adjusted after mounting the specimens in the materials testing machine. Into three native coxal bones without implants, size-matched biconical screw sockets, made of titanium (Bicone plus, Smith&Nephew GmbH, Hamburg, Germany) were implanted manually post-mortem by an experienced orthopedic surgeon immediately before the tests. Two additional steel rods were mounted on top of each of the coxal bones to reinforce the bone-polyurethane-composite from loosening. Metallic sockets were mounted to the testing machine by means of a surgical extractor tool (Endocon GmbH, Heidelberg, Germany), tightened with 60 Nm. The testing setup is depicted in Fig. 1. The coxal bones containing polyethylene sockets were mounted to the testing machine by means of a custom-made ball extractor, fixed to the sockets by means of bone screws (Fig. 1). Before the mechanical tests started, the coxal bones were moistened and warmed in isotonic saline (0.9% by mass, T = 37 °C).

Uniaxial tensile tests were performed using a mechanical testing device (DYNA-MESS, Aachen, Germany). A preload of 10 N was defined for all experiments. The testing rate was 20 mm/min ranging up to the point of material failure, indicated by a visible extraction of the implant and a loss of strain of at least 30% of $F_{max}$. A 10-kN load cell was utilized to record the force-displacement data. The site and type of implant loosening was photo-documented for a qualitative description of the implant behavior.

### 2.3. Statistical analysis

Statistical comparison of the data was performed by using Microsoft Excel (version 2013, Redmond, USA) and SPSS software

**Table 1**
Baseline data body donors.

| Specimen | Age | Sex | Cup size (left/right) | Cup type | State of ingrowth | Cause of death |
|---|---|---|---|---|---|---|
| 31–13 | 60 | ♀ | ××/54 mm | Screw socket – Bicone plus | Post-mortem implanted | Cardiac insufficiency |
| 43–14 | 77 | ♂ | 54 mm/54 mm | 2× screw socket – Bicone plus | Post-mortem implanted | Respiratory insufficiency |
| 45–14 | 84 | ♀ | 48 mm/52 mm | 2× screw socket – type: biconical | Osseointegrated | Glomerulonephritis |
| 49–14 | 87 | ♀ | 48 mm/50 mm | 2× PE – type: unknown | Cemented | Epilepsy |
| 91–14 | 91 | ♂ | 52 mm/54 mm | 2× screw socket – type: biconical | Osseointegrated | Anemia |
| 94–14 | 90 | ♀ | ××/48 mm | PE – type: unknown | Cemented | Respiratory insufficiency |
| Mean value | 81.5 | 4♀/2♂ | | | | |
| Standard deviation | 10.7 | | | | | |

PE: polyethylene cemented cup.