INTRODUCTION:
Ceramic hip components are known for their superior material properties concerning the in-vivo loading situation. In comparison to other commonly used materials, ceramics have a very low friction coefficient and a high fracture load. However, there are a few reported occasions of in-vivo fracture of ceramic ball heads.

An experimental set-up, that imitates the in-vivo loading situation is used to analyze different scenarios that may lead to the fracture of the ball heads, such as dynamic loading, edge loading and the metal taper condition.

In this paper it will be shown that even the worst-case set-up does not lead to fracture loads when the interface between ceramic ball head and metal taper is clean and dry. In contrast, certain disturbances/impurities of this interface can cause a further reduction of the fracture load.

METHODS:
Ceramic ball heads made of pure alumina have been loaded until fracture under various conditions. The angle between the loading direction and the metal taper equals 35°, the ceramic ball is mounted in an alumina insert, as shown in figure 1. Parameters under investigation are the inclination of the insert, the loading rate and the condition of taper and ball head (contamination of the interface between taper and ball with adipose and osseous tissue; stripe wear on the outside of the ball head).

RESULTS:
Altogether 58 specimens (all alumina head mounted on a titanium taper) have been tested, whereas respectively half of the ball heads were of the geometry 28-12/14 S and 28-12/14 L. Besides two exceptions, each measurement has been repeated two times. To resemble the position of the human acetabulum during walking and standing up, the inclination of the insert is chosen to differ between 45° (walking) and 80° (standing up). A variation of the loading speed is also tested, with a chosen parameters: 0.5 kN/sec and 25 kN/sec.

For fabric samples, bovine femur (corticalis) and porcine adipose tissue are used. The size of the samples is rather small: 0.5 x 2 x 4 mm for the osseous tissue and 1 x 2.5 x 2.5 mm for the adipose tissue.

All fractured ball heads are statistically analyzed regarding the appearance of fracture in general, the fracture origin, and the metal debris in the cone of the ceramic ball head. As a further criterion, the stiffness of the set-up in kN/mm is calculated for each test. A change in the stiffness of the set-up is due to the penetration of the taper in the cone of the ball head. The value includes information on the friction coefficient between the taper and the ball head.

Additionally, theoretical and numerical calculations are used to explain and support the experimental findings.

DISCUSSION:
The influence of edge loading and contamination of the interface between taper and ball with osseous tissue on the fracture load can be shown. If the insert has a high inclination angle, high bending forces are applied to the ball head amplifying the effect of edge loading. It should be accentuated, that the minimum fracture load of a ball head without contamination of the interface is still twice as high as the maximum forces measured in-vivo by Bergmann.

Contamination with osseous tissue leads to a minimum fracture load of approximately 8 kN (KK 28-12/14 L) was measured.

REFERENCE:
1 Bergmann et. al., J. Biomechanics. Vol. 26, No. 8; 1993