The Difference in Progression of Osteoporosis Decides the Mode of Femoral Neck Fracture

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Introduction

The fracture mode of intracapsular-femoral neck fracture is generally classified into two types; typical fracture type (Type A) and crescent fracture type (Type B). In our previous study in which relationship between a mechanical strength and an anisotropy of osteoporotic trabecular bone to principal compression trabecular group (PCTG) in femoral heads were examined, it was confirmed that the anisotropy was lost as osteoporosis progress and that Type B fracture increased accordingly. That is, the fracture type is decided not only by bone mineral density but also by the structure of trabecular bone. In this study, bone density, histomorphometric indices and micro-fracture behaviors of trabecular bones from two types of the fracture are examined; and relationship between osteoporotic alternation of the trabecular structure and the fracture types are investigated.

Materials & Methods

Fig.1 shows X-ray figures of the fractured femoral heads that were excised for prosthetic replacement of the femoral neck fracture. PCTG is composed of both a longitudinal plate like trabecula (Plate-Tb) orient parallel to the fabric orientation of PCTG, and a transverse rod like trabecula (Rod-Tb) perpendicular to Plate-Tb.

In this experiment, 14 Type A (average age 76) and 9 Type B (average age 84.9) femoral heads and 8 non-fractured femoral heads from embalmed cadavers as a control were used. The specimens for mechanical test obtained from PCTG were machined into the board-like pieces (16×16×7mm). The apparent dry density of these specimens was measured. Undecalified section of the specimens was made, and two histomorphometric (micro-structural) indices, Trabecular thickness (Tb.Th) and Node number per tissue volume (N.Nd/T.V) were measured.

Those specimens were subjected to the shear test, to observe the micro-fracture of the trabeculae as shown in Fig.2a. A notch (8mm in length and 0.6mm in width) was machined parallel to the orientation of PCTG in order to make observation of the micro-fracture in the trabecula easier (Fig.2b). In perpendicular specimen was, the notch was machined in perpendicular direction across the orientation. Then the load was applied along the notch by a platen (loading rate was 0.2mm/min). During the test, the fracture behavior of trabeculae around the end of notch was recorded by VTR system.

Figure 1: X-ray figures of the fractured and non-fractured femoral heads. “PCTG” means the principal compression trabecular group.

Figure 2: Schema of the shear test. Configuration of the specimen (a) and the test procedure (b); where the platen moves upward along the notch.
Results & Discussion

Fig. 3 shows the apparent dry densities of three types of femoral heads. The density for Control was 0.379 g/cm³, then decreased Type A and Type B in that order. As shown in Fig. 4, both Tb.Th and N.Nd/T.V of the fractured groups were smaller than that of Control. Tb.Th and N.Nd/T.V of Type B were smaller than that of Type A. From those results, it might be said that osteoporosis is more advanced in Type B than Type A.

![Graph comparing apparent dry densities of three types of femoral heads.](image)

**Figure 3:** Comparison of apparent dry density in three types of the femoral heads. Apparent dry density was delivered from that a mass of the specimen was divided by an apparent volume of it.

Fig. 5 shows micro-fracture behaviors of the trabeculae in the parallel specimen of Control. As shown with arrows, the micro-fractures were developed in Rod-Tb that were on the extension line of the end of notch. The fracture behaviors of Type A (parallel) were similar to those of Control. The observation with VTR suggests that transverse trabeculae were broken first by bending load in Control and Type A.

![Micro-fracture behaviors in Control.](image)

**Figure 5:** Photos show the micro-fracture of two trabeculae in the parallel specimen of Control. Preloaded condition (a), as load is increasing Rod-Tb that are indicated by arrows fractured (b).

![Micro-fracture behaviors in Type B.](image)

Fig. 6 shows a micro-fracture behavior in the parallel specimen of Type B. The micro-fractures were also developed in Plate-Tb on the extension of the end of notch. This fracture mode seemed to be buckling due to compressive force. The reason of this buckling is explained, first by much advanced osteoporosis.
on Rod-Tb and second, by disappearance of the mechanical function of Rod-Tb which play the role as ribs for Plate-Tb in the structure.

Fig.7 shows micro-fracture behaviors in the perpendicular specimens of Control and Type B. In the case of Control, Plate-Tb that was on the extension of the end of notch was bended, and then fractured (Fig.7a). On the other hand, any micro-fractures of trabeculae were not observed around the end of notch in Type B, but just the trabeculae at the contact area of load platen were crushed (Fig.7b). That is, it can be considered that Rod-Tb did not work as a pillar and could not resist the loading because an effective diameter of Rod-Tb was decreased by osteoporosis.

Those results explain that the why Plate-Tb lost stiffness in the parallel specimens of Type B and consequently it was fractured by buckling. Those results also suggest that osteoporosis take the mechanical function away from Rod-Tb especially and that it is deeply involved in a biomechanical etiology of the femoral neck fracture.

**Conclusions**

The importance of trabecular structure in decision of the fracture types was confirmed by this study. In the less advanced osteoporosis such as Control or Type A, the transverse trabeculae play role in protecting the micro-fracture of longitudinal trabeculae. In accordance with the advance in osteoporosis, the transverse trabeculae cannot play such roles and both trabeculae fracture at the same time. In other words, the anisotropy disappeared in advanced osteoporosis in which PCTG plays no more role, that lead to impaction-type fracture, namely crescent type fracture Type B.

**Reference**