INTRODUCTION
The location of the lateral boundary of the necrotic lesion is well known to affect the fate of osteonecrosis of the femoral head. When the lateral boundary is located at the weight-bearing portion of the femoral head, collapse of the femoral head frequently occurs. On the other hand, collapse rarely occurs when the lateral boundary is located at the medial portion of the femoral head. These facts suggest that a fracture at the lateral boundary of the necrotic lesion may be an important point for a collapse. To our knowledge, however, there have been few reports investigating the morphological characteristics of a collapsed region.

In this study, we assessed whether a collapse always involved the fractures at the lateral boundary of the necrotic lesion, and also examined whether a collapsed region was associated with the size of necrotic lesion.

METHODS
Thirty consecutive femoral heads (from 25 patients, 17 males and 8 females) were obtained during surgeries for the treatment of stage-3A (defined as less than 3 mm femoral head collapse) or -3B (3 mm or more) osteonecrosis. The mean age at the time of the operation was 47 (range, 31-69 years). Thirteen femoral heads were associated with the use of corticosteroids, 15 with alcohol abuse, and two without any etiological factors.

Based on the whole serial cut sections, gross photographs, specimen radiographs, and histological sections were evaluated in each case.

Thirty femoral heads were divided into two groups based on the positional relationship in the central cut section (through the fovea of femoral head) between the site of medial boundary of necrotic lesion and the distal end of the fovea (Fig. 1A). A univariate analysis between the groups was performed by means of Fisher exact probability test in proportion of collapse in the subchondral region.

RESULTS
In all of 30 femoral heads, a collapse always involved the fractures at the lateral boundary of the necrotic lesion, which was observed in all serial cut sections. Histologically, the fractures occurred at the junction between the thickened trabecula associated with appositional bone formation and the necrotic bone trabecula. The histological features were consistent for all femoral heads. In two femoral heads, which were both characterized by a beak-shaped intact region in the lateral area, the fractures at the lateral boundary of the necrotic lesion were not obvious in both the gross photographs and specimen radiographs, but were seen in microscopic sections (Fig. 2).

When the medial boundary between the necrotic and viable zone was located lateral to the fovea of femoral head on the central cut section (Small Group), 18 of 19 femoral heads (94.7%) collapsed in the subchondral region (Fig. 1B). In the remaining one femoral head, collapse appeared deep within the necrotic lesion. On the other hand, when the medial boundary was located medially beyond the fovea (Large Group), collapse in the subchondral region was found in four of 11 femoral heads (36.4%). In the four of the other seven femoral heads, collapse appeared in the deep necrotic region near the underlying necrotic-viable interface (Fig. 1C). In the remaining three femoral heads, collapse appeared deep within the necrotic lesion. Regarding the proportion of collapse in the subchondral region, two groups differed significantly (p = 0.0011).

DISCUSSION
This study demonstrated that a collapsed femoral head in osteonecrosis inevitably involves the fractures at the lateral boundary of the necrotic lesion. Considering the histological findings of these fractures, we supposed that focal concentration of stress at the junctions between the thickened trabecula of the reparative zone and the necrotic bone trabecula may be one of the significant causes of the fractures at the lateral boundary of the necrotic lesion.

In this study, collapse in the subchondral region was significantly associated with the location of medial boundary of the necrotic lesion. Meanwhile, in cases with large necrotic lesions, we often found collapse in another region, including a deep necrotic region near the underlying necrotic-viable interface. Our findings may be partially explained by a previous three-dimensional finite elementary model study, which demonstrated that high stress in the deep necrotic portion above the necrotic-viable interface was loaded with an increased necrotic angle. We therefore consider that the size of the necrotic lesion may be one of the influential factors for the collapsed regions.

REFERENCES