

Phenotype classification of advanced knee osteoarthritis based on occurrence of subchondral bone cysts

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Purpose: Subchondral bone cyst (SBC), which is a pseudo-cystic lesion of the subchondral bone, is one of the cardinal radiographic features of OA hip and knee; yet its exact role in the pathogenesis and pathophysiology of OA are still poorly understood and remain debatable. Finite-element analysis studies have indicated that such lesion may alter the stress distribution of the subchondral bone, leading to severe loading on the pericystic region; and to look into that hypothesis, we have previously performed a micro-CT study and was able to observe sclerotic changes in subchondral trabeculae adjacent to SBC. The links between SBC and the overall subchondral bone turnover and structure however, remains unknown. Here, we examine the correlation between presence of SBC in various load-bearing and non-load-bearing locations and its effect & correlation with different regions of the tibial plateau, also explore its relationship with functional disability of OA knees.

Methods: A total of 144 advanced knee OA patients undergoing total knee arthroplasty (TKA) were selected. The resected tibial plateaux were divided into three regions, namely lateral compartment, tibial eminence and medial compartment for Micro CT imaging and histo-morphology analyses. Lower limb axial alignments were measured on pre-op long film standing X-rays. Knee functions were assessed by orthopaedic specialists based on Knee Society Knee Score & Functional Scores systems.

Results: Out of the 144 tibial plateaux, 84.7% were SBC+, and a total of 184 SBCs were identified. Among these 184 SBCs, 53.3% occurred in tibial eminence, 29.3% in the medial compartment and 17.4% in the lateral compartment.

The presence of SBCs in tibial eminence is correlated with lower bone mineral density ($.63 \pm .047 \text{g/cm}^3$ versus $.65 \pm .054 \text{g/cm}^3$, $p=.011$), bone volume fraction ($17.62 \pm 4.31\%$ versus $20.36 \pm 8.44\%$, $p=.047$), bone surface to tissue volume ratio ($3.41 \pm .78\%$ versus $3.87 \pm .91\%$, $p=.002$), trabecular number ($.92 \pm .25$ versus $1.01 \pm .30$, $p=.002$) and connectivity density ($7.16 \pm 3.28/\text{mm}^3$ versus $8.55 \pm 3.47/\text{mm}^3$, $p=.021$) and larger trabecular separation ($.70 \pm .10 \text{mm}$ versus $.64 \pm .13 \text{mm}$, $p=.002$), pointing towards an osteopenia-like phenotype of lateral compartment; we have also observed a similar correlation between presence of SBC in medial compartment and tibial eminence bone parameters. Our histo-morphology analysis had shown that bone changes in SBC-positive specimens are accompanied by presence of densely nucleated tissues in the marrow space, indicating fibrotic changes ($21.9 \pm 7.9\%$ versus $11.1 \pm 7.4\%$, $p=.037$). There was no significant difference between SBC-having and SBC-negative groups in terms of axial alignment angle (167.88 ± 10.92 versus 167.79 ± 5.03 , $p=.953$).

Generally speaking, patients with SBCs tended to be more severe functional disabilities, presenting more joint pain and having poor walking capability before surgery ($p=.017-.034$).

Conclusions: We have observed osteopenia-like changes in the lateral compartment of SBC-positive tibial plateaux, namely lower bone mass and increased trabecular separation; this alteration cannot be simply accounted for by unloading-induced bone loss of lateral compartment in knees with more severe varus deformity as there is no correlation between presence of SBC and degree of axial alignment in our cohort.

We hypothesise the osteopenia-like phenotype, with lower mechanical strength, could make the subchondral environment more vulnerable to trauma and thus bone marrow oedema & chronic inflammation, and may be a risk factor for SBC formation.