Osteoarthritic bone structural changes may result from physiologic bone adaptation

Orthopaedic Biomechanics

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Introduction

No cure is available for osteoarthritis (OA), the most common joint disease. Therapies focus on the degenerating cartilage, but bone plays an important role in the disease process as well. Bone microarchitecture changes, cartilage is replaced with bone, and cysts develop (Fig. 1). Each of these changes may contribute to OA progression or aggravate symptoms. The question is whether the bone changes result from a pathologic process or from physiologic adaptation in response to altered circumstances in OA joints.

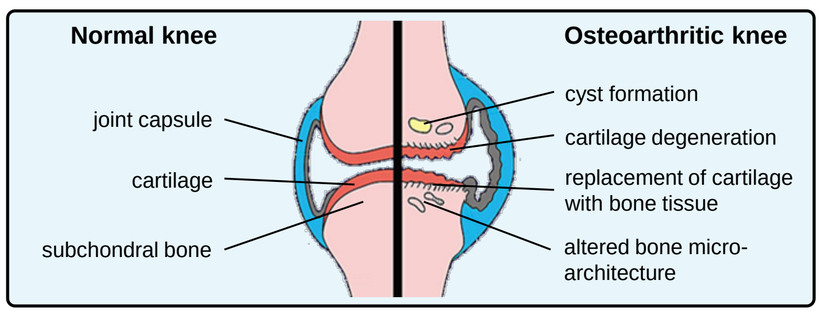

Fig. 1: *During OA progression both cartilage and bone tissue change.*

Methods

We tried to answer this question using an established computational bone adaptation model[1] (Fig. 2). In the model, osteoblasts form bone in response to mechanical load sensed by osteocytes, and osteoclasts resorb bone near randomly occuring microcracks. With finite element analysis we calculated strain energy density (SED) values.

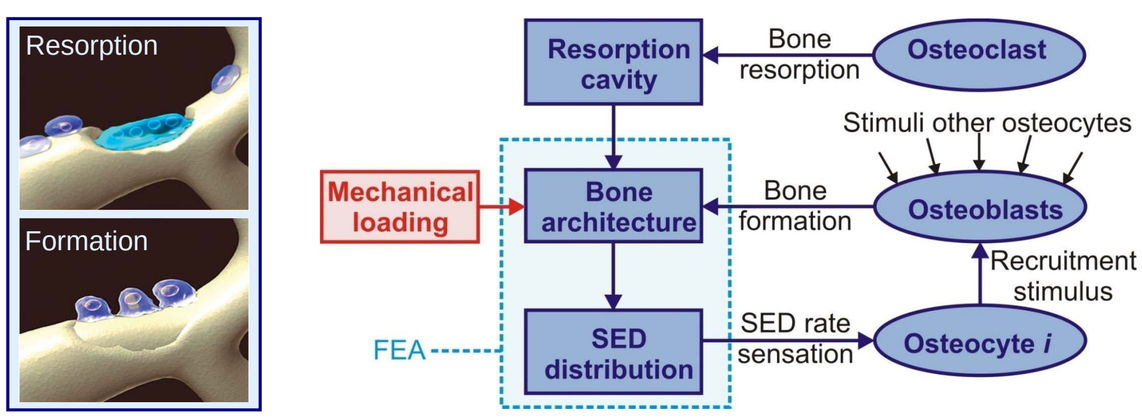

Fig. 2: *Left:* Bone adaptation of a single trabecula. *Right:* Schematic representation of the mathematical model.

Based on experimental and clinical data from the literature, we investigated the effect of bone adaptation in reponse to various factors that may play a role in OA joints (Table 1).

Table 1: OA bone structural changes and altered joint circumstances that may initiate an adaptation response causing these changes.

Bone structural change	Altered joint circumstance
1. altered microarchitecture	- high joint loading - low bone matrix mineralization
2. replacement of cartilage with bone tissue	osteoclast delivery as a result of vascularization of the mineralized cartilage
3. cyst development	entrance of joint fluid into the bone tissue

Results

<u>Altered microarchitecture</u>

Predicted changes in microarchitecture in response to both high joint loading and low bone matrix mineralization were similar to those observed in OA (Table 2).

Table 2: Increases (+) and decreases (-) in bone structure parameters.

Parameter	OA	high load	low mineralization
bone volume fraction	+	+	+
trabecular thickness	+	+	+
trabecular number	-	-	-
trabecular separation	-	-	-

<u>Replacement of cartilage with bone tissue</u>

Bone adaptation simulations resulted in the successful replacement of cartilage with bone tissue (Fig. 2).

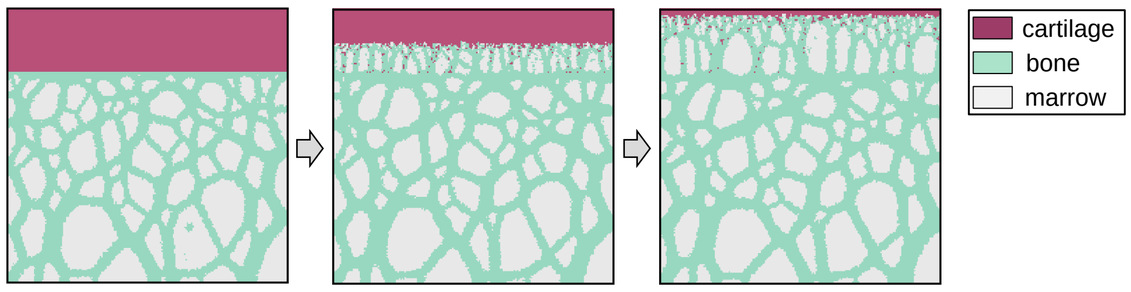

Fig. 3: The bone adaptation process may result in cartilage thinning.

<u>Cyst development</u>

Simulations of bone adaptation in response to fluid pressure resulted in the development of cavities with a typical cyst-like appearance (Fig. 3).

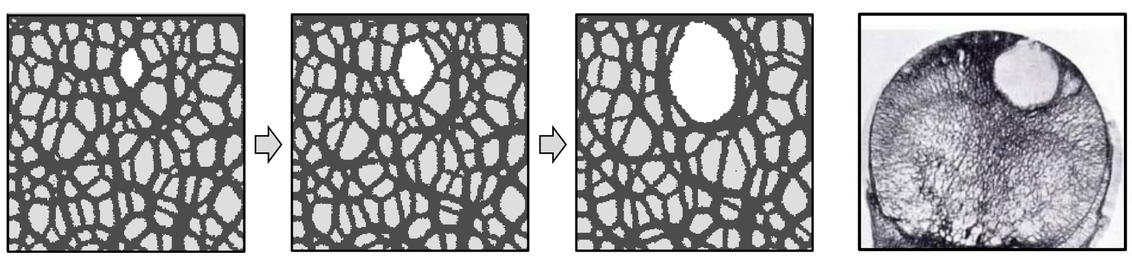

Fig. 4: *Left:* Simulation of the growth of a rounded fluid-filled cavity with a sclerotic rim. *Right:* Subchondral bone cyst in the femoral head.

Discussion

Currently OA therapies are being developed that inhibit bone cellular activity. However, our simulations indicate that bone cells may not be affected in OA. Instead, bone changes may result from physiologic adaptation in response to altered circumstances in OA joints. As bone adaptation serves to remove microdamage and optimize local bone tissue load, inhibiting bone cellular activity could have an adverse effect and compromise bone strength.

References

[1] Huiskes *et al.*, Nature, 2000.