The ultrastructure of the peri-articular osteophytes – an evaluation by scanning electron microscopy

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Summary

Objective: **Osteophytes are intra-articular osteochondral tissues, which are usually found at the margins of degenerating synovial joints. The aetiology or pathogenesis of this tissue has been a subject of protracted debate. The aim of this study was to offer a possible aetiology and or pathogenesis of this expendable yet important osteochondral tissue using the scanning electron microscopy to evaluate the structure of the cartilage mantle of osteophytes and the relationship of this mantle with that of the adjoining normal articular cartilage.**

Methods: **Sections of periarticular osteophytes and osteophyte-normal articular cartilage composite tissues were obtained during total knee replacement for osteoarthritis (OA). These sections were routinely processed and examined using the scanning electron microscope with emphasis on the osteophytic cartilage mantle and the merger of the osteophyte and the adjoining normal articular cartilage.**

Results: **The cartilage mantle of osteophytes was found to be thinner but continuous with that of the adjoining normal articular cartilage. However, a longitudinal bar of acellular tissue was found to separate the subchondral bones of both tissues. The cellular (chondrocyte) arrangement in the osteophytic cartilage was similar to that of the adjoining normal articular cartilage. In addition, in the superficial layer, there was looping of collagen fibres between the normal articular cartilage mantle and that of the osteophytic tissues.**

Conclusion: **The continuity between the cartilage mantle of osteophytes and the adjoining normal articular cartilage may suggest that in the formation of osteophytes, the chondrocytes from the adjoining normal articular cartilage greatly influence the mesenchymal tissue precursor of osteophyte to differentiate along a chondrocytic pathway initially. With subsequent vascular invasion probably from the periosteum, the neocartilage develops a bony core with a completely separate blood supply from that of the adjoining subchondral bone.**

Key-words: ***Osteophyte, Osteoarthritis, Cartilage mantle, Critical point drying scanning electron microscope.***

Résumé

Objéctif: Les ostéophytes sont des tissus ostéochondité intra-articulaire qui sont normallement trouvé dans les marges d'articulation synoviale dégénerative. L'étiologie ou la pathogénèse de ce tissu est toujours le sujet de débat prolongé. L'objet de cette étude est de donner une étiologie possible et on pathogénèse de ce extensible et encore tissue ostéochnodral significatif avec l'utilisation d'électron microscope scanneur pour évaluer la structure du manteau du cartilage d'ostéophyte et le rapport de ce manteau avec le cartilage articulaire moyen normal.

Methodes: Les sections d'ostéophytes périarticulaires et tissus composite cartilage ostéophyte moyen articulaire ont été obtenuses pendant remplacement total du genou pour ostéoarthrite (OA). Ces sections sont traités d'usage et étudié avec l'utilisation du microscope électronique scanneur avec l'insistance sur le manteau cartilage ostéophytique et la fusion d'ostéophyte et le cartilage articulaire moyen à côté.

Résultat: Le manteau du cartilage d'ostéophyte est noté d'être mince mais continue avec celui du cartilage articulaire moyen à côté. Toutefois, une barre longitudinale du tissu acellulaire était trouvée qui sépare l'os subchondral des deux tissus. La disposition cellulaire (chondrocyte) dans le cartilage ostéophytique était semblable au couche superficielle il y a eu un looping des fibres collagène entre le manteau cartilage articulaire moyen et celui des tissus d'ostéophytique.

Conclusion: La continuité entre le manteau cartilage d'ostéophytes, et le cartilage articuliaire moyen à côté pourrait suggérer que dans la formation d'ostéophytes, les chondrocytes à partir du cartilage articulaire moyen à côté influence fortement le précurseur tissus mesencymal d'ostéophyte afin de différencier le long de sentier chondrocytique au départ. Avec l'invasion vasculaire ultérieure probablement à partir du périosteum, le néocartilage développe un noyau oseux avec approvisionnement du sang complètement separé du celui de subchondral oseux à côté.

Introduction

Osteophytes are intra-articular outgrowths that are commonly found at the margins of the articular cartilage in synovial joints in response to a more central full

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thickness damage to the cartilage[1,2,3]. They are composed of a cartilage mantle and subchondral bone. The native collagen types found in the cartilage mantle of osteophytes have been shown to be similar to those found in normal articular cartilage[4].

However, the exact mechanism of formation of osteophytes remains unknown and various hypotheses have been proposed[5]. It has been established that these osteochondral tissues merge with or even overgrow the adjoining articular cartilage[4,6]. The subchondral bone of osteophyte is also presumed to merge with and communicate freely with that of the adjoining articular cartilage subchondral bone[7,8]. These conclusions will therefore suggest that osteophyte do play a role in load transmission in the degenerate synovial joint and that this tissue is closely linked to the normal articular cartilage.

Scanning electron microscopy on the other hand has been shown to have a great depth of focus and high degree of resolution permitting an adequate investigation of relatively large specimens in three planes[9,10,11]. The aim of this study was to investigate the cellular architecture of osteophytes, evaluate osteophyte-articular cartilage junction and assess the link between these two intra-articular structures.

Materials and methods.

Osteophytes were obtained from the trochlear margin of the distal femur in 6 patients undergoing total knee replacement for osteoarthritis (OA). The patients were aged 66-88 years. Sections of osteophytes and osteophyte-normal articular cartilage composite tissues were also obtained from the same set of patients.

Both groups of specimens were fixed in 2% cacodylate buffer for 3 weeks. Thereafter, the cacodylate buffer was replaced with 50% ethanol (30 minutes), 70% ethanol (30 minutes), 90% ethanol (30 minutes), 100% ethanol (1 hour) and stored in 100% acetone until ready for critical point drying. The specimens were transferred into a gelatin capsule and the capsule transferred into the boat of the critical point dryer chamber. The boat was flushed with liquid CO_2 about three times over a period of about 10 minutes to remove all the acetone and the specimens left for one hour. Thereafter, the chamber was heated with hot water until the temperature reached 35°C and then the pressure inside the chamber was slowly reduced to complete the critical point drying. The specimens were removed from the chamber, glued unto specimen stubs, coated with 15 nanometre of gold using a Polaron coating unit and viewed with the DS 130 scanning electron microscope[12].

Results

There were fewer lacunae in the osteophytic cartilage mantle and they were surrounded by dense collagen mesh (Figure 1). The sagittal section of the osteophyte-articular cartilage composite tissue revealed a thinner cartilage mantle in the osteophytic segment although there was continuity of the cartilage mantle of osteophyte with that of the adjoining normal articular cartilage. The subchondral bones of both tissues were also clearly demarcated by a continuous ridge of acellular tissue, which originated from the apex of the cartilage merger (Figure 2). At a higher magnification, bridging collagen fibres were observed connecting the cartilage mantles of the osteophyte and the adjoining normal articular cartilage in the superficial layer (Figure 3). The collagen fibres in the normal articular cartilage mantle were observed to form loops and meshes with a few of the fibres terminating in rounded knobs. However, most of

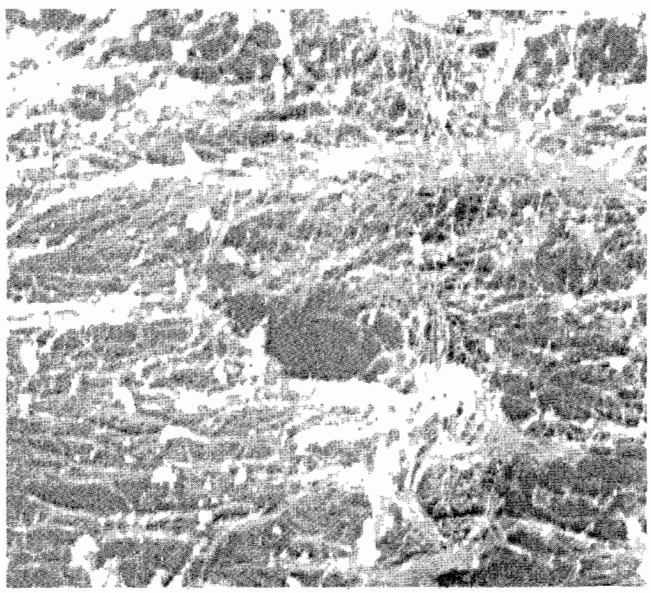

Fig. 1 ***A lacuna in the osteophytic cartilage mantle surrounded by dense collagen mesh.***

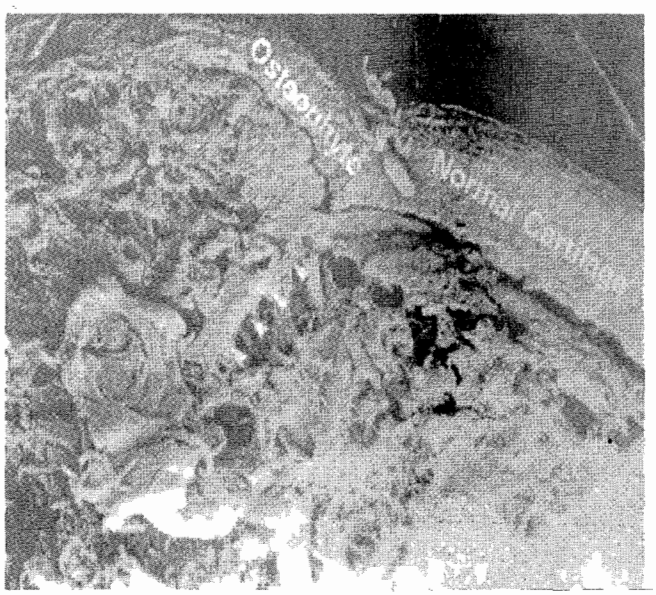

Fig. 2 ***Sagittal section of the composite tissue showing continuity of the cartilage mantle of osteophyte (os) with that of the adjoining normal articular cartilage (nc) but the subchondral bones of both tissues are clearly demarcated by a continuous ridge of acellular tissue (white arrows).***

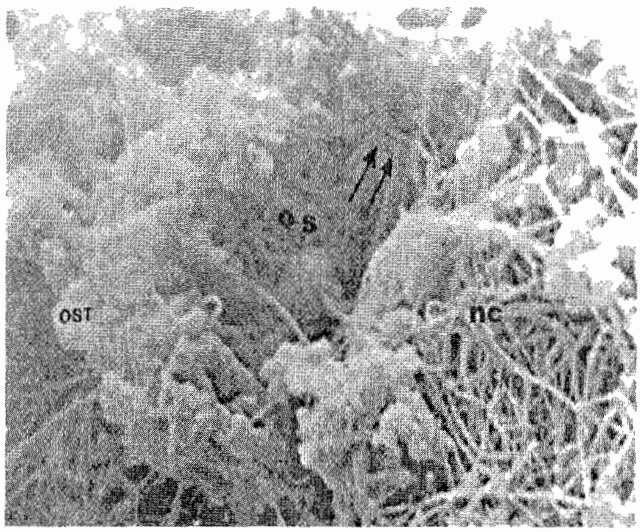

Fig. 3 ***Section of the composite tissue showing bridging collagen fibres (arrows) connecting the cartilage mantles of the osteophyte (os/ost) and the adjoining normal articular cartilage (nc) in the superficial layer.***

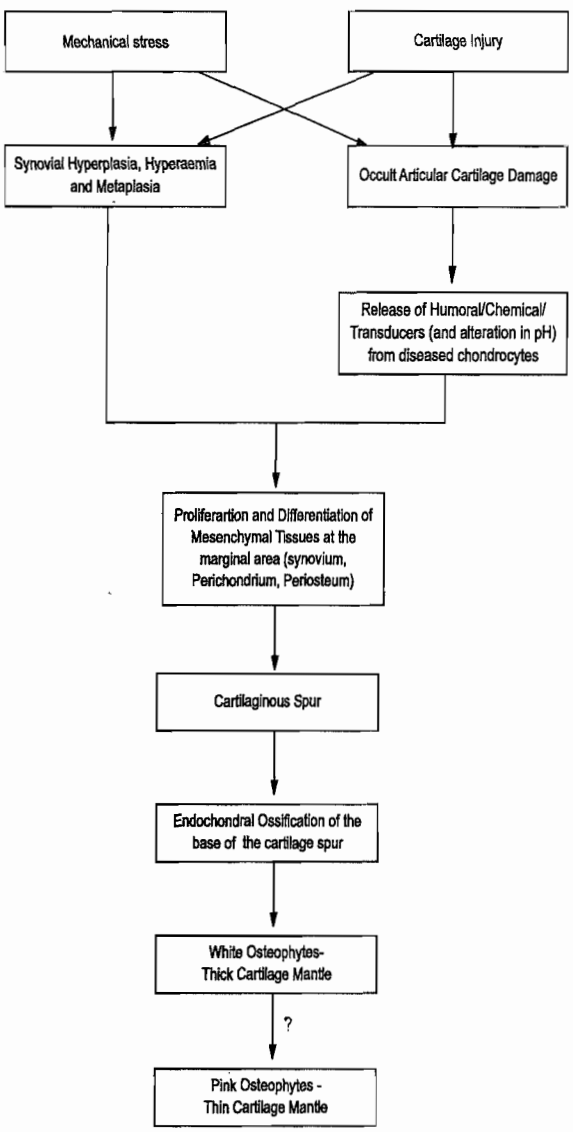

Fig. 4a ***Proposed schema of osteophyte aetiopathogenesis.***

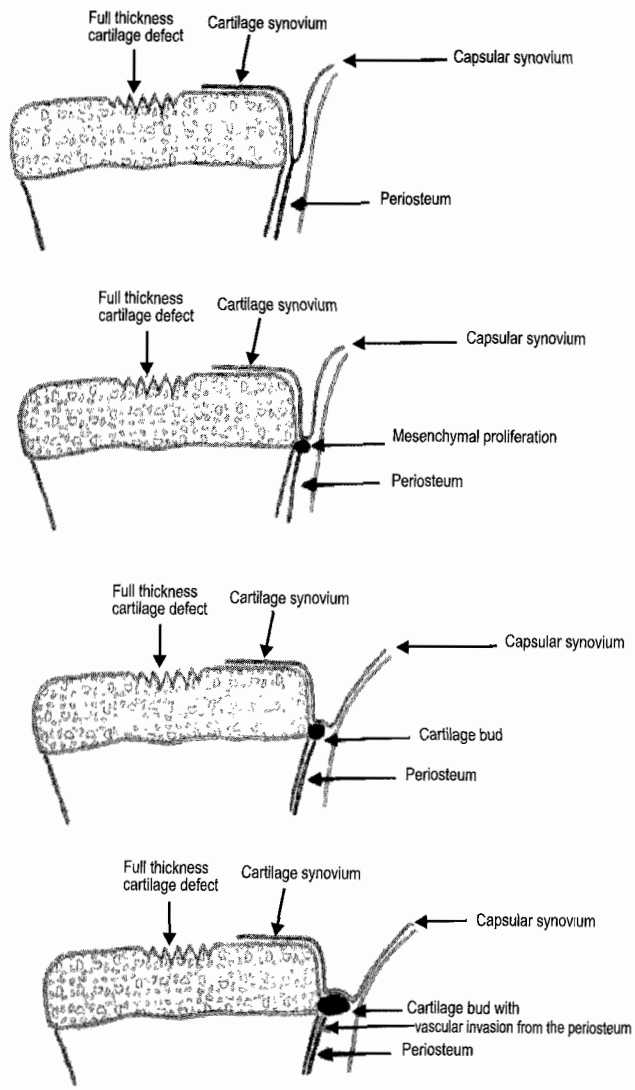

Fig. 4b ***Proposed mechanism of osteophyte formation.***

the collagen fibres in the superficial layer of the osteophytes segment terminated in knobs without forming loops and their meshes were fewer (Figure 3).

Discussion

The findings from this study show that the cartilage mantle of osteophyte was morphologically similar and was continuous with that of the adjoining relatively normal articular cartilage. This similarity probably explains why osteophytes, particularly 'white' osteophytes have similar compressive and stress-stiffness values with normal articular cartilage [13].

Osteophytes have been thought to provide no benefit to the joint in which they occur and they are generally implicated as important causes of local joint pain, nerve compression and restriction of joint movement[7, 14, 15]. Pottenger *et al*[16] however, found that excision of osteophytes in valgus and varus knees led to instability of the joints. The ability of osteophyte to assist in joint stabilisation in these situations is probably due to buttressing of the adjoining articular cartilage by the

osteophytic cartilage during load transmission since their cartilage mantles are continuous.

From this study, it would also appear that in the pathogenesis of osteophytes, the tissue(s) of origin must bear close proximity to the adjoining articular cartilage. The cross-linking of collagen fibres between the osteophytic and normal articular cartilage may also suggest that the adjoining normal articular cartilage contribute to the formation of osteophytes.

Fisher [2] has shown that the more lateral or marginal area of the normal articular cartilage is covered by synovial reflection, which we refer to as 'cartilage synovium'. This 'cartilage synovium' meets with the synovial lining of the joint or 'capsular synovium' and the periosteum, in an area which for the purpose of this discussion will be referred to as the tri-furcation. At the tri-furcation, the normal articular cartilage also terminates and it becomes continuous with bone.

Hypotheses

Following a full thickness defect more centrally in the articular cartilage, chemical, humoral and other factors are released by the damaged chondrocytes as well as an alteration in the pH of the tissue. The factors released permeate through the cartilage matrix and are subsequently transmitted through the 'cartilage synovium' to the tri-furcation. These chemical agents or factors acting at the tri-furcation initiate the proliferation and subsequent differentiation of mesenchymal tissue(s) in this area. The chondrocytes of the normal cartilage adjoining the tri-furcation may direct or influence the differentiation of the proliferating tissue along a cartilaginous pathway. The resultant cartilaginous tissue is then secondarily invaded by blood vessels probably from the periosteum and this in turn leads to ossification of the basal region of the 'neocartilage'. Although the cartilage mantle of the resulting osteophyte is continuous with the adjoining articular cartilage, the newly formed subchondral bone in this tissue is completely separated from that of the adjoining normal articular cartilage as found in this study (Figure 4a&4b).

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References

1. Key JA. Experimental arthritis : The changes in joints produced by creating defects in the articular cartilage. *J Bone Joint Surg*. 1931; 13 : 725-739.

2. Fisher AGT. The structure and function of synovial membrane and articular cartilage. *BMJ*. 1939: 390-393.

\3. Peterson L, Menche D, Grande D, Klein M, Burmester G, Pugh J, Piman M. Chondrocyte transplantation - An experimental model in rabbit. 30th Annual ORS. Atlanta. 1984.

4. Aigner T, Dietz U, von der Mark K. Differential expression of collagen types I, II, III and X in human osteophytes. *Laboratory Investigations*. 1995 ; 73 : 236-243.

5. Moskowitz RW, Goldberg VM. Osteophyte evolution: Studies in an experimental partial meniscectomy model. *J Rheumatol*. 1987; [Suppl 14]: 116-118.

6. Resnick D, Revell P A, Eulderink F, Schaffler M B, Bland J, Mazieres B, Forgacs S, Scharf H-P. Osteophytes. Why they matter and what to do about them. International Workshop, XII European Congres of Rheumatology, Budapest. 1991.

7. Marshall J L . Periarticular osteophytes. Initiation and formation in the knee of the dogs. *Clin. Ortho. Rel. Res*. 1969; 62 : 37-47.

8. Gilbertson E M M. Development of periarticular osteophytes in experimentally induced osteoarthritis in dogs. *Ann. Rheum. Dis*. 1975 ; 34 : 12-25.

9. Redler I, Zimny ML. Scanning electron microscopy of normal and abnormal cartilage and synovium. *J Bone Joint Surg*. 1970; 52-A : 1395-1404.

10. Clark JM. The organisation of collagen in cryofractured rabbit articular cartilage: A scanning electron microscopy study. *J Ortho Res*. 1985; 3 : 17-29.

11. Jeffery AK, Blunn GW, Archer CW, Bently G. Three-dimensional collagen architecture in bovine articular cartilage. *J Bone Joint Surg*. 1991; 73-B (5) : 795-801.

12. Hall DJ, Skerrett EJ, Thomas WDE. Critical point drying for scanning electron microscopy ; a semi-automatic method of preparing biological specimens. *J Microscopy*. 1978; 113: 277-290.

13. Alonge TO, Oni OOA, Morrison CJ. A comparison of the compressive and shear stiffness of periarticular osteophytes, hypertrophic femoral intercondylar notch and normal articular cartilage. *J Musculoskeletal Res*. 1998; 2: 247-255.

14. Fisher AGT. A contribution to the pathology and etiology of osteoarthritis : with observations upon the principles underlying its surgical treatment. *The British J Surg*. 1922. Vol. X; 37 : 52-80.

15. Jeffery AK. Osteophytes and the osteoarthritic femoral head. *J Bone Joint Surg*. 1975; 57-B: 314-324.

16. Pottenger LA, Phillips FM, Draganich LF. The effect of marginal osteophytes on reduction of varus-valgus instability in osteoarthritic knees. *Arthr. Rheum*. 1990; 33: 853-858.