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# A histological study of articular cartilages of the human sternoclavicular joint, proposals for modification in the established descriptions and for improvement of the cartilage tissue classification

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## ABSTRACT

Articular surfaces of the human synovial joint are mostly covered with hyaline cartilage. As exceptions to this, surfaces of the sternoclavicular joint(SCJ), acromioclavicular joint and temporomandibular joint are described to be formed by fibrocartilage. We executed a histological examination of articular cartilages of the SCJ, using 62 cartilages obtained from 31 autopsy cases. In each case, SCJ was selected at random from either the left or the right one, and obtained in the routine autopsy technique of thoracotomy.

Histological findings revealed that 10 articular surfaces showed the fibrocartilage tissue, 6 surfaces showed a likeness to the hyaline cartilage tissue, but not typical one. All of these 6 cartilages belonged to the sternal surface. Remaining 46 surfaces were estimated to be covered with transition or combination of the fibrocartilage tissue and the hyaline cartilage tissue. These observations seem to indicate the inevitability of a modification in the established description, and the necessity of an improved histological classification of the cartilage tissue.

## KEY WORDS

human sternoclavicular joint, articular cartilage, hyaline cartilage, fibrocartilage, histology

## Introduction

The classification of the cartilage is described as for the macroscopic characteristics and biochemistry. As a general rule, it is divided into 3 types of the hyaline cartilage, the white fibrocartilage and the yellow elastic cartilage. Hyaline cartilage has a glassy, bluish, opalescent, homogeneous appearance, firm consistency and some elasticity, consists of chondrocytes and an extensive extracellular matrix mainly composed of type II collagen and proteoglycan<sup>1-3)</sup>. Fibrocartilage is dense, fasciculate, white fibrous tissue, with attendant fibroblasts and small interfascicular groups of chondrocytes, having much

type I collagen in its matrix<sup>1-3)</sup>. Fibrocartilage is thought to be a transition tissue that lacks a perichondrium and has structural and functional properties intermediate between those of dense fibrous connective tissue and hyaline cartilage<sup>4)</sup>. Elastic cartilage contains typical chondrocytes and matrix with type II collagen, resembling typical hyaline cartilage, but its matrix is pervaded by yellow elastic fibers<sup>1-3)</sup>.

Histologically, there is no precise definition or borderline of three cartilage types. As a matter of fact, fibrocartilage observed in human materials is composed predominantly of visible collagenous fibers

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Table 1. Clinical Summary of 31 Cases Used in this Study

Case	Sampling			Main Disease	Cause of Death
	No.	Age	Sex Side		
1	21	F	L	non-Hodgkin lymphoma	Renal Failure
2	77	M	L	Cholangiocellular Carcinoma	SL
3	76	F	L	Aplastic Anemia	Sepsis
4	63	F	R	Cerebellar Infarction	Cardiac Failure
5	53	F	R	AML	SL
6	64	M	R	Esophageal Carcinoma	SL
7	72	M	R	Gastric Carcinoma	SL
8	25	M	L	non-Hodgkin lymphoma	Sepsis
9	67	F	R	SLE	MOF
10	83	M	L	DIC	SL
11	17	M	R	Myelodysplastic Syndromes	Sepsis
12	40	F	L	AML	Pneumonia
13	81	F	L	Mitral Regurgitation	Pneumonia
14	88	F	R	Myocardial Infarction	SL
15	74	F	R	Acute Cardiac Failure	Cardiac Failure
16	76	M	R	Myocardial Infarction	Cardiac Failure
17	66	M	L	Angiosarcoma of Heart	SL
18	81	F	L	Dissecting Aneurysm	SL
19	73	F	R	Infectious Peritonitis	SL
20	58	M	L	Liver cirrhosis	Liver Failure
21	75	M	L	Gastric Carcinoma	Renal Failure
22	49	M	R	Vasculitis Syndrome	unknown
23	71	M	L	Lung Carcinoma	SL
24	58	M	L	Hepatocellular Carcinoma	Liver Failure
25	54	M	R	Hepatocellular Carcinoma	Liver Failure
26	39	F	L	CML	MOF
27	78	F	L	Liver Failure	Liver Failure
28	73	M	R	Carcinomatous Meningitis	SL
29	72	F	L	Liver Failure	Liver Failure
30	70	F	R	Pancreatic Carcinoma	SL
31	70	F	L	Lung Carcinoma	SL

M, Male ; F, Female ; L, Left ; R, Right ; SL, Same as in the Left  
 MOF, Multiple Organ Failure ; CML, Chronic Myeloid Leukemia  
 SLE, Systemic Lupus Erythematosus, ; AML, Acute Myeloid Leukemia  
 DIC, Disseminated Intravascular Coagulation

arranged in irregular bundles, containing type I collagen, with a few chondrocytes surrounded by a sparse cartilage matrix between the bundles.

Articular surfaces of the human synovial joint are mostly covered with hyaline cartilage. As exceptions to this, surfaces of the sternoclavicular joint (SCJ), acromioclavicular joint and temporomandibular joint are described to be formed by dense fibrocartilage<sup>1)</sup>. For understanding histological features of the normal articular cartilage, it is essential to investigate

histological variation of the cartilage tissue. Our preceding report<sup>5)</sup> suggested that the articular surfaces of the SCJs were not only formed by a fibrocartilage but a hyaline cartilage or combination of both cartilage tissue types. But these indications were based on the observation of only 14 articular surfaces out of 7 cases. The aim of this study is to clarify the microscopic features of the human SCJs using enough number of materials. And the results lead us to the inevitability of modification in the established

**Table 2. Histological Classification of the 62 Articular Surfaces**

Case No.	Clavicular Surface	Sternal Surface
1	F	F
2	HF	HF
3	F	A
4	HF	HF
5	HF	HF
6	HF	A
7	HF	A
8	F	HF
9	HF	HF
10	F	HF
11	HF	A
12	F	A
13	HF	HF
14	HF	HF
15	HF	A
16	HF	HF
17	F	HF
18	HF	HF
19	F	HF
20	F	HF
21	HF	HF
22	HF	HF
23	HF	HF
24	HF	HF
25	HF	HF
26	HF	HF
27	HF	HF
28	F	HF
29	HF	HF
30	HF	HF
31	HF	HF

F, Fibrocartilage ; HF, Hyaline Fibrocartilage ;  
A, Atypical Hyaline Cartilage

descriptions, and the necessity of improved histological classification of the cartilage tissue.

### Materials and Methods

SCJs were obtained from thirty one autopsy cases, executed from April 2000 to November 2001, at Kanazawa university graduate school of medicine. Cases which had the ante mortem diagnosis of the musculoskeletal disease were excluded from the objects. There were 15 males and 16 females and the age ranged from 17 to 88 yr (mean  $\pm$  SD :  $63.9 \pm$

18.6). Clinical features of the 31 cases containing age, sex, main disease, and cause of death are summarized in Table. 1.

In each case, SCJ was selected at random from either the left or the right one, and obtained in the routine autopsy technique of thoracotomy. The specimens were fixed in 10% neutral buffered formalin, decalcified in the Plank-Rychlo's solution (7% aluminum chloride, 3.6% hydrogen chloride, and 4.6% formic acid solution) for 1 day, then cut and sampled from coronal plane of the SCJs and subsequently, embedded in paraffin. Sections of 3  $\mu$  m thicknesses were cut from each paraffin block, and were stained with hematoxylin and eosin (HE), Azan Mallory, and Elastica-van Gieson. Then, we observed the stained sections under a light microscope (BX-50, Olympus Co., Japan). There were sixty two articular cartilages available because SCJ had the sternal and clavicular surfaces in each.

### Results

#### *A Tentative classification of the cartilage tissue*

Articular cartilages of the human SCJs showed complicated findings. Their histological features spreaded out between the fibrocartilage and the hyaline cartilage. In this study, we classified tentatively the cartilage tissue into four types to exclusion of the elastic cartilage. That is, typical hyaline cartilage, atypical hyaline cartilage, hyaline fibrocartilage, and fibrocartilage. Typical hyaline cartilage indicates the same as the thing generally described. Atypical hyaline cartilage is defined as a likeness to the typical hyaline cartilage tissue. It shows the almost same as the typical one, but slight collagen bundle and/or irregularity in its matrix. Fibrocartilage is equivalent to the typical fibrocartilage, composed predominantly of visible collagenous fibers arranged in irregular bundles, with a few chondrocytes surrounded by a sparse cartilage matrix between the bundles. Hyaline fibrocartilage indicates transition or combination between the fibrocartilage tissue and the hyaline cartilage tissue.

#### *Results of the classification*

The histological findings of the articular cartilages were shown in Table. 2. Six articular cartilages, the sternal surfaces of the case 3, 6, 7, 11, 12, 15

Fig. 1-A

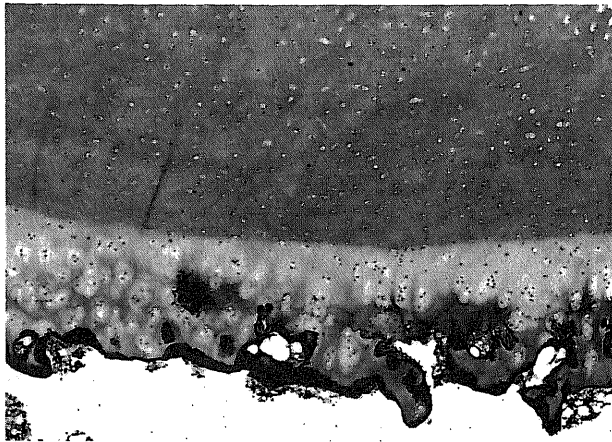


Fig. 1-B

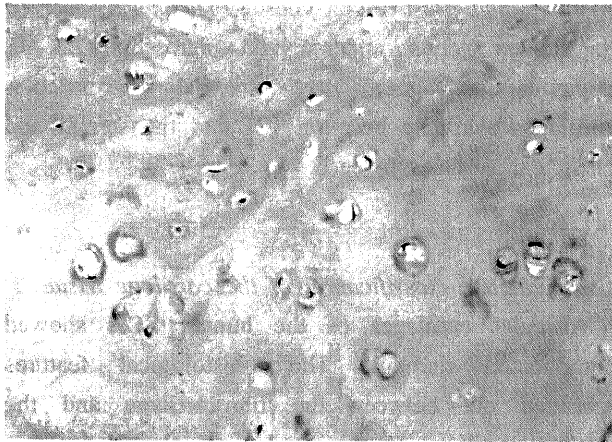


Fig. 1, (A) Low-power view and (B) high-power view of atypical hyaline cartilage tissue. Note the similarity to the typical hyaline cartilage with slight collagen bundle and/or irregularity in its matrix.

Fig. 2-A

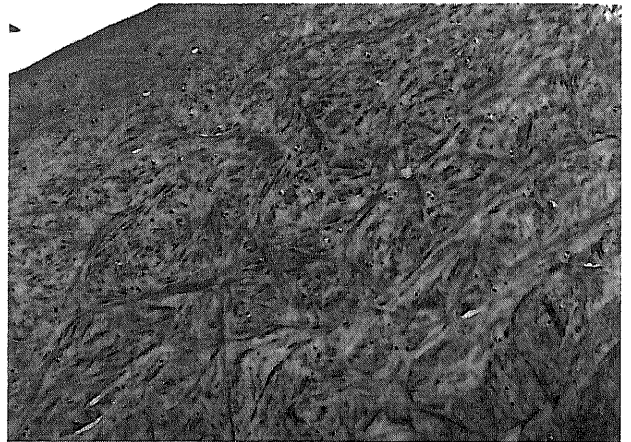


Fig. 2-B

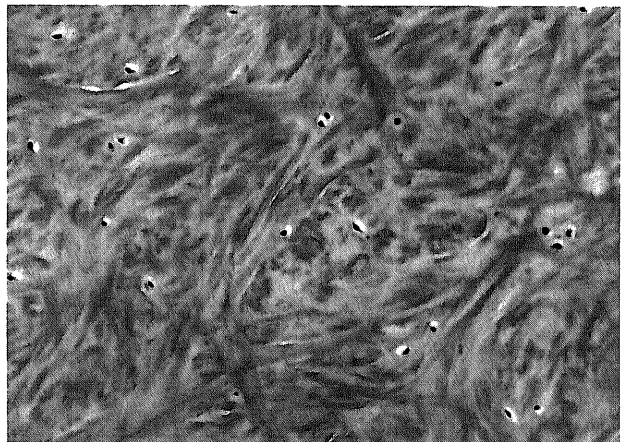


Fig. 2, (A) Low-power view and (B) high-power view of fibrocartilage shown in this study with a little difference from the typical fibrocartilage observed in the menisci.

belong to the atypical hyaline cartilage (Fig1-A, B). Ten articular cartilages, both surface of case 1, the clavicular surface of cases 3, 8, 10, 12, 17, 19, 20, 28 was assorted with the fibrocartilage, but it was a little different from the typical fibrocartilage tissue. (Fig2-A, B). Remaining forty-six cartilages (24 sternal surfaces and 22 clavicular surfaces) were estimated to be the hyaline fibrocartilage (Fig. 3-A, B). No typical hyaline cartilage was identified in the articular surfaces of the SCJs.

### Discussions

Articular surfaces of the human synovial joint are mostly covered with hyaline cartilage. As exceptions

to this, surfaces of the SCJ, acromioclavicular joint and temporomandibular joint are described to be formed by dense fibrocartilage<sup>1)</sup>. Most of the articular cartilage of the whole body does the origin as a mold of the endochondral ossification in the cartilage formed at the time of development<sup>6)</sup>. The clavicle which is one end of the SCJ has bone formation given by membranous ossification. The articular cartilage is described to be formed in the same way<sup>7)</sup>.

Cartilages are classified by the macroscopic characteristics and the difference in cartilage matrix composition element. As a general rule, it is divided into 3 types of the hyaline cartilage, the fibrocartilage and the elastic cartilage.

Fig. 3—A



Fig. 3—B

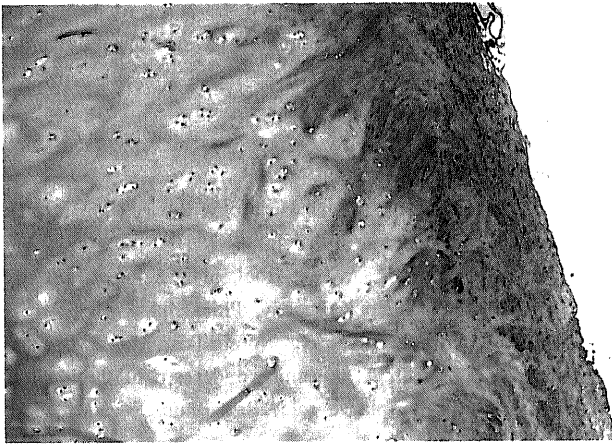


Fig. 3, (A) Low-power view and (B) high-power view of hyaline fibrocartilage indicate transition or combination between the fibrocartilage tissue and the hyaline cartilage tissue.

Hyaline cartilage has a glassy, bluish, opalescent, homogeneous appearance, firm consistency and some elasticity<sup>1-4)</sup>. Histologically, hyaline cartilage is composed of intercellular matrix of hyaline cartilage and chondrocytes embedded. The matrix looks homogenous. Hyaline cartilage is unique in containing type II, IV, VI collagens, although water is the most abundant component. The collagen fibers are not visible, because most of the collagen is in the form of submicroscopic fibrils and the refractive index of collagen is very close to that of the surrounding ground substance. Chondroblasts and chondrocytes secrete the macromolecular constituents of cartilage matrix, such as tropocollagen molecules. Chondrocytes

buried in the matrix live in tiny matrix spaces known as lacunae in the matrix they have secreted. Typically, chondrocytes have a rounded nucleus with one or more nucleoli, and vary in size and shape<sup>1-3, 8-10)</sup>. In contrast, fibrocartilage is dense, fasciculate, white fibrous tissue, with attendant fibroblasts and small interfascicular groups of chondrocytes, having much type I collagen in its matrix<sup>1-3)</sup>, considered to be the intermediated type of the fibrous connective tissue and the hyaline cartilage<sup>4)</sup>. Typical fibrocartilages observed in human materials especially obtained from articular disks, are composed predominantly of visible collagenous fibers arranged in irregular bundles, mainly containing type I collagen, with a few cartilage cells surrounded by a sparse cartilage matrix between the bundles. These findings correspond to the established descriptions<sup>1-3, 8-10)</sup>. But we often observed the variety of fibrocartilage tissue. For example, cartilages seen in the intervertebral disks are presumed to be a transition tissue between the dense fibrous connective tissue and the hyaline cartilage, though they tend to be assorted as the hyaline cartilage by pathologists.

In this study, we performed a histological examination of articular cartilages of the SCJ, using 62 cartilage surfaces obtained from 31 autopsy cases. The results were interesting. There was no typical fibrocartilage tissue described above. Articular surfaces of the SCJs showed the spectrum of tissue between the hyaline cartilage and the fibrocartilage. In this study, we classified the cartilage tissue tentatively into four types to exclusion of the elastic cartilage. Hyaline cartilage like tissue observed in this study was considered to be not the same as the hyaline cartilage. We divided atypical hyaline cartilage from the typical one. The fibrocartilage includes widespread tissue type. We took a decision that a classification of the fibrocartilage must be divided for further examination of cartilage tissue, at least in this study. We partitioned a hyaline cartilage from the fibrocartilage. The hyaline fibrocartilage was defined as transition or combination of the fibrocartilage tissue and the hyaline cartilage tissue. The fibrocartilage observed in the SCJs, was, however a little different from the typical fibrocartilage observed in the menisci.

Our study disclosed that 6 sternal articular cartilages were classified into the atypical hyaline cartilage, 10 articular cartilages were assorted with the fibrocartilage, and the remaining 46 cartilages were estimated to be the hyaline fibrocartilage. No typical hyaline cartilage was identified in the articular surfaces of the SCJs.

These observations indicate the inevitability of modification in the established descriptions of the SCJ. Because they are described that articular surface of the SCJ are formed by dense fibrous tissue, with isolated groups of chondrocytes and little surrounding matrix, reflecting their formation by mesenchymatous ossification<sup>1, 6)</sup>. To the best of our knowledge, there was only one report<sup>11)</sup> similar to our results so far. The report pointed out a sternal surface of human SCJ covered by hyaline cartilage, using only one case.

It is, furthermore, necessary to improve histological classification of the cartilage tissue. We disclosed the variation of cartilage tissue in this study. The existing classification of the cartilage depends on naked eye observation, is thought to be insufficient in histological investigation. Actually, in the research of regeneration medicine, it seems that current status of regenerative cartilage histology does not correspond with the existing classification<sup>12, 13)</sup>.

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## 胸鎖関節関節軟骨の組織学的研究，確立された記述の修正 および軟骨組織分類改変の提案

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### 要 旨

ヒト滑膜関節の関節面は，硝子軟骨により覆われているが，例外的に胸鎖関節，肩鎖関節，顎関節は，線維軟骨にからなると記述されている。そこで，31例の剖検症例から左右いずれかの胸鎖関節を採取し，胸骨面，鎖骨面あわせて62個の関節軟骨を組織学的に検討した。その結果，関節軟骨が線維軟骨からなっていたものは10個，硝子軟骨に極めて類似した軟骨からなっていたものが6個，他の46個は線維軟骨と硝子軟骨の移行もしくは結合した軟骨から形成されていた。この結果は，既に確立され成書に記載された胸鎖関節関節軟骨の記述の修正の必要性和，軟骨組織の分類の改変の必要性を示すと思われる。