A Histological Study of the Fusion Process of the Human Pubic Symphysis

—With Special Reference to that of the Human Mandibular Symphysis—

Shunsuke Nakatomi

The Department of Oral Pathology (Director: Prof. Norizo Hashimoto)

Faculty of Dentistry, Kyushu University, Fukuoka, Japan

The Second Department of Oral Surgery (Director: Prof. Minoru Kajiyama)

Kyushu Dental College, Kitakyushu, Japan

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Introduction

Although there are many morphological studies of the human pubic symphysis, most of them are performed based on the gross anatomy^{1~19)} and/or roentgenography^{20~25)}; and it is only Aeby (1858)²⁶⁾ who studied histologically on this subject.

As one of the serial studies on the postnatal fusion process of the human tissues or organs, Hashimoto (1969, 1970, 1973)^{27~29)} and Nakatomi (1985)³⁰⁾ have reported the fusion process of the human mandibular symphysis during the fetal up to senile period.

The purpose of this study is to examine histologically the fusion process of the human pubic symphysis, and to determine the fusion mechanism and functional significance. It is also aimed to determine the biological significance on the basis of the comparison of the fusion process between the mandibular and pubic symphysis.

Materials and Methods

Fifty-nine cases examined in this study consisted of 13 fetal cases (7 males and 6 females) and 46 postnatal cases (24 males and 22 females). All the specimens were collected at the Department of Oral Pathology, Faculty of Dentistry, Kyushu University. The fetuses were delivered in accordance with the Eugenic Protection Law, while the postnatal cases were obtained at autopsy.

The pubic symphysis area was removed with the surrounding tissues from the fetuses which had been fixed in 10% formalin.

Then, the removed specimens from fetal and postnatal cases underwent the X-ray examination to confirm the presence of the pubic symphysis in the removed specimens.

Following the X-ray examination, all the specimens (except for the early prenatal cases without significant calcification) were decalcified by Hashimoto's method and

prepared by large celloidin-embedded section methods. Frontal sections, 15 μ -thick, were cut and stained with hematoxylin-eosin, silver impregnation, and Mallory-Azan method. The body length of the fetuses in this study was from crown to heel (CH length).

Results

I. Fetal period (13 cases) (Table 1)

The midline area of the pubic symphysis consisted of connective tissue layer, while the peripheral area was composed of cartilaginous layer.

The width of the connective tissue layer varied from narrow (+) to wide (++). The connective tissue layer had three parts: upper, middle and lower parts. The collagen fibers in the connective tissue were classified into immature and mature according to the maturity, and into vertical, oblique and horizontal according to the arrangement. Chondrocytes were observed at the outer area or the entire of the connective tissue layer.

The cartilaginous layer consisted of inner and outer parts. The former part was further divided into slight (+), moderate (++), and marked (++) according to the amount. In the latter part, there were 5 zones; a zone with swollen chondrocytes, one with calcium deposits, one with columnar array of chondrocytes, one with provi-

Table 1 Histological Findings at Pubic Symphysial Area

—Prenatal Cases—

Sex	No of Case	Crown -Heel Length (cm)	Connective Tissue Layer							Border between Both Layers	Cartilaginous Layer					
			Width	Amount			Maturity	Array	Immature Chondrocyte		Inner Part	Outer Part				
				U	M	L			Appear- ance	Location		Swollen Chondro- cyte	Calcium Deposit	Columnar Chondro- cyte	Provi- sional Calcifi- cation	Osteo- clasts
M	1	11	+	+	+	+	immature	vertical	-	/	clear	##	-	-	-	-
	2	28	+	+	+	+	"	"	-	/	"	##	+	-	-	-
	3	31	+	+	+	+	mat> immat	vertical oblique	-	/	"	##	+	+	+	++
	4	38	++	++	++	++	"	"	+	outer	vague	##	+	+	+	++
	5	41	++	+	+	+	+	vertical	+	"	"	##	+	+	##	##
	6	48	++	+	+	+	+	hori- zontal	+	outer central	"	##	+	+	##	##
	7	51	++	+	+	+	+	hori- zontal vertical	+	"	"	##	+	+	##	##
F	1	15	+	+	+	+	mat< immat	vertical	-	/	clear	##	-	-	-	-
	2	18	+	+	+	+	"	"	-	/	"	##	-	-	-	-
	3	21	+	+	+	+	mat> immat	"	-	/	"	##	+	-	-	-
	4	25	+	+	+	+	"	"	-	/	"	##	+	-	-	-
	5	35	++	+	++	++	"	vertical hori- zontal	-	/	"	##	+	+	+	+
	6	45	++	+	++	++	mat= immat	hori- zontal	+	outer	vague	##	+	+	++	+

Note U: Upper part, M: Middle part, L: Lower part

sional calcification and one with osteoclasts.

A Seven male cases

1. Connective tissue layer

During the period from 11 up to 31cm in length, the width of the connective tissue layer was narrow (+) without any differences among upper, middle and lower parts (Fig. 1). During the period from 38 to 51cm in length, the width was moderate (++), and the lower one-third was slightly wider than the upper two-thirds. Except for 2 cases (11 and 28cm in length) which showed immature collagen fibers, all the other cases revealed the predominance of mature collagen fibers.

The arrangement of collagen fibers was vertical in the cases of 11 and 28cm in length, oblique (two oblique arrays crossing each other) in 31 and 38cm in length, horizontal in 48 and 51cm in length (Fig. 2). Thus, the arrangement of collagen fibers shifted from vertical, oblique to horizontal as the age increased.

In a case of 38cm in length, a few chondrocytes appeared first in the most outer part of the connective tissue layer. In 2 cases of 48 and 51cm in length, the chondrocytes were seen in both outer and central areas (Fig. 3).

2. Cartilaginous layer

In the inner part of the cartilaginous layer, active formation of chondrocytes was always observed during the fetal period. In the outer part, swollen chondrocytes were observed during the period from 28 to 51cm in length. In the most outer part of the case of 31cm in length, there was the first appearance of calcium

Fig. 1 A male case of 28cm in crown-heel (CR) length, showing a thin connective tissue layer in the center and bilateral cartilaginous layers. $\times 15$.

Fig. 2 Higher power of Fig. 1 showing a vertical arrangement of connective tissue fibers. $\times 230$.

Fig. 3 A male case of 51cm CR length, showing a horizontal arrangement of fibers and chondrocytes. $\times 200$.

deposits, chondrocytes showing columnar arrangement, provisional calcification and osteoclasts. The appearance of chondrocytes and the formation of provisional calcification became dominant after the case of 41 cm in length (Fig. 4).

B Six female cases

1. Connective tissue layer

In the period from 15 to 25cm in length, the connective tissue layer was narrow (+) in width, showing no difference in each of 3 parts. In 2 cases with 35 and 45cm in length, the layer became wider (++) in width; and the lower two-thirds were wider than the upper one-third. In 2 cases of 15 and 18cm in length, collagen fibers consisted mainly of immature ones, while the predominance of the mature fiber or the mixture of both mature and immature fibers were observed first in a case of 21cm in length. The collagen fibers were vertical in arrangement until 25cm in length, changing into oblique in 35cm in length and horizontal arrangement pattern in 45cm in length (Fig. 5). The appearance of chondrocytes was not apparent except for the slight appearance in a case of 45cm in length.

Fig. 4 A female case of 45cm CR length showing a columnar array of chondrocytes, provisional calcification and osteoclasts in the outer layer of the cartilaginous layer. $\times 200$.

2. Cartilaginous layer

In the period from 15 and 45cm in length, an active formation of chondrocytes was noted in the inner part of the cartilaginous layer. In the outer part of the layer, swollen chondrocytes were observed in the period from 21 to 45cm in length (Fig. 6). In 2 cases of 35 and 45cm in length, calcium deposits, columnar array of chondrocytes, provisional

Fig. 5 A female case of 21cm CR length showing a vertical arrangement of fibers. $\times 260$.

Fig. 6 Higher power of Fig. 5 showing swollen chondrocytes in the outer part of the cartilaginous layer. $\times 260$.

calcification and osteoclasts were also observed. The columnar array of chondrocytes and the provisional calcification were remarkable in the case of 45cm in length.

II. Postnatal period (46 cases) (Tables 2 and 3)

The width of connective tissue layer in the postnatal period was classified into narrow (+), moderate (++) and wide (+++). The postnatal cases showed various findings which had not been observed in the prenatal period. The new findings were myxoid degeneration of chondrocytes, degeneration and liquefaction necrosis of cartilaginous tissue in connective tissue layer. Besides, the surface contour of cartilaginous layer (even or uneven), and the border between the cartilaginous layer and bone marrow were examined in the postnatal cases.

A Twenty-four male cases

1. Connective tissue layer

Until 2 years after birth, the width of the connective tissue layer was moderate

Table 2 Histological Findings at Pubic Symphyseal Area —Postnatal Cases, Males—

No of Case	Age	Connective Tissue Layer								Border between Both Layers	Cartilaginous Layer									
		Width	Amount		Maturity	Array	Chondrocyte				Inner Part	Outer Part								
			U	M L			Appear- ance	Location	Degen- eration			Necrosis	Swollen Chondro- cyte	Calcium Deposit	Columnar Chondro- cyte	Provi- sional Calcifi- cation	Osteo- clasts	Irregu- larity of Border	Border with Bone Marrow	
1	36w	++	+	++	++	immat	vertical	+	central	-	-	clear	##	+	+	##	##	##	-	vague
2	2d	++	+	++	++	mat=immat	vertical horizontal	+	"	-	-	vague	##	+	+	##	##	##	-	"
3	2y	++	+	++	++	mat>immat	"	++	entire	-	-	"	++	+	+	##	##	##	-	"
4	15y	##	++	++	++	mat	horizontal	++	"	-	-	"	+	+	+	+	+	+	-	"
5	19y	##	+	+	+	mat	horizontal	++	"	-	-	"	+	+	+	+	+	+	-	"
6	29y	##	-	-	-	/	/	++	"	+	+	"	+	+	+	-	-	-	+	"
7	29y	##	-	-	-	/	/	++	"	+	+	"	+	+	+	-	-	-	-	"
8	36y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	clear
9	39y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
10	45y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
11	55y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
12	57y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
13	58y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
14	58y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
15	64y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
16	68y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
17	72y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
18	75y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
19	75y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
20	76y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
21	77y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
22	79y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
23	80y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"
24	90y	##	-	-	-	/	/	##	"	##	++	"	+	-	+	-	-	-	+	"

Note U: Upper part, M: Middle part, L: Lower part

Table 3 Histological Findings at Pubic Symphysial Area —Postnatal Cases, Females—

No of Case	Age	Deli- very	Connective Tissue Layer								Border between Both Layers	Cartilaginous Layer								
			Width	Amount			Maturity	Array	Chondrocyte				Inner Part	Outer Part						
				U	M	L			Appea- rance	Location		Degene- ration		Necrosis	Swollen Chondro- cyte	Calcium Deposit	Columnar Chondro- cyte	Provi- sional Calcifi- cation	Osteo- clasts	Irregu- larity of Border
1	2d		+	+	+	mat)immat	horizontal oblique	-	/	/	/	clear	+	+	+	+	+	+	-	vague
2	5d		+	+	+	"	horizontal	-	/	/	/	"	+	+	+	+	+	+	-	"
3	35d		+	+	+	"	"	+	outer	-	-	"	+	+	+	+	+	+	-	"
4	3m		+	+	+	"	"	+	"	-	-	"	+	+	+	+	+	+	-	"
5	3m		+	+	+	"	"	+	"	-	-	"	+	+	+	+	+	+	-	"
6	1y 2m		+	+	+	"	"	+	"	-	-	"	+	+	+	+	+	+	-	"
7	7y		+	+	+	"	"	+	"	-	-	"	+	+	+	+	+	+	+	"
8	12y		+	+	+	mat	"	+	entire	-	-	"	+	+	+	+	+	+	+	"
9	17y		+	+	+	mat	"	+	"	+	+	vague	+	+	+	-	-	+	+	clear
10	17y		+	-	-	/	/	+	"	+	+	"	+	+	+	-	-	+	+	"
11	19y		+	-	-	/	/	+	"	+	+	"	+	+	+	-	-	-	+	"
12	25y		+	-	-	/	/	+	"	+	+	"	+	+	+	-	-	-	+	"
13	29y		+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
14	29y	3	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
15	29y	1	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
16	31y	1	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
17	55y	2	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
18	70y	2	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
19	73y	4	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
20	73y	2	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
21	74y	7	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"
22	77y	4	+	-	-	/	/	+	"	+	+	"	+	-	+	-	-	-	+	"

Note U: Upper part, M: Middle part, L: Lower part

(++), and the lower two-thirds were thicker than the upper one-third. From 15 to 90 years, the width was always wide (++). Irrespective of the 3 parts, the width of the connective tissue was moderate (++), and slight (+) in 15 and 19 years respectively. There was no connective tissue after 29 years. The mature collagen fibers were always predominant except for 1 case with the age of 0 year (fetal age of 36 weeks). After 15 years, only mature fibers were present.

The arrangement of collagen fibers in connective tissue layer was vertical at 0 year. At the age of 2 days and 2 years, the array was vertical in the upper one-third of the connective tissue layer, and oblique in the lower two-thirds. At the age of 15 and 19 years the arrangement was horizontal.

The extent of the appearance of chondrocytes was slight (+) at the age of 0 and 2 days, moderate (++) during the period from 2 to 29 years and marked (+++) after 36 years (Fig. 7). In cases of the slight appearance, the chondrocytes were observed mainly in the center of the connective tissue layer. Chondrocytes were observed in every part of the connective tissue layer during the age of 2 to 90 years. The cases

Fig. 7 A 2 day-old-male case showing chondrocytes in the connective tissue layer. $\times 260$.

Fig. 8 A 36 year-old case showing myxoid degeneration of chondrocytes in the connective tissue layer. $\times 220$.

after the age of 45 years showed the cartilaginous transformation in the connective tissue layer.

The degenerative chondrocytes appeared first at the age of 29 years and were remarkable during 36 to 90 years (Fig. 8). These degenerative chondrocytes were associated with the appearance of necrotic chondrocytes (Fig. 9)

2. Cartilaginous layer

The width of inner part of the cartilaginous layer was wide (++) until 2 days after birth, moderate (++) at the age of 2 years, and it was always thin (+) after the age of 15 years. Swollen chondrocytes in the outer part of the cartilaginous layer were always slight in degree and noted during the age of to 29 years. During the age of 0 to 19 years, there was a constant appearance of chondrocytes with columnar array, provisional calcification and osteoclasts, which was most remarkable during 0 to two years. Then, these 3 findings became gradually inconspicuous and absent following the age of 29 years. Slight deposits of calcium were always noted in all the postnatal cases.

There was a poorly demarcated, vertical and linear border between the outer surface of the outer cartilaginous layer and the bone marrow during the age of 0 to 19 years. During the age of 19 to 90 years, the outer surface showed wavy and irregular contour and well demarcated from the bone marrow.

B Twenty-two female cases

1. Connective tissue layer

The width of the connective tissue layer was moderate (++) until the age of 7 years.

Fig. 9 A 55 year-old-male case showing liquefaction of cartilaginous tissue in the connective tissue layer. $\times 170$.

During the age of 2 days to 3 months, the lower one-third was moderate (++) in width, and thicker than the upper two-thirds which were narrow (+) in width. This difference in the width was not observed during the age of 3 months to 12 years, and all 3 parts showed the moderate (++) width.

Except for 1 case with the age of 2 days which had horizontal as well as oblique arrangement of collagen fibers, the arrangement was constantly horizontal until 17 years. No connective tissue was present after the age of 17 years.

The first and slight appearance of chondrocytes was noted at the age of 35 days. The extent of the appearance was moderate (++) during the age of 7 to 12 years, and was constantly marked (+++) after the age of 12 years (Fig. 10). The chondrocytes were located in the outer part of the connective tissue layer during the age of 35 days to 7 years, and were observed in the entire layer during the age of 12 to 77 years. The case with the age of 29 years showed a chondroid transformation in the connective tissue layer. Slightly degenerative chondrocytes were noted first at the age of 17 years, and moderate (++) in degree during 17 to 29 years, and marked (+++) after 29 years (Fig. 11). The degenerated chondrocytes were combined with appearance of necrosis or liquefaction of cartilaginous tissue whose extent of the appearance was proportional to that of degeneration of chondrocytes.

Fig. 10 A 17 year-old-female case showing chondrocytes and the horizontal arrangement of fibers. $\times 220$.

Fig. 11 A 17 year-old-female case showing myxoid degeneration and liquefaction of cartilaginous tissue in the connective tissue layer. $\times 220$.

2. Cartilaginous layer

The width of inner part of the cartilaginous layer was moderate (++) during the age of 2 days to 7 years, and narrow (+) during the age of 12 to 77 years. Swollen chondrocytes in the outer part of the cartilaginous layer were observed until the age of 25 years, while the calcium deposits were always present in all the postnatal cases.

The columnar arrangement of chondrocytes and the provisional calcification were remarkable (+++) during the age of 2 days to 3 months, moderate (++) during 3 months to 7 years, slight (+) at 12 years, and absent after 17 years. Osteoclasts were many

(++) during the age of 2 days to 3 months, moderate (++) during 3 months to 7 years, few (+) during 12 to 17 years, and absent after 19 years.

The outer surface of the outer part of the cartilaginous layer was vertical with linear contour, having a vague border. After the age of 7 years, this contour became uneven, showing a wavy and irregular pattern. These irregular patterns were most prominent during the age of 12 to 25 years (Fig. 12). Then, this irregularity diminished in degree rapidly. The cartilaginous layer was well demarcated from the marrow cavity after the age of 17 years.

Fig. 12 A 12 year-old-female case showing a wavy and irregular contour of the outer part of cartilaginous layer. $\times 4$.

Discussion

Dividing the pubic symphysis into connective tissue and cartilaginous layers, the sequential change of both layers have been described during the fetal to senile period.

In the following description, the fusion process, the mechanism, and the age change of the cartilaginous layer will be discussed. The comparison with those results reported by previous workers will be also made.

1. Fusion process of the pubic symphysis

Most previous reports dealing with the pubic symphysis were performed based on the gross anatomy¹⁻¹⁹⁾ and roentgenography²⁰⁻²⁵⁾. The histological study has been reported only by Aeby (1858)²⁶⁾ who examined the fetal cases. He stated that ossification occurred after the degeneration of the hyaline cartilage in the symphysis area, resulting in the fusion.

The present study revealed that the width of the connective tissue layer was narrow in the early fetal period, moderate in the late fetal period, and broad after the age of 12 years.

This increase in width was combined with the change of cellular components as described below. Until 25cm in length in fetal period, the amount of the connective tissue was slight (+), and then it became moderate (++) . None of the cases had a high amount (++) of connective tissue. The change of the amount was also associated with the increasing maturity of collagen fibers which was chiefly immature in the early fetal period, and mature after the late fetal period.

Besides, the arrangement of collagen fibers also changed as the fiber matured. The arrangement of collagen fibers shifted from the vertical one in the early fetal period to the horizontal one in the late fetal period via oblique one crossing each other in the

middle fetal period.

Of these changes of the arrangements of collagen fibers, the patterns of oblique or horizontal array seemed to start at the center of the connective tissue layer, spreading into all the parts. In the postnatal period, the connective tissue persisted until the age of 39 years, containing collagen fibers which was fully matured with horizontal array.

There were no chondrocytes in the connective tissue layer before 38cm in length, when a few immature chondrocytes appeared in the most outer part of the connective tissue layer. Then, the appearances of chondrocytes became more prominent. In the case with the age of 2 years, the chondrocytes were moderate in number (showing diffuse distribution throughout the connective tissue layer), and showed the further increase after the age of 17 years. These findings suggest that chondrocytes which appeared first in the outer part of the connective tissue layer increased in number gradually, and finally replaced totally connective tissue layer, resulting in chondroid change.

As the age increased, chondrocytes appearing in the connective tissue layer underwent slightly myxoid degeneration after the age of 17 years. This degeneration was moderate in degree in the third decade, and marked in the fourth decade. Besides, this myxoid degeneration was always associated with degeneration, necrosis or liquefaction of cartilaginous tissue. There was a parallel relation between the myxoid degeneration of chondrocytes and the latter changes in terms of the extent.

The age change of the fusion process of the pubic symphysis can be summarized as follows. In the early stage, the connective tissue between bilateral cartilaginous layers contained vertical fibers which changed into horizontal fibers via oblique ones. In this process, the change of the array of fiber started in the central part of the connective tissue layer. Thus, bilateral pubic cartilages were combined by the horizontal collagen fibers like a bridge.

In the more advanced stage, chondrocytes, which had appeared first in the outer part of connective tissue layer, increased in number with the increasing age and replaced totally the connective tissue layer about at the age of 30 years. This replacement resulted in the fusion of both pubic bones by the cartilaginous tissue. Therefore, the fusion process consisted of the fibrous connection in type in the early stage and then the cartilaginous connection in the late stage.

After the fusion of both pubic bones, the intervening cartilaginous tissues showed various changes, including myxoid change of chondrocytes, degeneration or necrosis and liquefaction of cartilaginous tissue which prompted the softening of the cartilages.

2. Sexual difference of the fusion process.

The pubic bone is one of the bones composing the pelvis which is widened because of the enlarged uterus during pregnancy. Therefore, it is necessary to discuss the sexual difference in terms of the fusion process including the end stage and of the

degenerative features.

In the fetal period, there was no sexual difference in both connective tissue and cartilaginous layers. Although females showed a remarkable increase in width of connective tissue at the age of 12 years after birth, and males at 15 years, this minor difference does not seem significant.

In terms of the amount of collagen fibers in the connective tissue layer, females had a moderate amount of collagen fibers in all the 3 subdivisions, showing the decrease at the age of 17, while in cases of males the moderate amount of collagen fibers was observed at the age of 15 and the decrease was at 36 years with the subsequent loss at 45 years. These findings suggest the earlier occurrence of the age change of the amount of fibers in females.

There was no obvious sexual difference in the maturity of the connective tissue layer. Concerning the arrangement of fibers, the first appearance of the completely horizontal array was noted at 5 days after birth in females, while it was seen at 15 years in males, suggesting the earlier occurrence of fully horizontal array of fibers in females.

As for the chondrocytes in the connective tissue layer, females showed the first appearance at the age of 35 days, showing subsequently the moderate and remarkable appearances at 7 and 17 years respectively. In cases of males, the first appearance was observed at the age of 0 year (fetal age of 36 weeks). Moreover, the moderate and remarkable appearances were noted at 2 and 36 years respectively. These findings indicate that females show the late occurrence of the first appearance, and that chondrocytes increase in number sooner in females than in males.

With regard to the distribution of chondrocytes in the connective tissue, in cases of females the distribution shifted from the periphery to the entire with the increasing age; and the complete transformation of the connective tissue into cartilage was noted at the age of 29. In cases of males, the first appearance of chondrocytes was located at the center of the connective tissue; and the complete transformation was confirmed at the age of 45, leading to the conclusion that the transformation into the chondroid tissue occurred earlier in females than in males.

With respect to the degeneration of chondrocytes, in cases of females, the slight and marked appearances were seen at the age of 17 and after 29 years respectively. In cases of males, the degeneration was of slight degree at the age of 29, becoming prominent after 36 years. Therefore, the degeneration occurs earlier in females.

In both sexes, the occurrence of degeneration, necrosis or liquefaction of cartilaginous tissue was parallel to that of degeneration of chondrocytes in terms of the extent as well as the time of occurrence. In cases of females, these degenerative or necrotic changes were most remarkable after the age of 29, especially in those females with the history of delivery. Therefore, these changes seem to be related to the expanded or contracted pubic symphysis during pregnancy.

3. The role of the cartilaginous layer for the fusion process

When the cartilaginous layer was divided into inner and outer parts, the former revealed a quantitative age change, and the latter qualitative one.

During the fetal period with a connective tissue layer, the inner part was formed actively, showing subsequently a gradually decreased activity after birth.

Inversely, the outer part showed manifold changes including swollen chondrocytes, calcium deposits, columnar array of chondrocytes, provisional calcification and osteoclasts with the simultaneous appearance of mature collagen fibers in the connective tissue layer. As the age increased, the columnar array and osteoclasts became more prominent, resulting in ossification and resorption of the outer part of the cartilaginous layer. This process finally arrived at the formation of marrow cavity in the pubic bone at the age of 17. When the connective tissue disappeared, the ossification and resorption of the outer cartilaginous layer also disappeared with the concomitant remarkable appearance of chondrocytes in the connective tissue layer. The appearance of chondrocytes changes the connective tissue layer into a chondroid tissue.

In both sexes, when the linear borders between the outer surface of the outer cartilaginous layer and marrow cavity changed into wavy and irregular borders, the columnar array of chondrocytes and provisional calcification disappeared.

In females, these changes occurred earlier and more remarkable, arriving at the peak.

As the connective tissue showed the sequential changes including the differentiation, growth and fusion in order of the appearance, the role of the cartilaginous layer, especially of the outer part, also shifted from the supportive and protective ones to the participation in the marrow cavity formation by means of the own differentiation and growth. Therefore, the main role of the outer part of the cartilaginous layer was related to the formation of marrow cavity rather than to the fusion process itself.

4. The comparison of the fusion process between the pubic and mandibular symphyses

It is well known that a human has 3 sites where the fusion of bones occurs after birth; the mandibular and pubic symphyses and sutures of the skull. In the following sentences, a comparative study between the former 2 symphyses will be done based on previous reports about the process of the mandibular symphysis²⁷⁻³⁰⁾, in order to determine the difference and characteristics of both symphyses.

The symphyseal area of the mandible differentiated into 3 layers in the fetal case of 8cm in length. They were osteoblastic, transitional and connective tissue layers from outside to inside.

The first appearance of a partial fusion by means of the increased bone formation was confirmed at the age of 2 months after birth. This bony fusion was well developed at the age of less than 1 year, when the first eruption of deciduous teeth occurred. Because this period is also the time for the fatty marrow to begin the appearance at the anterior part of the mandible, this process can be regarded as the first step for the

completion of the mandibular growth.

In contrast, the pubic symphysis area showed an omen of fusion in both connective tissue and cartilaginous layers in the fetal case of 15cm in length. The first appearance of chondrocytes in the connective tissue layer was noted in the fetal case of 38cm in length, followed by the complete change of the connective tissue into the chondroid tissue at the age of 25 years after birth.

Thus, the fusion process of the mandibular symphysis preceded the pubic counterpart in terms of the initiation and completion. These phenomena can be interpreted as follows: The earlier appearance of the well developed mandibular symphysis may be related to the fact that the mandible begin the function of sucking or chewing soon after the birth. The structure of the pubic symphysis may be related to the function of the pelvis as described below.

5. The biological role of the pubic symphysis

The completion of the pubic symphysis occurred at the age of 25 which was much later than the mandibular counterpart.

This difference may be related to the fact that pelvis containing the pubic bones play the functional role in adults. Moreover, the cartilaginous combination at the pubic symphysis correspond to the pelvic function with the elasticity to expand or contract. This view is supported by the fact that the degeneration or liguefaction in the cartilaginous tissue is more dominant in females with history of delivery than in females without it or in males. In other words, the damages of the pubic symphysis by the extension or contraction during pregnancy give rise to the remarkable degenerative changes.

In summation, the cartilagnous combination of both pubic bones is a very reasonable structure from the view point of the function of the pelvis. In addition, the pubic symphyses has manifold degenerative changes with increasing age, as seen in the intervertebral discs. In contrast, the mandibular symphysis consisting of bony tissues does not show such changes.

Summary

In order to determine the fusion proceess of the pubic symphysis, a histological study was performed, using 13 fetal cases (7 males and 6 females) and 46 postnatal cases (24 males and 22 females). With the aid of the previous reports on the mandibular symphysis, it was also aimed to determine the difference between both symphysis and to characterize the fusion process of the pubic symphysis. The results were summarized as follows.

1. The symphysial area consisted of two layers: connective tissue and cartilaginous tissue layers.

2. The collagen fibers in the connective tissue layer was always slight in the amount during the fetal period, except for female cases of more than 25cm in length,

showing a moderate amount of fibers. In the postnatal cases, it was only female that had a moderate amount of fibers.

The connective tissue layers disappeared at the age of 2 in males and at 12 years in females.

3. The extent of the maturation of collagen fibers in the connective tissue layer was parallel to the amount of fibers in the fetal periods, followed by the constant predominance of matured fibers in the postnatal period.

The array of the fibers shifted from vertical to horizontal via oblique one in the postnatal period.

The first appearance of chondrocytes in the connective tissue layer was noted at the same time with the occurrence of the horizontal fibers. Subsequently, the chondrocytes increased in number with the increasing age, showing the dominant appearance at the age of 15.

4. The amount of chondrocytes in the inner part of the cartilaginous layer was always remarkable in the fetal period, followed by the reduction after birth. The chondrocytes were few after the age of 12.

In the outer part of the cartilaginous layer, the first appearance of swollen chondrocytes was confirmed in the case of 21cm in length, followed by the unchanged number until 21 years after birth, when they disappeared. The first appearances of calcium deposits, columnar array of chondrocytes, provisional calcification and osteoclasts were observed in the fetal case of 31cm in length, followed by the increased degrees of appearances until birth. After birth, these findings decreased in degrees with the increasing age, showing the disappearances following the age of 19.

5. The bilateral pubic bones were connected by the chondroid tissue; and the connection was completed at the age of 25.

6. Following the completion, the chondroid tissue underwent degeneration, necrosis and liquefaction. These degenerative changes were more dominant in females, especially in those with a history of delivery.

7. The comparison between the fusion processes of both pubic and mandibular symphysis revealed the earlier occurrence of initiation as well as completion of the latter symphysis and the later fusion of the former symphysis. Besides, the cartilaginous fusion of pubic symphysis showed the different biological significance from the mandibular symphysis, and also showed the reasonable structure for the function of the pelvis containing the pubic symphysis.

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ヒト恥骨結合部の癒合過程に関する組織学的研究

—特に下顎結合部のそれとの比較検討—

九州大学歯学部口腔病理学教室（指導：橋本紀三教授）

九州歯科大学口腔外科学第二講座（指導：梶山 稔教授）

中 富 俊 介

胎生期例13例（男性7，女性6例）と生後例46例（男性24例，女性22例）の恥骨結合部を組織学的に検索し，恥骨結合部の癒合過程を明らかにするとともに，先に報告した下顎結合部のそれとを比較して，どのような差異を示すものか，ひいてはどのような特徴があるのかを研究目的とし，以下の結果を得た．

1．恥骨結合部の構成組織は，結合繊維層と軟骨層に2分することができた．

2．結合繊維層における線維の量は全胎生期を通して軽度で，ほぼ同程度であったが女性例の25cm例以降の例では中等度に増加していた．生後例でも女性例のみは，中等度に維持されていたが，結合繊維層は男性で2歳，女性では12歳で消失した．

3．結合繊維層における線維の成熟度は，胎生期例では線維の量に平行して，成熟化していたが，生後例では全例とも成熟優位であった．配列も胎生期では縦走よりしだいに斜走，横走を示し，生後例では横走のみを示した．軟骨細胞の出現は，胎生期では結合繊維層の横走の一定化時期に一致し，生後例では細胞がさらに増加し25歳では高度となった．

4．軟骨細胞層のうち，内側の軟骨細胞の量は全胎生

期を通して高度で，不変であったが，生後例ではしだいに減少し，12歳より軽度で存在するのみとなった．外側の軟骨細胞の膨化は他の所見に先行して胎生21cm例においてみられ，生後例でもほぼ同じ傾向を示したが，29歳例より消失した．他の所見としての石灰沈着，柱状層形成，予備石灰層形成および破骨細胞の出現は胎生31cm例より出現し，胎齢の増加とともに高度となり，生後例では高度，中等度と年齢増加に伴い減少し，19歳例で消失した．

5．恥骨結合の癒合機転は軟骨性癒合によるもので，25歳で完成した．

6．恥骨結合部の完成後，軟骨細胞変性および軟骨の変性，融解がみられ，女性により高度で，かつ出産歴を有する例ではより著明であった．

7．恥骨と下顎骨の両結合部は，開始時期および完成時期ともに下顎結合が先行し，恥骨結合ははるかに遅く癒合するものであることがわかった．さらに，恥骨結合部の軟骨性癒合の生物学的意義は下顎結合部の骨性癒合と異り，恥骨結合部を含む骨盤の機能に合目的性を示した．