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= Abstract =

## The Biomechanical Responses of Intervertebral Disc due to Degenerative Change in Porcine Lumbar Spine

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**Purpose:** The biomechanical responses of degenerative porcine intervertebral disc were compared with those of non-degenerative disc.

**Materials and Methods:** Two groups were set; Group A (44.0 ± 2.8 months old, female) and Group B (6.2 ± 1.3 months old, female). Histological (H&E stain) observations were carried out to see the degeneration for both groups. Then biomechanical responses were investigated by measuring height changes in disc, intradiscal pressure values and relaxation time for each specimen under axial compressive loads.

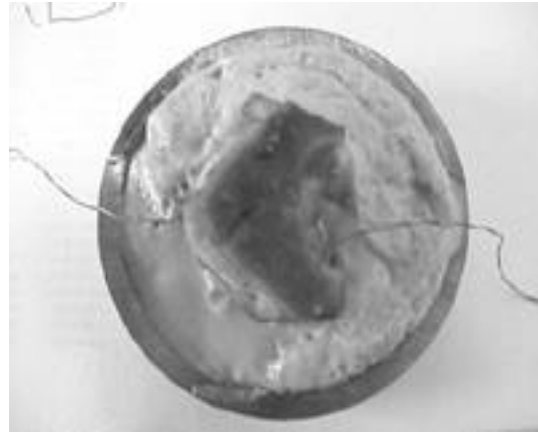
**Results:** Degenerative changes were confirmed through H&E staining in Group A. The ratios of the nucleus pulposus area to total area were 14.7 ± 4.5% and 29.2 ± 6.0% in Group A and B, respectively (p=0.000). The decrease rates in disc height were 12.1 ± 3.3% and 21.6 ± 7.6%, in Group A and B, respectively under the axial compression of 740 N (p=0.000). No significant difference in intradiscal pressure measured in anterior zone between-groups except at axial load of 740N (p>0.05). However, significant difference in pressure was found in posterolateral zone when the load was 542 N and higher (542 N: p=0.015, 740 N: p=0.010). The average relaxation time for Group A was significantly longer than that for Group B at 740N, i.e., at maximum load

:





**Fig. 1.** Motion segment tested was prepared by cutting the lumbar spine column.



**Fig. 2.** Motion segment was fixed with dental cement and pressure transducer was into the annulus fibrosus position of lumbar intervertebral disc.

3 mm, 2 mm, B  
 3 mm, 2  
 mm, 2 mm, 2  
 mm (Fig.  
 2). 가

(strain scanner)(A11600, Cas., Korea)  
 5 Hz

가

2)

가 (vernier  
 calipers)(CD-15CP, Mitutoyo, Japan) mm<sup>2</sup>

mm “ ” B  
 / (RPC-3002,  
 Ricoh, Taiwan),  
 (HL-Image++97, Microsoft, U.S.A.) and Eosin)  
 /  
 (pixel)

(Fig. 3).

“ ”

5 mm

Japan)

3

0.1 mm .

(threshold value) 105 , 240  
 (8 bit gray scale)

(Fig. 4).

“ ”

25 mm<sup>2</sup>

25 mm<sup>2</sup>

3 3

25

1.4

A

B

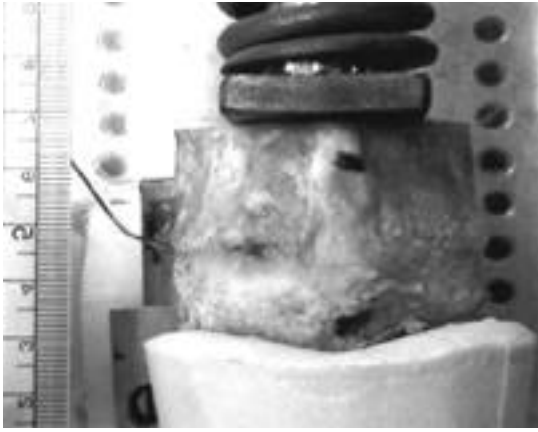
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H & E(Hematoxylin

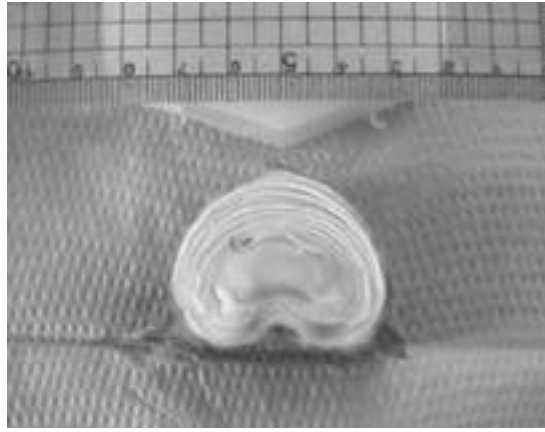
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(BH-2, Olympus,

(×200, ×500)



**Fig. 3.** Two black dots were marked on the body along with a ruler followed by digital image processing to measure the height change before and after loading.



**Fig. 4.** Cross-sectional area of the nucleus pulposus was measured through digital image processing.

**Table 1.** Calibration of load vs. spring displacement.

Distance (mm)	Load (N)				Mean	Std. Deviation	Std. Error
	No. 1	No. 2	No. 3	No. 4			
5	84	81	83	86	84	2.1	1.0
10	171	174	178	181	176	4.4	2.2
15	264	267	271	273	269	4.0	2.0
20	356	358	363	363	360	3.6	1.8
25	452	458	456	458	456	2.8	1.4
30	526	546	546	549	542	10.6	5.3
35	637	635	644	644	640	4.7	2.3
40	738	736	742	745	740	4.0	2.0
45	839	834	837	839	837	2.4	1.2

3) 가 , 가 .  
 ( )  
 .  
 (MTS)(858.20, MTS Systems, U.S.A.) 20 (25 KN) (ETB50 -B05LA23-FM200-A, Parker Hannifin, U.S.A.) (5 mm )  
 4  
 1.0 5.3 N (Table 1). (1) -  
 0.1 mm/sec  
 10 mm 4 SPSS  
 (Table 2). 11.0(SPSS, U.S.A.) .

**Table 2.** Four steps of compressive load based on displacement

Load steps	Displacement of actuator (mm)	Axial compression load (N)
1	10	176
2	20	360
3	30	542
4	40	740

**Table 3.** Descriptives of one-way ANOVA test for the ratio of nucleus pulposus area to total area in each group (unit: %).

Group	Motion Segment	N	Mean	Std. Deviation	p-value	
					Within Group	Between Groups
A	L1 2	3	13.0	3.8	.478	
	L2 3	3	14.0	5.7		
	L5 6	2	15.2	2.8		
	L6 7	1	21.6	.		
	Total	9	14.7	4.5		
B	L1 2	4	32.8	10.0	.698	.000
	L2 3	1	30.6	.		
	L3 4	3	25.6	1.9		
	L4 5	2	28.5	1.3		
	L6 7	3	28.1	4.1		
	Total	13	29.2	6.0		

Fig. 5).

(SPSS, Version 11.0, U.S.A.)

one-way ANOVA test

Tukey HSD

p=0.115, B : p=0.229).

(A :

7.9±0.2 mm 1.0±0.3 mm가

12.1±3.3% B

5.8±0.5 mm 1.3±0.4 mm가

1. 가 21.6±7.6% (Fig. 6).

/ B

(p=0.000)(Table 4).

A  
B

가

A

(Fig. 7-A)

( ) 가

(A : p=0.478, B : p=0.698). A

(Fig. 7-B).

1.3±0.7 cm<sup>2</sup> 14.7±4.5%

(giant) 가

B 2.0±0.7 cm<sup>2</sup>

(Fig. 7-C).

A 가

29.2±6.0%

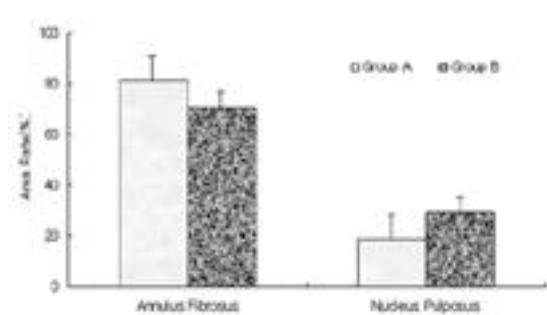
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. B

(p=0.000)(Table 3, (Fig. 8-A)

**Table 4.** Descriptives of one-way ANOVA test for decrease rate of the intervertebral disc in height in each group (unit: %).

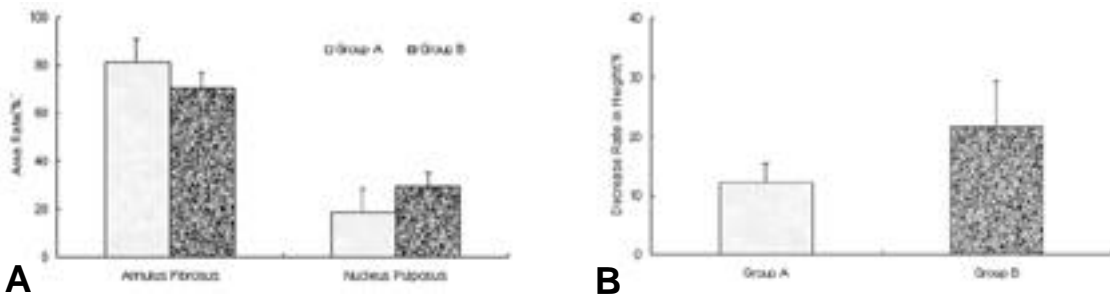
Group	Motion Segment	N	Mean	Std. Deviation	p-value	
					Within Group	Between Groups
A	L1 2	4	11.3	5.5	.322	
	L2 3	4	11.2	3.2		
	L3 4	4	11.4	2.8		
	L4 5	4	14.3	2.4		
	L5 6	3	9.6	1.3		
	L6 7	3	14.7	1.3		
	Total	22	12.1	3.3		
B	L1 2	4	17.9	6.3	.251	
	L2 3	5	21.7	9.5		
	L3 4	5	28.2	4.2		
	L4 5	5	18.4	6.7		
	L5 6	3	24.3	10.9		
	L6 7	3	18.3	3.5		
	Total	25	21.6	7.6		



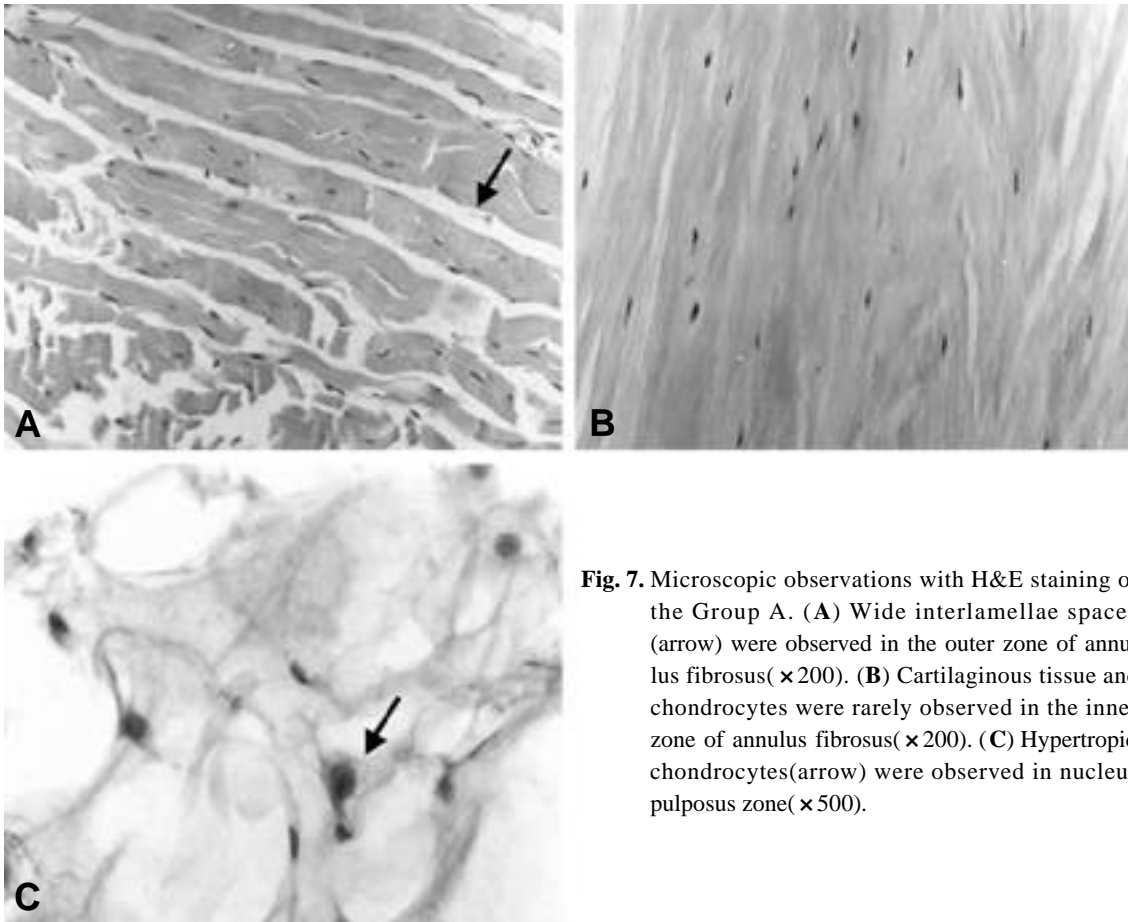
**Fig. 5.** The average ratio of the nucleus pulposus area to total area in Group A was significant lower than that in Group B.

N 740 N  
 (542 N: p=0.015, 740 N: p=0.001).  
 542 N  
 A 755.2±126.9 kPa, B 656.9±132.5  
 kPa, 740 N  
 995.4±192.5 kPa 816.0±162.0 kPa  
 (740 N: p=0.000) B A  
 (740 N: p=0.001)(Table 5).

가 ( 50%) 740 N  
 (Fig. 8-B).  
 가 p=0.010, : p=0.014). 740 N  
 (Fig. 8-C). B 가 A 196.4±  
 가 . 70.4 sec, B 145.5±53.2 sec ,  
 202.0±65.1 sec 161.2±  
 2. 40.5 sec , B A  
 740 N p=0.010, : p=0.014)(Table 6).  
 (A  
 729.9±135.0 kPa, B 610.6±105.1 kPa,  
 p=0.002). 542



**Fig. 6.** (A) Height of intervertebral disc in each group before and after test. (B) Decrease rate in height for each group. The degenerative disc was less flexible than non-degenerative disc.



**Fig. 7.** Microscopic observations with H&E staining of the Group A. (A) Wide interlamellae spaces (arrow) were observed in the outer zone of annulus fibrosus ( $\times 200$ ). (B) Cartilaginous tissue and chondrocytes were rarely observed in the inner zone of annulus fibrosus ( $\times 200$ ). (C) Hypertrophic chondrocytes (arrow) were observed in nucleus pulposus zone ( $\times 500$ ).

가 Kang (3,5,8,16)

가 , A B  
Kang (3,8)







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