

## Follower Load

### Analysis of Compression Behavior in Lumbar Spine – Under Simple Vertical Load vs Follower Load –

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#### – Abstract –

**Purpose** : To clarify the behavior of the lumbar spine under vertical compressive load and follower compressive load and to confirm the effect of the follower load on the stability of the spinal column using finite element method.

**Materials and Methods** : Describing follower compression test to overcome underestimation of load carrying capacity, the problem in existing ex- vivo lumbar spine compression test, with finite element analysis, comparing with the result of simple vertical compressive load, we analyze the property of kinetic behavior. After performing finite element modelling about L1- L5 lumbar vertebral column, analyze it about vertical compressive load and follower compressive load. Intervertebral discs with complex structure and mechanical properties was modeled using spring element that compensate stiffness and tube- to- tube contact element was employed to give follower load. With compressive load, change of lumbar spinal curve is so much, that geometrical analysis should be done.

**Results** : Under the follower compressive load, the vertebral column was so stiff that vertical displacement of the upper end plate of L1 was markedly reduced, comparing with that under the simple vertical compressive load. Sagittal rotation of that upper end plate was also decreased in the opposite direction. Compressive load on the intervertebral disc was evenly distributed along the entire column. The bending moment at each disc was reduced in the opposite direction. A lesser A- P shear force occurred at the intervertebral disc.

**Conclusion** : As a result of finite element interpretation of lumbar spine, the stability and load carrying capacity was increased largely, and the compressive load was transmitted through the column in a more pattern, when follower compressive load applied. This can provide the basis for explaining the difference of early buckling occurrence reported in ex- vivo testing, and load carrying capacity of the lumbar spine in- vivo, but, for more precise replication of behavior of lumbar spine in- vivo to variable loading. A invention of a more precious finite element interpretation model which consider the role of muscle around the spine is loaded.

**Key Words** : Lumbar spine, Finite element method, Follower load, Load carrying capacity, Biomechanics

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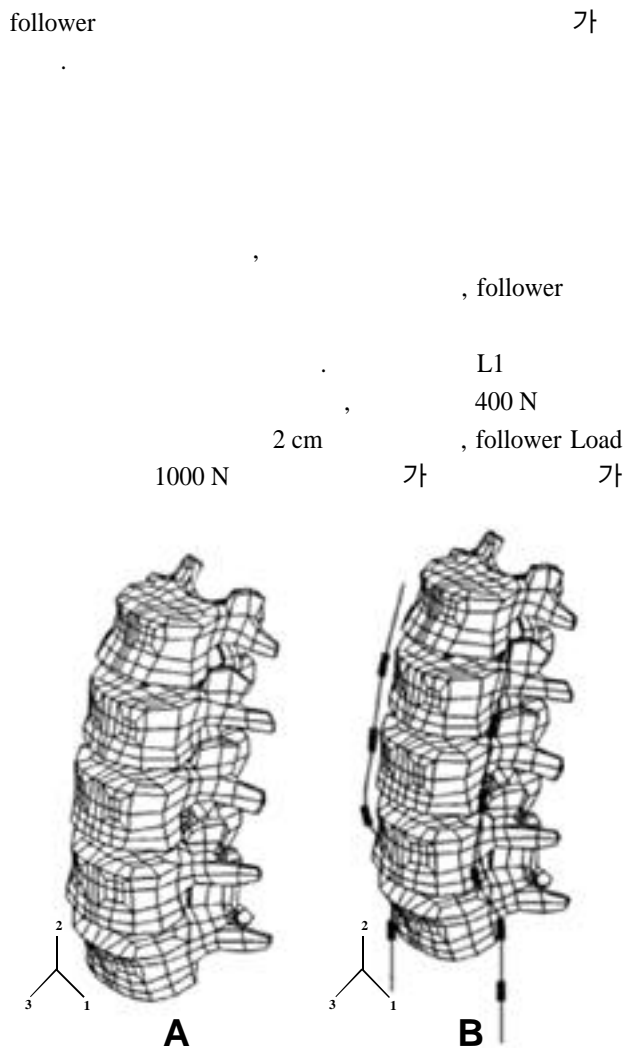
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12000 MPa 0.3 ,  
100 MPa 0.2 .

가 가  
Shirazi-Adl (rod) (fiber)  
1000N <sup>1)</sup>, 3  
(prolapse),  
<sup>2)</sup> ,  
Goel Shirzi-Adl  
가 ,  
80~100 , Steffe plate 가 3  
(buckling) <sup>8)</sup>  
in-vivo 가  
follower (stiffness)  
load 가  
(vertebral column)  
follower load 가  
, flexion extension  
6  
(end-plate) (centroid)  
(rigid beam)  
(kinematic constraint)  
Viewpoint Data Labs

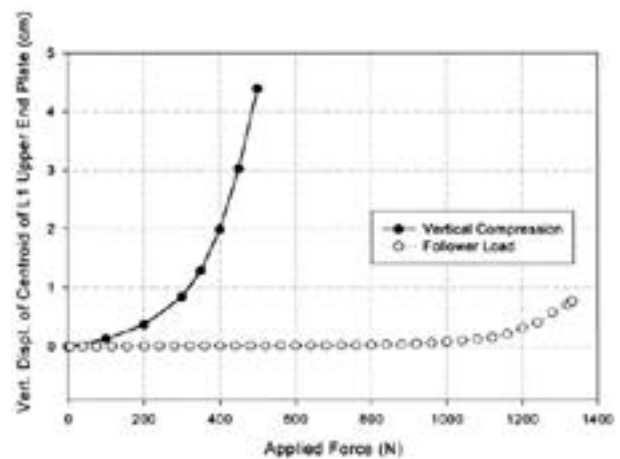
follower load  
pre-processor , Follower load 가 가  
TrueGrid 2.0(XYZ Scientific Applications, Inc., Livermore, CA, USA)  
5 8 3 0.2 mm 가  
(cortical bone) 1 mm 4 , 3 cm , 가  
<sup>5)</sup> 가  
Shirazi-Adl<sup>7)</sup>

가 ,  
(hollow) 0.5 mm  
0.2 mm 가  
가 가  
tube-to-tube  
(contact element)  
follower load  
Fig. 1  
Pre/Post Processor TrueGrid 2.0 MSC PATRAN  
2001(MSC Software Coperate, South Coast Metro, CA,  
USA) , ABAQUS 6.1(Hibbitt, Karlsson &  
Sorensen, Inc., Pawtucket, Rhode Island, USA)  
L1 가 ,  
follower 가

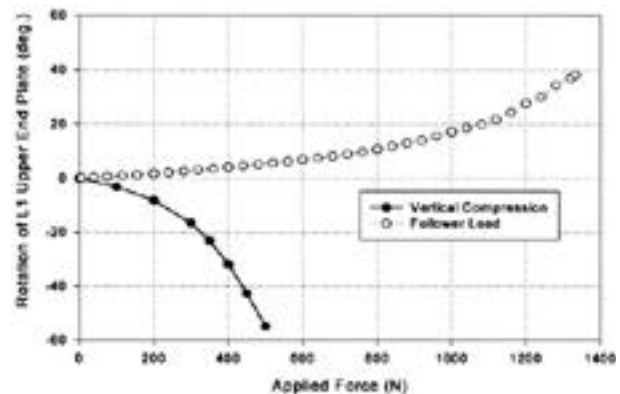


**Fig. 1.** Finite element model for lumbar spine under compression. **A.** vertical compressive load. **B.** follower compressive load.

(Fig. 2).  
가 (Fig.  
3). Fig.1 1  
가 L1  
L1 follower load  
han L1 Patward-  
(flexibility) L1-S 가  
가 가  
가 가 가 가  
(Fig. 4). 가



**Fig. 2.** Comparison of vertical displacement at L1 upper end plate.



**Fig. 3.** Comparison of rotation at L1 upper end plate on sagittal plane.

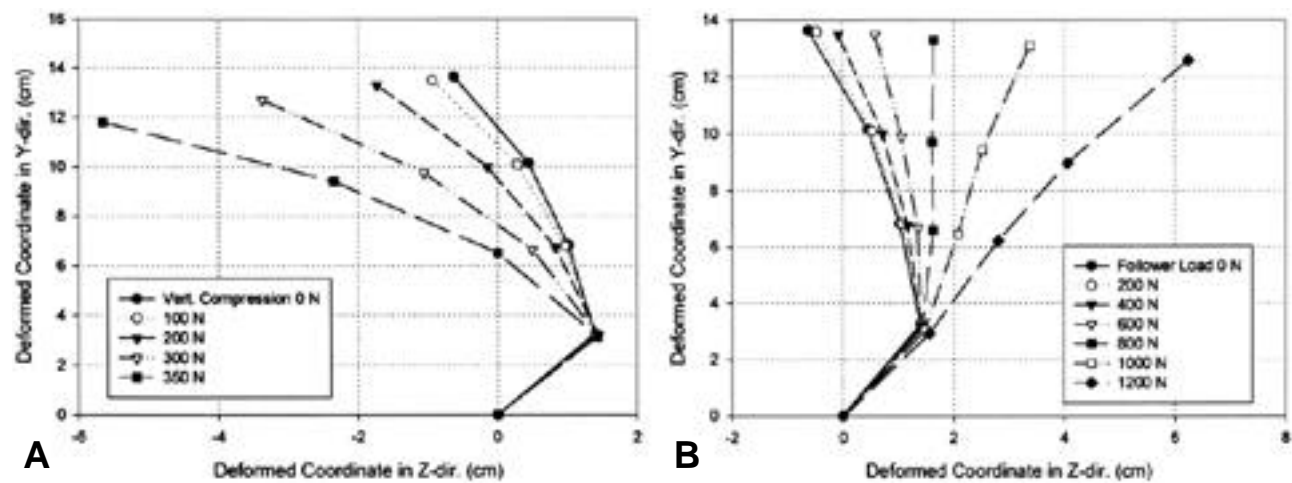


Fig. 4. Change of spinal curve due to compression. A. Vertical compressive load. B. Follower compressive load.

Fig. 4 (b)

L1, 350 N, 6 cm, Follower, 가

가, L1, 1000 N, 3 cm

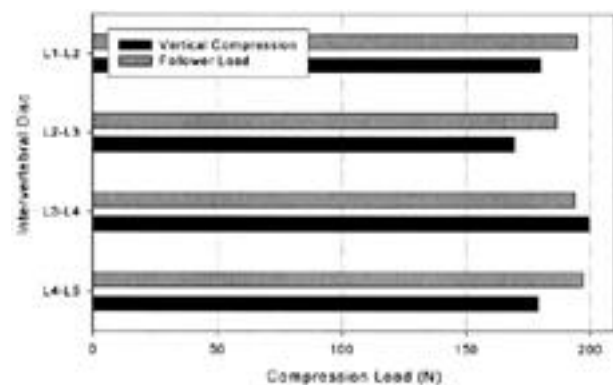


Fig. 5. Compressive load on intervertebral discs.

(Fig.

5). 가, L3-L4, 200 N, 가

Follower load

Follower load

가

가

follower load

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(Fig. 6).

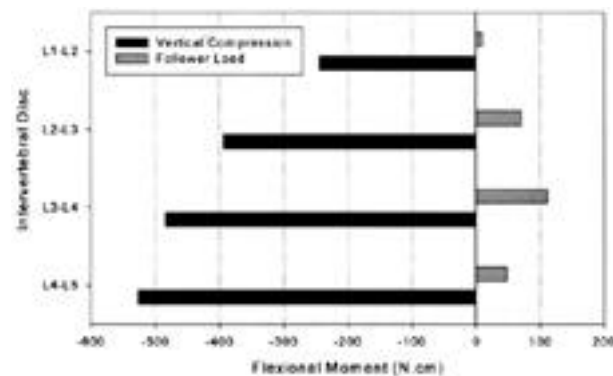


Fig. 6. Ext./Flex. Bending moment on intervertebral discs.

. Follower load

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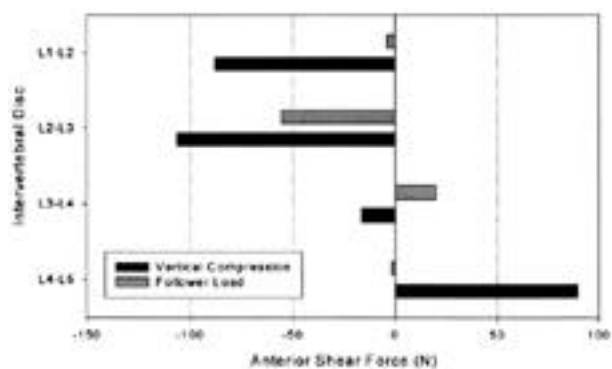
, L2-L3

60 N

가

(Fig. 7).

가



**Fig. 7.** Post./Ant. Shear Force on intervertebral discs.

Rohlmann <sup>4)</sup> ex-  
 vivo  
 가 follower load  
 . Patwardhan  
 (instability)  
 1200 N 가 .  
 , Chung ,  
 ,  
 (internal load)

5.6), L1 L5

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. L1 가

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follower load

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follower

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, follower

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가 ,

. ex-vivo

in-vivo

in-vivo

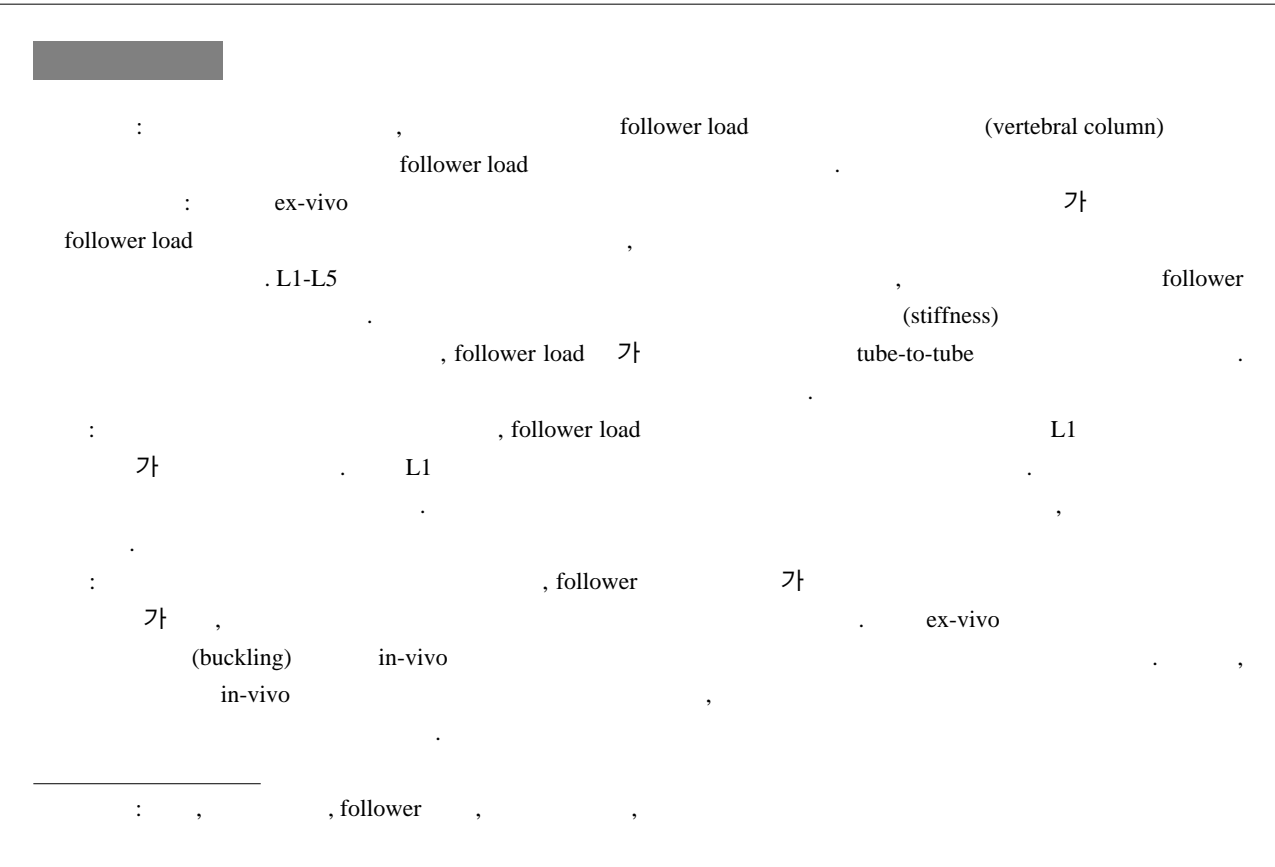
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