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Biomechanical Study on the Constructs of Bone Cement Incorporate with Screw for Anterior Spinal Stabilization: Comparison between the construct versus normal spine

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Abstract

The construct of bone cement incorporate with screw had been performed for anterior spinal stabilization since 1985, in Chulalongkorn Hospital, Thailand. It seemed to have achieved a very encouraging result, but there has not been any experiments to confirm its advantage. This biomechanical study was designed to determine whether there was actually any mechanical advantage. The experiment had shown that this construct had more rigidity than the normal spinal in axial compression loading and had no significant difference in torsional loading.

Introduction

Anterior decompression combined with anterior bone grafting is a widely accepted procedure for the reconstruction of a decompressed spine (Cleaveland, 1956; Hamby, *et al.* 1959; and Lee, *et al.* 1986) they believed that bone graft is the preferred choice of treatment for the patient with long life expectancy. However, bone graft required prolong immobilization (Arseni, *et al.* 1959; Fielding, *et al.* 1979; Hodgson, *et al.* 1960; and McAfee, *et al.* 1989), the use of polymethylmethacrylate is more favorable because of the instant stability obtained after surgery. It is much useful in an environment which prolong bed rest, hospitalization can be avoided (3-5) (Bernhang, *et al.* 1978; Bryan, *et al.* 1982; Cantu, 1974; and Harrington, 1981). It can be combined with bone graft to achieve long term stability.

Since 1959, Knight was the first to document the cases whom fixed the cervical spine with acrylic cement (Clark, *et al.* 1974; Hamby, *et al.* 1959; Knight, 1986; and Martin, *et al.* 1970). The use of polymethylmethacrylate in spine had become popular. The indications had been more widely including anterior and posterior stabilization in all regions of the spine. It may be employed as a spacer (Bryon, *et al.* 1982; Connally, *et al.* 1965; Cross, *et al.* 1971; Keggi, *et al.* 1976; and Scovill, *et al.* 1969) withstand for the compression loading, but not strong enough to withstand against the extension and rotational force (Cleaveland, 1956).

Scoville, *et al.* (1969) (Clark, *et al.* 1984; and Cross *et al.* 1971) whose first replacement and stabilization using polymethylmethacrylate as a spacer in experiments on dogs and later in patients, reported the result with adequate fixation, safe heat limits, absence of late infection.

Harrington (1981) reported the use of polymethylmethacrylate as anterior spacer following vertebral body resection in metastatic malignant disease. It was used safely and effectively to recreate and maintain the normal vertebral space.

Wang, *et al.* (1983) performed the experiment to compare the strengths of various anterior cement fixations of the cervical spine. The results indicated that all fixation methods failed to regain the normal structural strength in extension. Only the wire and chain fixation methods offered comparable strength to the normal spine.

Shono, *et al.* (1993) (Ono and Tada, 1975) performed the biomechanical study to compare 3 types of anterior reconstruction, composed of anterior iliac strut bone grafting, anterior carbon fibre composite cage packed with cancellous bone graft and polymethylmethacrylate construct. In this study, the carbon cage showed greater biomechanical potential than bone construct alone or polymethylmethacrylate, especially in flexion-extension testing.

Our bone cement construct only designed as an anterior spacer, but combined with screw to lessen the movement of the spacer. The basis of this construct relied on the screws and washers that were locked into the slot of vertebral bodies, then the ends of the screws were connected together with the application of bone cement. We preserved the end plates which were the rigid part of the vertebral body for anchoring the construct. Finally, this construct should resist the compression force with its good compressive strength of the bone cement, resist the extension and rotatory force by the screw and was hers which are locked into the bony slots.

Materials and Methods

Specimen Preparation.

10 freshly frozen, porcine cervical spine segments from C2 to C6 were used in this study. The pigs are aged about 1-1.5 years old. The specimens were dissected free of all non ligamentous soft tissue. The top and bottom vertebrae were mounted in polyester resin with the center of the superior most and inferior most vertebral bodies were vertically aligned. We added four fixation jigs to the specimen for more stabilization to the testing chamber.

We used the intact spine as a control specimen. After the intact spine had been tested, we performed the bone cement construct with the same specimen by one level corpectony, adjacent disc removal with remaining vertebral end plate. The upper and lower adjacent vertebra were created a slot like a mushroom shape. Finally, the screw with washer and bone cement were incorporated together as Figure 1.

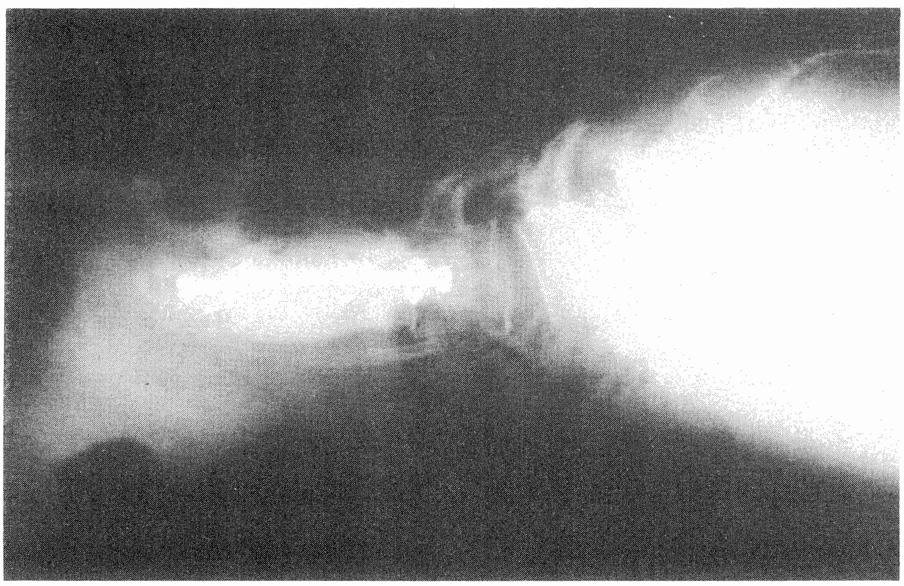

Figure 1 Lateral radiograph of lumbar spine show the bone cement construct fixation from L1-L4

Biomechanical Testing

The specimens were tested on a materials testing system (Instron/1341). Axial compression and torsional tests were performed.

Axial Compression

The axial loading was applied up to 1000 N at a constant speed of 0.05 mm/sec. The axial rigidity was a accepted as

AE = FI

Where	AE	: axial rigidity (N)
	F	: applied load
	I	: specimen length (m)
		: axial deformation (m)

Torsion

For torque test, the end of the specimen chamber were held by a torsion jig and torsional loads were applied through a pulley with a maximal load of 500 N. (about 500 N x 0.02 – 10 Nm torsional load). The strain rate was kept at 0.05 mm/sec. The rigidity at torsion defined as :

GJ = TL

Where	GJ	: torsional rigidity (N. m/deg)
	T	: torque (N. m)
	L	: specimen length
		: angle of twist (deg)

Each specimen was tested 4 times and both the load and deformation curved were recorded. Statistical analysis were performed by pair student's T test and $p < 0.05$ was accepted as statistically significant.

Results

The rigidity of stiffness of the specimen is always defined as the amount of force required to produce unit of deformation. In our study, the formulas of rigidities had a linear relationship with the slopes which calculated from the load deformation curves.

Compression Test

With the loading up to 1000 N., it was shown that the specimen with bone cement construct had more stiffness than normal spine. This was statistically significant ($p < 0.05$) Table 1.

Torsional Test

With the load up to 10 N m, the normal spine had more stiffness than bone cement construct but this difference was not statistical significant ($p>0.05$) Table 2. This implied that the construct had the rigidity similar to the normal spine.

Thoroughly testing, there was no any bone cement construct dislodged or failure.

Table 1 Compression test : Rigidities of Normal Spine and Bone Cement Construct. (N/mm)

Trials	Normal	Bone cement
1	451.70	435.00
2	433.90	409.00
3	422.60	416.60
4	344.80	433.60
5	379.70	445.50
6	367.00	476.40
7	417.00	439.90
8	409.30	468.70
9	412.00	490.00
Average	404.22	446.07
S.D.	33.98	27.20
P =	0.0107	

Table 2 Torsional test : Rigidities of Normal Spine and Bone Cement Construct (N/mm)

Trials	Normal	Bone cement
1	86.70	83.60
2	88.50	83.00
3	81.30	80.70
4	109.10	98.90
5	111.60	100.00
6	103.60	104.90
7	96.40	97.00
8	99.50	100.00
9	94.80	93.51
Average	96.83	93.51
S.D.	10.24	8.86
P =	0.07	

Discussion

We adopted to experiment with the procaine's cervical spine instead of human spine, based on the previous studies of Allen and Panjabe, that shown the similar configuration and size between porcine's cervical spine and human lumbar spine (Allan, *et al.* 1990; and Oxland, *et al.* 1991). Besides, our objective was only to determine the advantageous strength of bone cement construct.

Methylmethacrylate had been used both anteriorly and posteriorly to provide immediate fixation for a destabilized spine. There were biomechanical evaluation of cement construct reported with favourable results especially with the compression test, but have the drawback with the flexion – extension and torsional testing (White and Panjabi, 1990). This bone cement construct had shown in vitro that it could withstand without extrusion or displacement with either compression or torsional force which was the frequent normal posture. It could also imply that this construct should be beneficial on immediate anterior stabilization of the spine.

The major disadvantages of polymethylmethacrylate include wear debris, progressive loss of fixation with time and difficulty in the treatment of infectious complications (Wang, *et al.* 1984). In our experience, after decompression and fixation with bone cement construct, we also added bone graft surrounding the construct to promote new bone fowtion for long term stability. We have had no incidence of infection with the anterior construct of bone cement in our 15 case series. The antibiotic gradually released from the cement to combat the surrounding infectious tissue and bone. Finally, we was able to provide or perform this construct easily in any operating rooms, not expensive and efficient.

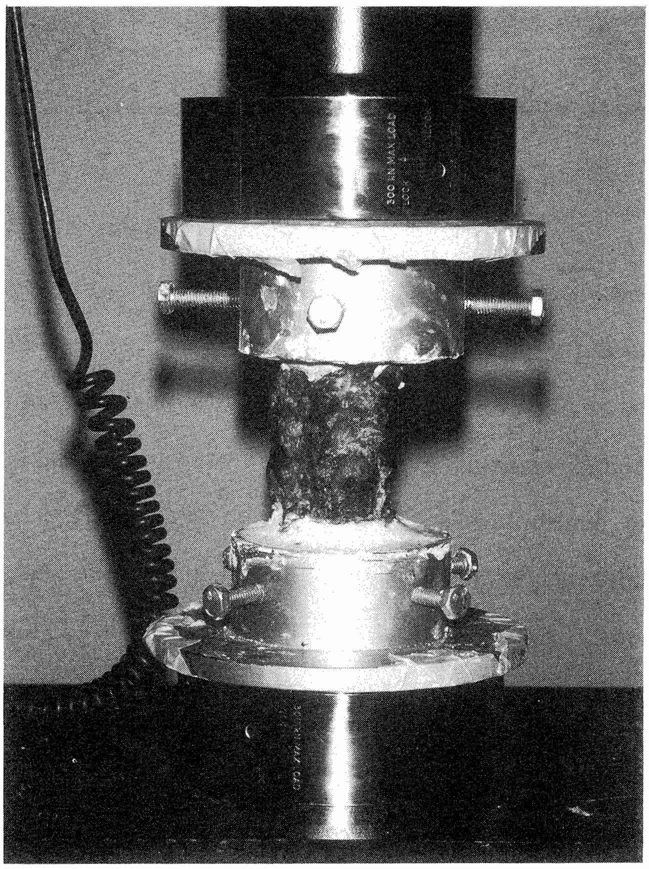

Figure 2 Compression test

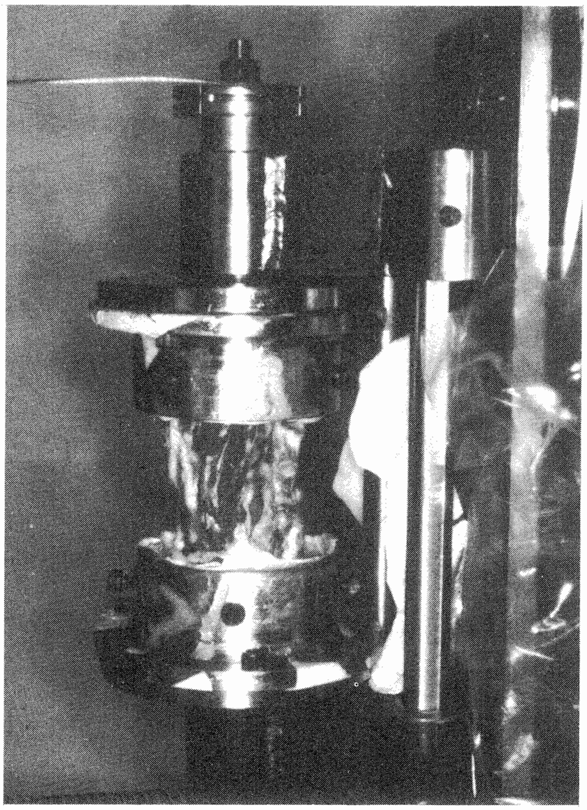

Figure 3 Torsional test

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