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ORIGINAL ARTICLE

# Posterior instrumentation for osteoporotic fractures in the thoracic or lumbar spine: Cement-augmented pedicle screws vs hybrid constructs

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## Abstract

**Background:** Cement-augmented pedicle screws (CPS) and hybrid construct (HC), consisting of pedicle screws and additional hooks, are common fixation methods for osteoporotic spine fracture. No study has compared surgical results of CPS and HC for treating osteoporotic spine fracture. The aim of the study was to compare surgical results using CPS or HC for osteoporotic fractures of the thoracic or lumbar spine.

**Methods:** This retrospective cohort study included 84 patients who received surgical treatment with CPS (n = 43) or HC (n = 41) for osteoporotic spine fractures from January 2011 to December 2015, with a mean follow-up of 67 months. Sixty-five patients with neurological deficits received long posterior instrumentation, short posterior decompression, and posterolateral fusion. The 19 patients without neurologic deficits received long posterior instrumentation without posterior decompression and fusion. Radiographic, clinical, and neurologic outcomes were evaluated.

**Results:** The HC group had significantly shorter operative times (231 vs 258 minutes), greater blood loss (497 vs 427 mL), better immediate postoperative kyphosis reduction (10.6° vs 9.1°), and greater final reduction loss (9.8° vs 7.1°) than the CPS group. In both groups, significant loss of the kyphotic angle was apparent during follow-up. Improved ambulation after surgery occurred in 51.2% and 58.5% of patients in the CPS and HC groups, respectively. Neurologic function after surgery improved 0.5 and 0.7 grades in the CPS and HC groups, respectively. Implants failed in 2.3% and 2.4% of patients in the CPS and HC groups, respectively. The incidence of cement leakage from screw augmentation was 38.9%.

**Conclusion:** The CPS and HC techniques for treating osteoporotic fractures of the thoracic or lumbar spine did not differ statistically in terms of improved radiologic and clinical outcomes, final neurologic and ambulatory function, or implant failure rates, making them equally comparable alternatives.

**Keywords:** Burst fracture; Cement augmentation; Hook; Hybrid construct; Pedicle screws

## 1.INTRODUCTION

Osteoporosis, the most common metabolic bone disease, leads to alteration in bone density that has been shown to compromise the strength of spinal instrumentation.[1] With elderly populations growing, rates of spine surgery performed on osteoporotic patients have increased to treat a variety of conditions.[1] Vertebral fracture is the most common osteoporotic fracture in the elderly, and surgical intervention is sometimes needed for patients diagnosed with nonunion, failure of vertebroplasty, and neurologic deficits.[2–4] Therefore, spine surgeons will increasingly face the challenge of achieving rigid fixation of osteoporotic spines.

Cement-augmented pedicle screws (CPS), the most commonly used strategy, maximizes pullout strength in fixation of osteoporotic spines.[2] Hybrid constructs (HC), a combination of pedicle screws and hooks, offer an alternative approach to avoid implant failure and increase construct stability when placing instrumentation in the osteoporotic spine.[5–7] Biomechanical studies of either CPS[8,9] or HC[5–7] for osteoporotic spine have demonstrated superior implant pullout strength, compared with pedicle screws only. However, few clinical investigations to date have focused on comparing surgical results of the CPS and HC techniques. The goal of this retrospective cohort study was to compare the surgical outcomes and surgery-, patient-, and implant-related complications between the CPS and HC techniques for osteoporotic vertebral fractures of the thoracic or lumbar spine.

## 2. METHODS

### 2.1. Patient collection

The institutional review board of our hospital approved the research protocol (2021-01-030CC). The requirement for

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informed consent was waived because of the retrospective nature of this study. This study was performed in accordance with the ethical principles set out in the 1964 Declaration of Helsinki. This study included 99 consecutive patients with osteoporotic vertebral fractures who were treated surgically at our hospital from January 2011 to December 2015. The indications for surgery were failure of conservative treatment or vertebroplasty or neurologic deficit. We defined treatment failure as persistent back pain without improvement following conservative treatment or vertebroplasty. Fifteen patients were excluded from the study: eight were lost to follow-up (they did not complete the latest plain radiograph of spines), two died of unrelated medical conditions, three had degenerative scoliosis, and two had *T* scores greater than –2.5. Consequently, 84 patients, 22 males and 62 females, were included in the study.

All patients underwent long posterior instrumentation with or without posterior decompression, depending on whether or not they had neurological deficits. All operations on the CPS and HC groups were performed by two senior surgeons. The CPS group consisted of 43 patients who received long instrumentation with CPS; the 41 patients in the HC group received a combination of pedicle screws and hooks. Long instrumentation was defined as instrumentation at least two levels above and below the fractured level for implant insertion, regardless of technique used.

We used the World Health Organization criterion for osteoporosis, which is a *T* score less than –2.5 using dual-energy X-ray absorptiometry (DXA) of the hips,[10] completed before or right after the index surgery. The worst *T* score at either hip on the DXA report was used to decide whether the patient met the definition of osteoporosis. Surgeries were scheduled on a priority basis, except that patients with neurologic deficits were scheduled on an emergency basis. Patients were placed in a prone position on a four-poster frame with postural reduction of the fracture and were checked under an image intensifier.

### 2.2. CPS techniques

For the CPS group, we used cement-augmented polyaxial cannulated pedicle screws (Smartlock Omega, A-Spine Inc., New Taipei City, Taiwan), with a diameter of 6.0 mm and side holes, two levels above and below the fractured vertebra.[2,11] Long instrumentation of five levels was used for all patients in the CPS group. Under C-arm guidance, approximately 1 to 1.5 mL of cement (Cohesion, Vexim Sa, Balma, France) was injected through the cannulated lumbar pedicle screw and approximately 1 mL was used for the thoracic pedicle screw (Fig. 1).

### 2.3. HC techniques

For the HC group, we inserted regular pedicle screws (Smartlock Omega, A-Spine Inc., New Taipei City, Taiwan) with a diameter of 6.0 mm into the lumbar spine two levels below the fractured vertebra. Appropriate hooks were chosen based on the individual patient's anatomy. Four pedicle hooks were used two levels above the fractured vertebra in the thoracic spine, except for T12 and the decompressed level. Two additional wide-blade transverse process hooks were placed, pointing downward toward the head in a pedicle-transverse claw configuration. At the most caudal level of the instrumented vertebra, we applied two additional offset laminar hooks pointing upward for a hook-screw claw construct. Long instrumentation of six to seven levels was applied in the HC group (Fig. 2).

### 2.4. Decompression and fusion techniques

We performed posterior decompression and posterolateral fusion one level above and below the fracture for patients who had neurologic deficits. On neurologically intact patients,

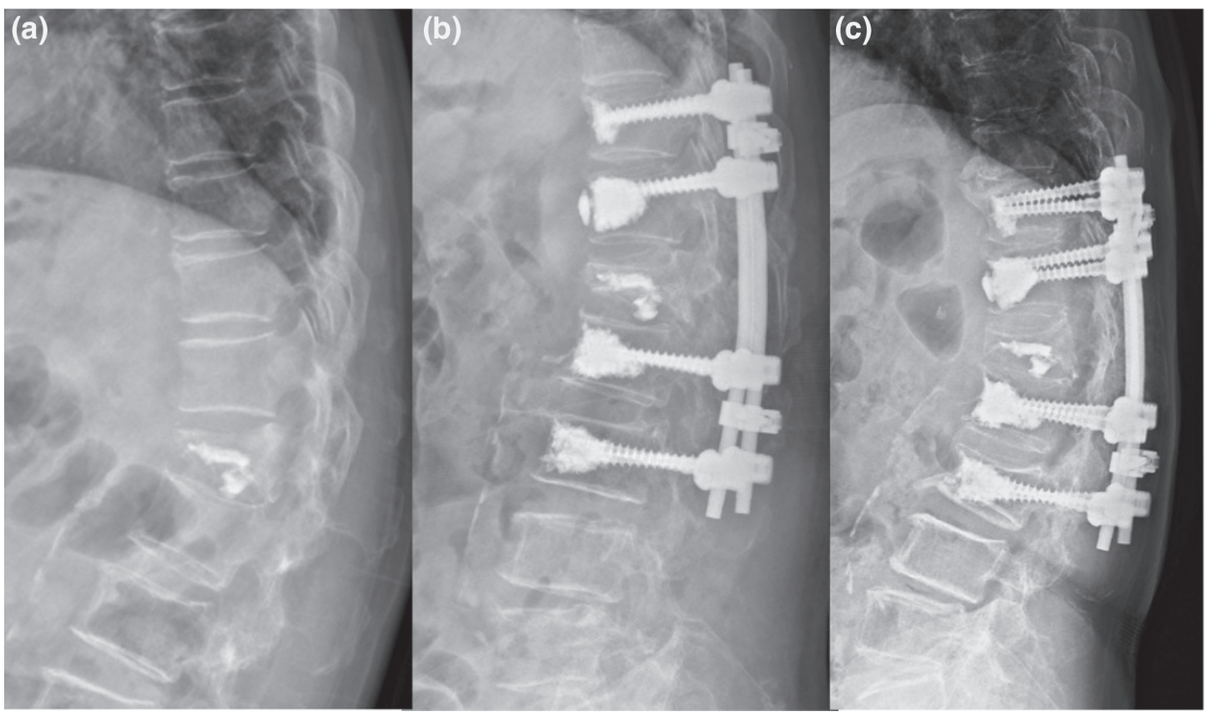


**Fig. 1** Illustration of the cement-augmented pedicle screws (CPS) group. A, Preoperative lateral plain radiograph of spine. B, Immediate postoperative lateral plain radiograph of spine. C, Lateral plain radiograph of spine at final follow-up. Pedicle screws (6.0 mm in diameter with side holes) were used at two levels above and below the fractured vertebra.

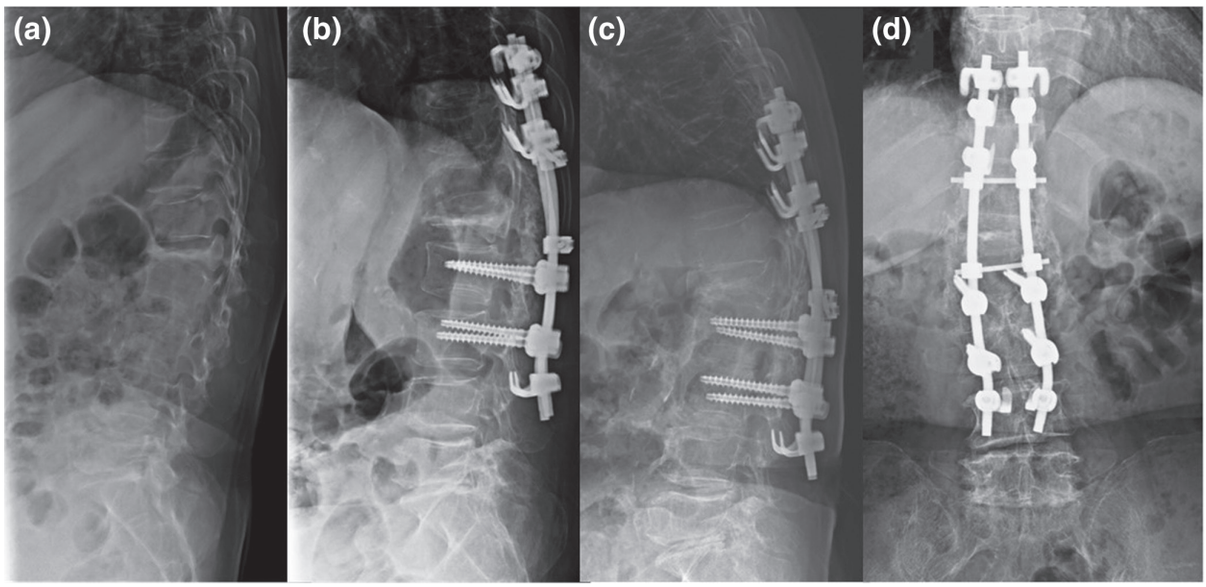


**Fig. 2** Illustration of the hybrid construct (HC) group. A, Preoperative lateral plain radiograph of spine. B, Immediate postoperative lateral plain radiograph of spine. C, Lateral plain radiograph of spine at final follow-up. D, Anteroposterior plain radiograph of spine at final follow-up. Six hooks (four pedicle hooks with two additional transverse hooks) were applied at the cephalad end, except at T12, to create a pedicle-transverse claw construct. Four regular pedicle screws (6.0 mm in diameter) and an additional two offset laminar hooks were used to form a hook-screw claw construct.

posterior fusion without posterior decompression was done. In total, all patients in both groups received three levels of fusion (fractured level and one level above and below). Bone grafting was accomplished using a mixture of autogenous bone graft, which was harvested from decompressed laminae and the spinous processes, and bone substitute (synthetic β-tricalcium phosphate, chronOS, DePuy Synthes, PA, USA). Patients with pseudarthrosis at the fractured vertebrae received additional vertebroplasty using bone cement (Cohesion, Vexim Sa, Balma, France) under C-arm guidance.

### 2.5. Postoperative care and fusion evaluation

The wound was closed with a suction drain left in. Patients were allowed to walk in a brace depending on their condition and an antiosteoporotic agent was prescribed after surgery. Every patient was followed up at our clinic with serial supine anteroposterior and lateral radiographs every 6 weeks postoperatively for 3 months; at 3, 6, and 12 months; and then annually.

Sound fusion or union was defined as bone healing in the fractured vertebra or bridging callus across the intervertebral disc on the lateral plain radiograph, or a posterior or posterolateral fusion mass seen on the anteroposterior plain radiograph in patients with no loss of correction or increase in back pain. The fusion status was evaluated by the same author (P.H.C.) (a 10-year experienced spine surgeon) at two different time points, separated by at least 1 to 2 weeks. Any discordance was resolved by consultation and agreement with another experienced spine surgeon (C.L.L.). In order to reduce costs and the exposure to radiation, and in accordance with the National Health Insurance (NHI) policy in our country, we did not routinely employ postoperative computed tomography (CT) scans to assess union, screw position, and cement distribution. Implant failure was defined as pullout or breakage of the implant.[12]

To examine the radiographs more objectively and to minimize bias, two surgeons not previously involved in the surgery measured all the parameters using the Picture Archiving and Communication System (PACS) (Smart Viewer 3.2; Taiwan Electronic Data Processing Cooperation, Taipei, Taiwan). They employed Cobb's method to measure the regional kyphotic angle.[13] The regional kyphotic angles were measured between the superior endplate of the vertebra one level above the fractured vertebra, and the inferior endplate of the vertebra one level below.

### 2.6. Functional outcomes evaluation

To evaluate pain and disability, we used the Visual Analog Scale (VAS) for back pain and the Oswestry Disability Index (ODI), respectively, preoperatively and at final follow-up. We classified ambulatory performance into four categories: bed-ridden, wheelchair-bound, ambulation with an aid (walker, cane, crutches, or needing assistance), and ambulation without an aid.[14] Neurologic function was evaluated with the Frankel grading system.[15] Ambulatory performance and neurologic function were evaluated preoperatively and at final follow-up.

### 2.7. Statistical analysis

Statistical analysis was performed using the SPSS for Windows statistical package (version 15.0, Chicago, IL, USA) with a $p$ value <0.05 considered significant. To compare parameters between the two groups, we used the Mann-Whitney U test (for continuous data) and the chi-square test (for categorical data). Repeat measure analysis of variance (ANOVA) testing was conducted to investigate changes in the postoperative kyphotic angle over time. To determine whether these tests were appropriately powered, power analysis was also performed using G*Power software (Heinrich-Heine Universität Dusseldorf, Düsseldorf, Germany) for each comparison between the two groups.

## 3. RESULTS

The mean age at the index operation was 77.7 ± 8.5 years, 77.3 ± 7.6 years for the CPS group and 78.2 ± 9.7 years for the HC group. Seven patients had fractures on T10, 15 on T11, 22 on T12, 24 on L1, 13 on L2, and 3 on L3. The overall preoperative kyphotic angle was 24.8° ± 6.2° (range, 14° to 44°); 24.6° ± 5.9° for the CPS group and 25.1° ± 6.5° for the HC group. No

**Table 1**

**Demographic data for the CPS and HC groups before operation**

| | Total | CPS | HC | |
|---|---|---|---|---|
| | (n = 84) | (n = 43) | (n = 41) | *p* |
| Age | 77.7 ± 8.5 (70-87) | 77.3 ± 7.6 (70-85) | 78.2 ± 9.7 (71-87) | 0.506 |
| BMI | 20.8 ± 3.9 (15.6-32.6) | 21.2 ± 4.3 (15.6-32.6) | 20.6 ± 3.6 (17.0-31.5) | 0.594 |
| Sex | | | | 0.357 |
| Male | 22 | 13 | 9 | |
| Female | 62 | 30 | 32 | |
| DXA | −2.8 ± 0.4 (−2.5 to −3.5) | −2.9 ± 0.3 (−2.5 to −3.5) | −2.8 ± 0.3 (−2.5 to −3.4) | 0.109 |
| Surgical indications | | | | 0.218 |
| Failure of conservative treatment or VP | 19 | 11 | 8 | |
| Neurologic deficit | 65 | 32 | 33 | |
| Injured level | | | | 0.656 |
| T10 | 7 | 3 | 4 | |
| T11 | 15 | 8 | 7 | |
| T12 | 22 | 12 | 10 | |
| L1 | 24 | 12 | 12 | |
| L2 | 13 | 6 | 7 | |
| L3 | 3 | 3 | 0 | |
| Comorbidities[a] | | | | 0.935 |
| Hypertension | 16 | 7 | 9 | |
| Diabetes mellitus | | 4 | 5 | |
| End stage renal disease | 3 | 2 | 1 | |
| Coronary artery diseases | 6 | 4 | 2 | |
| Lacunar infarction or cerebral infarction | 5 | 3 | 2 | |
| Chronic obstructive pulmonary diseases | 9 | 5 | 4 | |
| Parkinson's disease | 6 | 3 | 3 | |
| Benign prostate hyperplasia | 5 | 3 | 2 | |
| Preoperative functional scores | | | | |
| Visual Analog Scale at back | 8.0 ± 1.5 (6-10) | 8.1 ± 1.3 (7-10) | 7.9 ± 1.7 (6-10) | 0.637 |
| Oswestry Disability Index | 67.7 ± 13.8 (52-88) | 68.1 ± 15.4 (58-86) | 65.4 ± 16.2 (52-88) | 0.545 |

Data are presented as mean ± standard deviation (range).

BMI = body mass index; CPS = cement-augmented pedicle screw; DXA = dual-energy X-ray absorptiometry; HC = hybrid construct; VP = vertebroplasty.

[a]Some patients had more than one comorbidity.

statistically significant differences were observed between these two groups in preoperative kyphotic angle or demographic data (Tables 1 and 2).

Clinical and radiographic examinations were available for all 84 patients during an overall average of 67 ± 14 months of follow-up (range, 52-88 months), 68 ± 15 months (range, 58-86 months) for the CPS group and 65 ± 16 months (range, 52-88 months) for the HC group. The overall average postoperative kyphotic angle was 15.0° ± 5.6° (range, 6°–30°), 15.4° ± 5.6° (range, 6°-30°) for the CPS group and 14.5° ± 5.4° (range, 8°-30°) for the HC group. The overall immediate average correction of the kyphotic angle was 9.8° ± 2.1° (range, 6°-14°), 9.1° ± 1.6° (range, 6°-12°) for the CPS group and 10.6° ± 2.3° (range, 6°-14°) for the HC group, indicating significantly better immediate correction in the HC group ($p < 0.001$; Table 2).

Significant progressive loss of correction of the kyphotic angle was observed with time, regardless of fixation technique ($p < 0.05$). No statistical difference in loss of correction between the two groups was observed at various postoperative follow-up times (Fig. 3). At final follow-up, the overall average loss of reduction of the kyphotic angle was 8.4° ± 2.9° (range, 1°-13°), 7.1° ± 1.3° (range, 3°-13°) for the CPS group and 9.8° ± 2.7° (range, 1°-13°) for the HC group. The loss for the CPS group was statistically significantly greater ($p < 0.001$). However, in the final kyphotic angle, no statistically significant difference was observed between the CPS and HC group (22.6° ± 5.7° vs 24.3° ± 6.4°, $p = 0.321$; Table 2).

Average overall operative time for the 84 patients in the study was 243 ± 51 minutes (range, 180-350 minutes), 258 ± 54 minutes (range, 190-350 minutes) for the CPS group, and 231 ± 49 minutes (range, 180-340 minutes) for the HC group, indicating that operative times were significantly shorter for the HC group. The average estimated blood loss overall was 462 ± 140 mL (range, 230-950 mL), 427 ± 122 mL (range, 230-950 mL) for the CPS group and 497 ± 129 mL (range, 280-780 mL) for the HC group. In other words, patients in the CPS group lost significantly less blood.

The mean number of fixation segments was 5.6 levels (range, 5-7) for all patients, five levels for the CPS group, and 6.2 ± 0.4 levels (range, 6-7) for the HC group. The number of fused segments was three in both groups (Table 2).

At final follow-up, functional outcomes were similar for the two groups, with significant improvement for all of the patients, as measured by VAS and ODI (Table 2). According to the Frankel grading system, 65 patients had preoperative neurologic deficits with an incidence of 77.3% (32 in the CPS group and 33 in the HC group); two patients were identified as Frankel A, nine were Frankle B, 35 were Frankle C, and 19 were Frankel D (Table 3). After operation, the incidence of neurologic improvement was 68.8% (22/32) in the CPS group, with an average improvement of 0.5 ± 0.6 grade, and 75.8% (25/33) in the HC group, with an average improvement of 0.7 ± 0.5 (Tables 2, 4, and 5). No statistically significant difference was observed between the two groups in terms of neurologic improvement.

All patients had some degree of ambulatory deficit before the operation: 24 patients were bed-ridden, 31 were wheelchair-bound, and 29 were ambulatory with aid (Table 6). After surgery, 46 patients (54.8%) showed an average

**Table 2**

**Surgical results for the CPS and HC groups**

| | Total | CPS | HC | *p* | |
|---|---|---|---|---|---|
| | (n = 84) | (n = 43) | (n = 41) | | G power |
| Mean operation time (h)[a] | 243 ± 51 (180-350) | 258 ± 54 (190-350) | 231 ± 49 (180-340) | 0.013 | 0.9 |
| Mean blood loss (mL)[a] | 462 ± 140 (230-950) | 427 ± 122 (230-950) | 497 ± 129 (280-780) | 0.014 | 0.71 |
| Mean hospitalization (d) | 15.8 ± 5.8 (11-41) | 16.1 ± 4.2 (11-41) | 15.6 ± 4.7 (12-32) | 0.608 | |
| Mean kyphotic angle (°) | | | | | |
| Preoperative | 24.8 ± 6.2 (14-44) | 24.6 ± 5.9 (14-41) | 25.1 ± 6.5 (17-44) | 0.712 | |
| Postoperative | 15.0 ± 5.6 (6-30) | 15.4 ± 5.6 (6-30) | 14.5 ± 5.4 (8-30) | 0.447 | |
| Immediate postoperative correction[a] | 9.8 ± 2.1 (6-14) | 9.1 ± 1.6 (6-12) | 10.6 ± 2.3 (6-14) | <0.001 | 0.93 |
| 6-mo f/u | 16.7 ± 5.4 (5-34) | 18.3 ± 4.9 (5-31) | 16.3 ± 5.4 (9-34) | 0.08 | |
| 1-y f/u | 18.7 ± 5.7 (7-36) | 19.8 ± 5.1 (7-33) | 18.3 ± 5.8 (10-36) | 0.221 | |
| Final follow-up | 23.4 ± 6.0 (13-43) | 22.6 ± 5.7 (13-40) | 24.3 ± 6.4 (16-43) | 0.321 | |
| Loss of reduction at latest f/u[a] | 8.4 ± 2.9 (1-13) | 7.1 ± 1.3 (3-13) | 9.8 ± 2.7 (1-13) | <0.001 | 0.99 |
| Mean fixation segments | 5.6 ± 0.7 (5-7) | 5 | 6.2 ± 0.4 (6-7) | | |
| Mean fusion segments | 3 | 3 | 3 | | |
| Fractured healed/bridging callus/fusion mass | 62 | 32 (74.4%) | 30 (73.1%) | 0.902 | |
| ASA physical status classification | | | | 0.49 | |
| II | 24 | 14 | 10 | | |
| III | 44 | 31 | 31 | | |
| Vertebroplasty at fracture level | 26 | 14 (32.5%) | 12 (29.3%) | 0.753 | |
| Surgical complications | | | | 0.904 | |
| Wound infection | 4 | 2 (4.6%) | 2 (4.9%) | | |
| Dura tear | 0 | 0 | 0 | | |
| Implant-related complications | | | | | |
| Implant failure | 2 | 1 (1/43, 2.3%) | 1 (1/41, 2.4%) | 0.966 | |
| Cement-related complications | | | | | |
| Screw augmentation | | | | | |
| Linear or spotted pattern leakage of screws[a] | 134 | 134 (134/344, 38.9%) | 0 | <0.0001 | |
| Leakage into canal or epidural space | 0 | 0 | 0 | | |
| Symptomatic pulmonary embolism | 0 | 0 | 0 | | |
| Vertebroplasty | | | | | |
| Leakage into canal or epidural space | 0 | 0 | 0 | | |
| Symptomatic pulmonary embolism | 0 | 0 | 0 | | |
| Patient-related complications | | | | 0.659 | |
| Pneumonia | 7 | 4 | 3 | | |
| Urinary tract infection | 4 | 2 | 2 | | |
| Stroke (transient ischemia attack) | 1 | 1 | 0 | | |
| Peptic ulcer | 1 | 1 | 0 | | |
| Functional outcomes at latest f/u | | | | | |
| Visual Analogue Scale at back | 2.4 ± 0.9 (1-4) | 2.4 ± 0.9 (1-4) | 2.4 ± 1 (1-4) | 1.00 | |
| Oswestry Disability Index | 27.8 ± 7.1 (18-50) | 27.3 ± 6.5 (20-46) | 28.5 ± 7.6 (18-50) | 0.546 | |
| Improvement of ambulatory performance | 0.7 ± 0.8 (0-2) | 0.7 ± 0.8 (0-2) | 0.8 ± 0.76 (0-2) | 0.559 | |
| Improvement of neurologic function | 0.6 ± 0.57 (0-2) | 0.5 ± 0.59 (0-2) | 0.7 ± 0.53 (0-2) | 0.11 | |
| Mean follow-up times (mo) | 67 ± 14 (52-88) | 68 ± 15 (58-86) | 65 ± 16 (52-88) | 0.545 | |

Data are presented as mean ± standard deviation (range).

ASA = American Society of Anesthesiologists; CPS = cement-augmented pedicle screw; F/U = follow-up; HC = hybrid construct.

[a]Statistical significance.

improvement of 0.7 grade. In the CPS group, 51.2% (22/43) showed an average grade improvement of 0.7 and 58.8% (24/41) of the HC group showed an average improvement of 0.8 grade; none of the patients was bed-ridden (Tables 2, 7, and 8). No statistically significant difference was observed between the two groups in terms of ambulatory improvement.

In those receiving CPS, a total of 344 screws were inserted; 4 screws had medial wall violation and 2 had anterior wall violation when preparing the trajectory. Asymptomatic cement leakage occurred during cement augmentation with 134 screws, for an incidence of 38.9%, with a spotty or linear leakage pattern suggesting that the cement leaked through small vessels around the vertebral body. No cement leakage occurred during vertebroplasty in either group (Table 2).

Two patients experienced implant failure during follow-up. One occurred 6 months postoperatively in the CPS group and the other one at 7 months in the HC group. The patient in the CPS group had back-out of the four cephalad cemented screws and the patient in the HC group had back-out of the distal hook-screw claw construct. Implant removal was performed due to skin impingement in the HC patient, but the patient in the CPS group refused implant removal due to his medical condition. The incidence of implant failure in the CPS and HC groups was 2.3% (1/43) and 2.4% (1/41), respectively. Postoperative pneumonia was not uncommon in both groups, with an incidence of 9.3% and 7.3% in the CPS and HC groups, respectively. Nonunion, infection, or intraoperative neurologic injury did not occur. However, posterior or posterolateral fusion was difficult to evaluate on radiograph, because of the overlapping

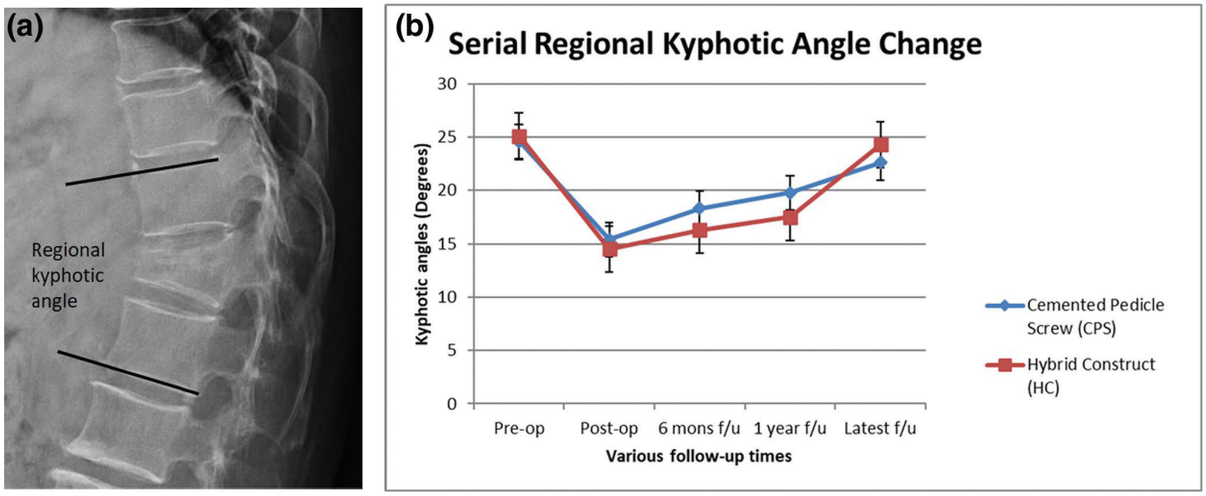


**Fig. 3** Serial change in regional kyphotic angle at different follow-up (f/u) times. A, Illustration of the regional kyphotic angle. B, Postoperative progressive kyphotic changes over time were observed regardless of fixation technique ($p < 0.05$). No statistical difference between the two groups was observed at various postoperative follow-up points.

**Table 3**

**Neurologic status by Frankel classification before surgery and at final follow-up in both groups**

| | Final follow-up | | | | | |
|---|---|---|---|---|---|---|
| **Preoperative** | **A** | **B** | **C** | **D** | **E** | **Total** |
| A | | | 2 | | | 2 |
| B | | | 9 | | | 9 |
| C | | | 7 | 28 | | 35 |
| D | | | | 11 | 8 | 19 |
| E | | | | | 19 | 19 |
| Total | | | 18 | 39 | 27 | 84 |

**Table 4**

**Neurologic status by Frankel classification before surgery and at final follow-up in the CPS group**

| | Final follow-up | | | | | |
|---|---|---|---|---|---|---|
| **Preoperative** | **A** | **B** | **C** | **D** | **E** | **Total** |
| A | | | 1 | | | 1 |
| B | | | 5 | | | 5 |
| C | | | 4 | 13 | | 17 |
| D | | | | 6 | 3 | 9 |
| E | | | | | 11 | 11 |
| Total | | | 10 | 19 | 14 | 43 |

CPS = cement-augmented pedicle screw.

**Table 5**

**Neurologic status by Frankel classification before surgery and at final follow-up in the HC group**

| | Final follow-up | | | | | |
|---|---|---|---|---|---|---|
| **Preoperative** | **A** | **B** | **C** | **D** | **E** | **Total** |
| A | | | 1 | | | 1 |
| B | | | 4 | | | 4 |
| C | | | 3 | 15 | | 18 |
| D | | | | 5 | 5 | 10 |
| E | | | | | 8 | 8 |
| Total | | | 8 | 20 | 13 | 41 |

HC = hybrid construct.

**Table 6**

**Ambulatory performance before surgery and at final follow-up in both groups**

| | Final follow-up | | | | |
|---|---|---|---|---|---|
| **Preoperative** | **Bed-ridden** | **Wheelchair-bound** | **Ambulation with an aid** | **Ambulation without an aid** | **Total** |
| Bed-ridden | | 7 | 17 | | 24 |
| Wheelchair-bound | | 16 | 15 | | 31 |
| Ambulation with an aid | | | 22 | 7 | 29 |
| Ambulation without an aid | | | | | |
| Total | | 23 | 54 | 7 | 84 |

**Table 7**

**Ambulatory performance before surgery and at final follow-up in the CPS group**

| | Final follow-up | | | | |
|---|---|---|---|---|---|
| **Preoperative** | **Bed-ridden** | **Wheelchair-bound** | **Ambulation with an aid** | **Ambulation without an aid** | **Total** |
| Bed-ridden | | 3 | 9 | | 12 |
| Wheelchair-bound | | 9 | 8 | | 17 |
| Ambulation with an aid | | | 12 | 2 | 14 |
| Ambulation without an aid | | | | | |
| Total | | 12 | 29 | 2 | 43 |

CPS = cement-augmented pedicle screw.

**Table 8**

**Ambulatory performance before surgery and at final follow-up in the HC group**

| | Final follow-up | | | | |
|---|---|---|---|---|---|
| **Preoperative** | **Bed-ridden** | **Wheelchair-bound** | **Ambulation with an aid** | **Ambulation without an aid** | **Total** |
| Bed-ridden | | 4 | 8 | | 12 |
| Wheelchair-bound | | 7 | 7 | | 14 |
| Ambulation with an aid | | | 10 | 5 | 15 |
| Ambulation without an aid | | | | | |
| Total | | 11 | 25 | 5 | 41 |

HC = hybrid construct.

of the implant. There was no statistically significant difference observed between the two groups in terms of surgery-, implant-, or patient-related complications (Table 2).

## 4. DISCUSSION

Instrumentation of the osteoporotic spine is challenging because of the lower pullout strength and cut-out torque of each fixation point compared to normal spine.[16] Surgeons commonly agree that having more fixation points (three levels above and below the fracture) can increase pullout strength for rigid fixation of osteoporotic spines.[17] In addition to more fixation points,[18] biomechanical research has reported increased pullout strength with polymethyl methacrylate (PMMA) augmentation.[8,9] In prior studies, PMMA-augmented screws at two levels above and below the fracture level provided enough stiffness for the whole construct[2,11] and could save one more motion segment above and below. Moreover, no refracture of the index level was encountered, because vertebroplasty for the pseudarthrosis at the fractured level was performed after instrumentation, which may provide anterior support to the fractured vertebra[19] to prevent refracture, regardless of whether CPS or HC is used.

No screw loosening or pullout was observed among the 410 and 291 implanted screws reported by Girardo et al[4] and Chang et al,[2] respectively. However, revision surgery to remove cement-augmented screws as well as bone cement remains a major concern for spine surgeons. A biomechanical study revealed that removal of CPS was feasible without bone destruction.[20] However, that study reported pedicle fracture due to the cement-bone interface breaking before the screw-cement interface in several vertebrae during pullout testing.[20] Accordingly, it is not difficult for surgeons to remove the PMMA-augmented screws, but care should be taken to avoid pedicle fractures.

Cement augmentation for pedicle screw placement is a similar procedure to vertebroplasty. The incidence of infection at the injected vertebrae after vertebroplasty has been reported at 0.5% to 1%.[21] Postvertebroplasty infection may lead to devastating, life-threatening complications, with a perioperative mortality rate of 33.3%.[21] The surgeons in that study needed to perform corpectomy to eradicate the infected vertebrae via an anterior approach, which could be one of the major drawbacks of using CPS in osteoporotic spines. Moreover, Janssen et al[22] reported an incidence of asymptomatic cement-related complications after CPS of 66.7% (n = 110). The incidence of symptomatic complications was 5.5% (n = 9), including pulmonary cement embolism at 3% (5/165), with 1.2% (2/165) needing revision surgery due to epidural leakage, and 1.2% (2/165) needing resuscitation after experiencing anaphylactic shock. In our study, the incidence of asymptomatic cement leakage was 38.9% during the CPS procedure, with a leakage pattern of spotty or linear appearance, suggesting that cement leaked through small vessels around the vertebral body. Moreover,

radiation exposure associated with C-arm fluroscopy should be a concern for both surgeons and patients.[23] Consequently, using HC may be safer in terms of avoiding cement-related complications and reducing radiation exposure.

Thoracic pedicle hooks are placed in the facet joint cavity, but the more saggital orientation of the facet joint at T12-L1 makes the application of a pedicle hook difficult; thus, we applied pedicle hooks above the T12 level only. Moreover, if the planned level of pedicle hook application was within the decompressed levels, we moved up a level to apply the thoracic pedicle hook. This practice explains why we sometimes had more fixation levels (six or seven levels) in the HC group.

Biomechanical tests have shown that fixation using pedicle screws combined with hooks at both the cranial and caudal ends offers a stiffer construct compared with fixation with pedicle screws alone.[5–7] To increase pullout strength at the cephalad end of the long construct, Cordista et al[6] employed six hooks to create a "claw effect" in the thoracic spine. To increase pullout strength at the caudal end, pedicle screws combined with infralaminar hooks have been found to offer stiffer constructs than pedicle screws alone.[5,7] The claw or grip effect at both the cephalad and caudal ends in the long construct may provide greater pullout strength to avoid implant failure.[6] In one clinical investigation, laminar hooks preserved the initial correction and minimized the risk of instrumentation failure in treating thoracolumbar burst fracture.[24] Nevertheless, in our study, one patient in the HC group still had implant failure. Surgical exposure at more levels and soft tissue dissection to prepare for the transverse and laminar hooks may explain the significantly greater intraoperative blood loss in the HC group. However, even though the HC group had significantly greater intraoperative blood loss, the clinical significance may be nil, such that is it not a factor for surgeons when deciding on the type of implant to use.

In our study, the HC group had a better immediate postoperative kyphosis reduction and a greater loss of reduction over time, both of which were statistically significant. The difference in immediate postoperative reduction (1.5°) and final loss of correction (2.7°) between the two groups was extremely small; neither difference may indicate clinical significance, however, or impact the clinical practice of spine surgeons in terms of implant choice. Anatomic fixation of hooks applied at the posterior portion of harder cortical bone may provide better reduction of the kyphotic angle,[25] but aging-related kyphosis progression may inevitably occur,[26] resulting in significant progressive loss of kyphotic angle for both groups in our study.

Some clinical investigations have shown that the use antiosteoporosis medication with anabolic agents (teriparatide) could enhanced vertebral fracture healing[27,28] and some antiosteoporosis medications may influence the local kyphotic angle at the fracture level.[27,28] Tsuchie et al[28] reported that the local kyphotic angle was significantly lower in a group receiving daily teriparatide than in the antiresorptive and control groups (untreated group). Moreover, Min et al[27] reported no significant difference in kyphotic angle among untreated, bisphosphonate, and teriparatide groups. Accordingly, the effect of different antiosteoporosis medications on the local kyphotic angle at the fracture level remains controversial. In our study, surgical indications were failure of conservative treatment or vertebroplasty or neurologic deficit. According to NHI policy, every patient who has osteoporosis combined with a fragility fracture of the hip or spine may receive antiosteoporotic treatment. We merely compared surgical outcomes between two fixation methods to treat osteoporotic vertebral fractures in the thoracic or lumbar spine. Therefore, we could not compare the effects of antiosteoporotic agents in this study.

This study has several limitations. First, the sample size was too small to reach sufficient power. Second, the retrospective nature of the study and having two surgeons perform all surgeries are significant limitations that could bias the results. Third, CT scans were not routinely performed to evaluate cement leakage, fusion status, or pedicle screw trajectory, in accordance with NHI policy to reduce costs and radiation exposure. Fourth, one senior surgeon (M.C.C.) and the other senior surgeon (S.T.W.) always performed the CPS and HC techniques, respectively. The surgical technique of each surgeon may have biased the differences in surgical outcomes. Finally, we did not check intra- and interobserver reliability, which accounts for approximately 5° to 7° of interobserver variability.[29]

In conclusion, the surgical results of using either CPS or HC were not statistically different in terms of final kyphotic angle, clinical outcomes (including VAS and ODI), and neurologic or ambulatory improvement, making the two techniques equally acceptable alternatives for fixation of osteoporotic spines. The advantages of the CPS technique were less blood loss and less loss of kyphosis correction at final follow-up, but the disadvantages were cement leakage and less immediate postsurgical correction of kyphosis. On the other hand, the HC technique required a shorter operative time and produced more immediate correction of kyphosis without cement leakage, but a greater loss of kyphosis reduction over time was observed. Moreover, significant progressive kyphosis was observed with time, regardless of fixation technique. Long-term follow-up is recommended to investigate the effect of either strategy on correction maintenance in treating osteoporotic fractures of the thoracic or lumbar spine.

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