Surgical Trend Analysis for Use of Cement Augmented Pedicle Screws in Osteoporosis of Spine: A Systematic Review (2000-2017)

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Abstract

Study Design: Systematic review.

Objectives: (1) Study indications for cement-augmented pedicle screws (CAPS) in patients with osteoporosis. Have they changed over the years (2000-2017)? Are there any differences in usage of CAPS based on the geographical region? (2) What were the outcome of the studies? (3) What are the complications associated with this technique?

Methods: Electronic database and reference list of desired articles were searched from the database (2000-2017). Articles were selected discussing indications, clinical and radiological outcomes, and complications in cases of preexistent osteoporosis treated surgically using CAPS.

Results: Seventeen studies were identified; 3 were comparative studies and had a control arm (cemented vs noncemented screws). Most studies originated from Europe (10) or Asia (7). Painful vertebral fracture with or without neurological deficit, Kummell's lesion, deformity and failure to respond to conservative treatment are the common indications for cement augmentation. Visual analogue scale score was the most commonly used to assess pain and average improvement after surgery was 6.1. Average improvement in kyphosis was 13.21° and average loss of correction at the end of the study was 3°. Cement leak was the most common complication observed and pulmonary cement embolism was the most dreaded complication. Nevertheless, majority of cement leaks discussed in studies were asymptomatic.

Conclusion: CAPS are being increasingly used in osteoporotic spine. Pain scores, functional quality of life, and neurological function indices were studied. CAPS improved anchorage in osteoporotic vertebra and helped improve/maintain clinical and radiological improvement. Common risks of cement leak were observed.

Keywords

osteoporosis, PMMA, cement, vertebral fracture

Introduction

Osteoporosis is a systemic disease, primarily affecting the skeleton, leading to decrease in bone mass and micro-architectural derangement, rendering the bone fragile. Affected fragile bones are insufficient to withstand forces beyond physiological load and fractures with minimal trauma. Vertebral fractures are the most common among osteoporotic fractures. Loss of trabecular architecture weakens the bone and decreases the mechanical hold of the pedicle screws, compromising the strength and hastening osteolysis around the screws. Multiple cyclic loading leads to clear-zone formation around the screws preventing osseous integration at screws-bone interface resulting in screw loosening and screw pull-out in osteoporotic spine. Several strategies have been used by investigators to prevent screw pull-out. Cement (polymethylmethacrylate or PMMA) usage to fill trabecular space provides strong anchorage points for fixation. Studies have demonstrated increased pull-out strength and decreased loosening after PMMA

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augmentation of pedicle screws. Despite the frequent use of PMMA for osteoporotic spine fixation, several questions still remain unanswered. Authors did a systematic review of all the published studies between year 2000 and 2017 to find answers to the most important leading questions pertaining to the use of cement-augmented pedicle screws (CAPS) in osteoporotic spine cases.

Materials and Methods

Key Questions

1. What were the indications for CAPS in patients with osteoporosis? Have they changed over the years (2000-2017)? Are there any differences in usage of CAPS based on the geographical region?
2. What were the outcome of the studies? Has there been change observed in the outcome over the years?
3. What were the complications associated with this technique?

Eligibility Criteria for Selection of Studies

Prospective and retrospective observational studies were included in analysis. Patients included in analysis were adults (age >45 years) diagnosed with osteoporosis and treated surgically with CAPS.

Key Question 1. We searched for the indications of surgery by examining the inclusion and exclusion criteria of the studies available from year 2000 through 2017. Surgical treatment offered in osteoporosis were included in analysis.

Key Question 2. All the published data was searched regarding the outcomes of cement augmented screws used in osteoporosis since year 2000 and data was analyzed.

Key Question 3. We searched for all the publications reporting cement-related complications with screw augmentation in cases of osteoporosis since year 2000.

Data Collection

Data was collected based on a predetermined form which included study title, author details, year of study, age of patients, number of patients, indications of surgery, level of spine treated, follow-up duration, and complications of the surgery. Details of clinical outcomes were recorded from the studies as noted by visual analogue score (VAS), Oswestry disability index (ODI), MacNab’s criteria, Prolo’s score, and Short Form–36 (SF-36) questionnaire. Radiological parameters were recorded from the studies that included segmental kyphosis, kyphosis correction or restoration, canal occlusion, screw loosening, and degree of fusion.

Segmental kyphosis, in included studies was described on lateral spine radiographs by drawing tangent along the end plates using Cobb’s method or by measuring vertebral height (anterior, middle, and posterior). Canal occlusion and fusion were assessed by using computed tomography (CT) scans.
Pseudoarthrosis was recognized on lateral radiographs or CT scans by intervertebral cleft or vacuum sign. Screw loosening was identified using different methods in various studies by use of CT scans or specialized software. Neurological assessment was done using Frankel’s grading. Cement-related complications (cement leak) have been assessed using CT scan postoperatively and Yeom’s criteria were used in several studies to classify cement leak based on CT scan images.

Risk of Bias Assessment

The methodological quality of the studies meeting the inclusion criteria was evaluated in accordance with the Newcastle-Ottawa Quality Assessment Scale (NOS), as recommended by the Cochrane Collaboration for assessing the quality of nonrandomized studies. The NOS is a system based on a score (maximum 9 points) set in three different categories: selection of study groups, comparability of cases, controls and their ascertainment of the outcome/exposure on cases and controls. Studies were classified as high risk of bias (1-3 points), medium risk of bias (4-5 points), or low risk of bias (6-9 points) (Table 1).

Results

The initial search identified 77 potential articles, which were screened for eligibility based on the abstract of the study. One review article was excluded as well. Seventeen studies in total met the eligibility criteria and their full texts were retrieved for synthesis of review.

Out of 17 published articles selected for review, 6 were prospective studies, 10 were retrospective observational studies, and 1 was a case report presenting the complication of Palacos cement. Ten studies (Figure 2) were from European region (3 from Germany, 2 each from Spain and Italy, and 1 each from France, Turkey, and the Netherlands) and 7 were from Asia (5 from South Korea and 1 each from Japan and Taiwan). Table 1 describes the characteristics of the studies included in the review.

Two retrospective studies and 1 prospective study had control arm wherein outcome of cement-augmented screws was compared with noncemented screws (Table 2). Two studies included used the cement augmented screws in cases of Kummell’s lesion and 1 studied the outcome in pseudoarthrosis. Cumulatively, study included 1085 patients and sample size ranged from 7 to 313 patients.

Key Question 1: What were the indications for cement augmented screws in patients with osteoporosis? Have they changed over the years? Does the indication vary depending on the geographical region?

The details are presented in Table 1. Primary indication for using CAPS in various studies consistently included preexisting vertebral osteoporosis. Most common indications for surgery was painful osteoporotic vertebral fracture. Vertebral osteoporosis was either primary (senile and postmenopausal) or secondary osteoporosis. Etiologies of osteoporosis are mentioned in Table 1.

- Additional surgical indications were concomitant vertebral fractures, neurological deficit following vertebral fracture, progressive kyphosis, failure of conservative treatment leading to decreased quality of life.

- Sawakami et al, Park et al, and Cho et al considered pseudoarthrosis following vertebral fractures and Kummell’s lesion as indication for using CAPS. Sawakami et al and Cho et al performed corpectomy of the fractured vertebra with anterior...
| Authors            | Country (Year) | Age (Years), Mean | Indications                                                                 | No. of Patients | No. of Screws | Newcastle-Ottawa Scale Score | Follow-up Duration | Outcome                                           |
|--------------------|----------------|-------------------|------------------------------------------------------------------------------|-----------------|---------------|-------------------------------|-------------------|---------------------------------------------------|
| El Saman et al⁶     | Germany (2013) | C: 6 ± 9.3; NC: 75 ± 8.2 | 1. Osteoporotic vertebral fracture. DEXA: not done                           | 24 (C 15, NC 9) | 203 (C 117, NC 86) | 7                            | 430 days (range 44-1467) | No revision/radiological (loss of correction, change in kyphosis) |
| Sawakami et al⁷     | Japan (2012)   | 73.7 (range 51-86) | 1. Osteoporotic fracture (thoracic/lumbar) defined by Jikei University classification. 2. Neurological involvement. 3. Failure of conservative management or kyphosis | 38 (C 17, NC 21) | —             | 8                            | 31 months          | Clinical (Denis Pain Scale)/radiological (change in kyphosis, fusion) |
| Pesenti et al⁸      | France (2014)  | 73 ± 10.9 (range 60-87) | 1. Osteoporotic fracture (thoracic/lumbar) DEXA < −2.5. 2. Etiology: Primary osteoporosis (8), ankylosing spondylitis (1) | 12              | 96             | 6                            | Minimum 3 months    | Clinical/radiological                              |
| Piñera et al⁹       | Spain (2011)   | 77 (range 70-81)  | 1. Osteoporotic fracture (DEXA < −2.5). 2. Etiology: DS or LCS                | 23              | 103            | 6                            | 20-49 months, (mean 32 months) | Clinical/radiological                              |
| Amendola et al¹⁰    | Italy (2011)   | 67.2 ± 9.1 (range 55-85) | 1. Osteoporosis (DEXA < −2.5). 2. Etiology: DS (2), vertebral fracture (2), Posttraumatic kyphosis (2), revision surgery (3), tumor (10) | 21              | 81             | 6                            | 36.4 months (range 13-52 months) | Clinical/radiological                              |
| Seo et al¹¹         | South Korea (2012) | C: 66.5 (range 49-74); NC: 62.8 (range 46-69) | 1. Severe Osteoporosis (DEXA < −3.5) | 250 (C 157, NC 93) | C 947, NC 458 | 8                            | 10-23 months (mean 12 months) | Clinical/radiological                              |
| Park et al¹²        | Korea (2015)   | 72 (range 65-85)  | 1. Severe osteoporosis (DEXA < −3). 2. Kummel's lesion defined on lateral X-ray or CT by cleft sign | 10              | —             | 6                            | 12 months           | Clinical/radiological                              |
| Wuisman et al¹³     | Netherlands (2000) | 36.1 (range 11-62) | 1. Severe osteoporosis (DEXA < −2.5). 2. Etiology: osteoporotic vertebral fractures (32), LCS (5), tumor (4) | 7               | 48             | 6                            | 33 months (range 22-52 months) | Clinical/radiological                              |
| Chang et al¹⁴       | Taiwan (2008)  | 75.1 (range 50-90) | 1. Osteoporosis. 2. Etiology: osteoporotic vertebral fractures (32), LCS (5), tumor (4) | 41              | 300 (C 291) | 6                            | 22.3 months (range 4-35 months) | Clinical/radiological                              |
| Cho et al¹⁵         | South Korea (2017) | 72 (range 68-83) | 1. Kummel's lesion. (mean BMD 3.6 ± 7.6). 2. Local kyphosis >20°. 3. Neurologically intact | 22              | —             | 5                            | 26 months (range 13-40 months) | Clinical/radiological                              |
| Girardo et al¹⁶     | Italy (2017)   | 73.4 (range 65-82 years) | 1. Osteoporotic thoraco-lumbar fracture, type A3/A4 or B1 (AO); DEXA −2.7 (−2.1 to −4.1) | 52              | 410            | 6                            | 36 months (range 24-66 months) | Clinical/radiological                              |
| Kim et al¹⁷         | South Korea (2008) | 60.5 (range 42-67) | 1. Osteoporotic fracture, severe osteoporosis; DEXA < −3.0 (mean −3.62). 2. Local kyphosis >20°. 3. Neurologically intact | 20              | —             | 6                            | 15 months (range 12-25 months) | Clinical/radiological                              |
| Rasch et al¹⁸       | Germany (2010) | 55                | 1. Fracture L3-L4 vertebra. 2. Neurologically intact                        | 1               | —             | —                            | —                 | Complication                                      |
| Aydoğ˘an et al¹⁹    | Turkey (2009)  | 66 (59-78)        | 1. Severe osteoporosis (DEXA < −2.5) with neurological deficit. 2. Etiology: LCS (26), vertebral fracture (6), DS (3), metastasis (1) | 49 (36)        | —             | 6                            | 37 months (range 24-48 months) | Clinical/radiological                              |
| Moon et al²⁰        | Korea (2009)   | 68.7 (range 57-88) | 1. Osteoporosis (DEXA < −2.5)                                               | 37              | 168            | 6                            | Clinical/radiological                          |                                                                 |

(continued)
| Authors                        | Country (Year)          | Age (Years), Mean | Indications                                                                 | No. of Patients | No. of Screws | Newcastle-Ottawa Scale Score | Follow-up Duration | Outcome        |
|-------------------------------|-------------------------|-------------------|-----------------------------------------------------------------------------|----------------|---------------|-----------------------------|--------------------|------------------|
| Janssen et al\textsuperscript{21} | Germany (2017)          | 71 ± 11.2 (range 46-93) years | 2. Etiology: LCS (26), DS (6), spondyloytic spondylolisthesis (5) \n1. Osteoporosis. \n2. Etiology: osteoporotic fracture (40), metastasis (57), degenerative (59), infection (5), traumatic fractures (14). \n3. Neurological deficit (52) | 165            | —             | 6                          | 33.3 months (range 23-45 months) | Complications     |
| Martin-Fernández et al\textsuperscript{22} | Spain (2017)            | 73.6 ± 7.2 (range 40-90)  | 1. Osteoporosis with low BMD. \n2. Etiology: degenerative (223), spinal deformity (32), vertebral fracture (56), metastasis (2) | 313            | 1780          | 6                          | 29.68 ± 14.9 months (12-77 months) | Complications     |

Abbreviations: C, cemented; NC, noncemented; BMD, bone mineral density; DS, degenerative spondylolisthesis; LCS, lumbar canal stenosis; CT, computed tomography; DEXA, dual-energy X-ray absorptiometry.
reconstruction along with posterior stabilization using cement-augmented screws in their patients.

- Preexistent spinal pathological conditions in these osteoporotic spines included spinal stenosis and degenerative spondylolisthesis.

- Osteoporosis was defined by dual-energy X-ray absorptiometry (DEXA) scan with bone mineral density (BMD) assessment. A total of 10 studies used DEXA scan to determine BMD and classified osteoporosis according to World Health Organization guidelines ($T$ score $<-2.5$ with or without fragility fracture was defined as severe osteoporosis). Sawakami et al$^7$ used Jikei University classification for determination of osteoporosis. Patients with severe osteoporosis based on BMD were treated with CAPS in most of the studies.

- There is lack of evidence to determine that the indications of surgery changed over the year since year 2000.

- The reviewed articles are from Asian and European regions only. There is lack of difference regarding indications for using CAPS in the geographical regions under study.

**Key Question 2:** What were the outcomes of the studies? Has there been change observed in the outcomes over the years?

- VAS score was the most frequent pain assessment scale used in the studies. Total of 9 studies used VAS score and average improvement in VAS score was 6.1 points. Average postoperative VAS was 2.3 (range 1.42-4.8) compared with 8.4 (8-9.2) reported preoperatively. Sakawami et al$^7$ used the Denis pain scale for assessment of pain whereas Kim et al$^{17}$ and Park et al$^{12}$ used modified MacNab’s criteria for pain assessment. All patients reported good to excellent outcome.

- ODI was most commonly used to assess the functional outcome. Three studies used ODI for assessment of function and average improvement was 42.1. SF-36 questionnaire was used in 1 study.

**Table 2. Studies With Comparative Group With the Details of the Outcome and Complications.**

| Authors          | C/NC Patients | No. of Screws | No. of Patients | Outcome Clinical | Radiological | Complications Intraoperative | Postoperative |
|------------------|---------------|---------------|----------------|------------------|--------------|-------------------------------|--------------|
| El Saman et al$^6$ | C 15          | 117           | NC 9           | 1. Improvement in backache (Denis pain scale). C 11 (64.7%) | 1. Loss of correction. C 1.1$^2$ ± 0.78$^2$ | 1. Clear zone (CZ) around the screws or loosening. C 5 (4.3%) |
|                  | NC 9          | 86            | NC 21          | 1. Improvement in backache (Denis pain scale). C 9 (42.9%) | 1. Loss of correction. NC 4.9$^3$ ± 3.8$^3$ | 1. Clear zone (CZ) around the screws or loosening. NC 54 (62.8%) |
|                  |               | 21            | NC 21          | 1. Improvement in backache (Denis pain scale). NC 9 (42.9%) | 1. Loss of correction. NC 7.2$^2$ ± 1.3$^2$ | 1. CZ. NC 15 (71.4%). |
|                  |               | 17            | NC 21          | 1. Improvement in backache (Denis pain scale). NC 9 (42.9%) | 1. Fusion. C 16 (94.1%) | 2. Fusion. NC 16 (76.1%) |
|                  |               | 17            | NC 21          | 1. Improvement in backache (Denis pain scale). NC 9 (42.9%) | 1. Fusion back-out. C 0 | 3. Screw back-out. NC 3 |
|                  |               | NC 15         | NC 93          | 1. Improvement in VAS (back). NC 8.0 to 2.1 | 1. Fusion 100% | 1. Deep infection. NC- 2 |
|                  |               | 157           | NC 93          | 1. Improvement in VAS (back). NC 8.5 to 1.9 | 1. Fusion 100% | 2. Screw loosening. NC- 2 |
|                  |               | 947           | NC 93          | 1. Improvement in VAS (back). NC 76.6% to 40% | 1. Fusion 100% | 3. Revision. NC 5 |
|                  |               |               | 458           | 1. Improvement in ODI. C 76.6% to 40% | 1. Fusion 100% | 1. Deep infection. NC- 2 |
|                  |               |               | 458           | 1. Improvement in ODI. C 76.6% to 40% | 1. CL 2 (transient hypoesthesia 1, motor weakness 1) | 2. Screw loosening. NC 5 |
| Sawakami et al$^7$ | C 17          |               |                | 1. Improvement in backache (Denis pain scale). C 7 (41.2%) | 1. Loss of correction. C 3$^3$ ± 0.8$^3$ | 1. Superficial infection (C) |
|                  | NC 21         | 1. Fusion back-out. C 0 | 3. Screw back-out. C 0 | 1. Loss of correction. NC 11 (64.7%) | 1. Screw loosening. NC 3 |
|                  | NC 21         | 1. Fusion back-out. C 0 | 3. Screw back-out. NC 3 | 1. Loss of correction. NC 9 (42.9%) | 1. Superficial infection (C) |
|                  | NC 21         | 1. Fusion back-out. C 0 | 3. Screw back-out. NC 3 | 1. Loss of correction. NC 9 (42.9%) | 2. Fusion. NC 16 (76.1%) |
|                  | NC 21         | 1. Fusion back-out. C 0 | 3. Screw back-out. NC 3 | 1. Loss of correction. NC 9 (42.9%) | 3. Screw back-out. NC 3 |
| Seo et al$^{11}$  | C 157         | 947           | NC 93          | 1. Improvement in VAS (back). NC 74.6% to 38.2% | 1. Fusion 100% | 1. Deep infection. NC- 2 |
|                  | NC 93         | 458           | NC 93          | 1. Improvement in VAS (back). NC 74.6% to 38.2% | 1. Fusion 100% | 2. Screw loosening. NC- 2 |
|                  |               |               | NC 93          | 1. Improvement in VAS (back). NC 74.6% to 38.2% | 1. Fusion 100% | 3. Revision. NC 5 |

Abbreviations: C, cemented; NC, noncemented; ODI, Oswestry disability index; VAS, visual analogue scale.
Two studies (Pesenti et al. and Piféria et al.) looked at the length of the hospital stay after using CAPS. Average hospital stay was 7.2 days.

Improvement in kyphosis from presurgery to postsurgery was assessed using angular measurement and by assessing vertebral height restoration. Angular improvement of correction was studied in 5 studies and the average immediate correction of kyphosis was found to be 13.21° (7.8°-26.17°). Loss of angular correction (LOC) following CAPS was studied in 6 studies and average LOC was 3.0° (2°-4.6°) at the end of follow-up. Anterior vertebral height was measured in 3 studies where 56.26% height of the vertebral body could be restored in the postoperative period. Pesenti et al. used Beck’s index to assess improvement in local kyphosis.

Two studies compared the loss of angular kyphosis using noncemented screws and found average loss of 6.05° (4.9°-7.2°) at last follow-up. Objective improvement in neurological function was assessed using American Spinal Injury Association (ASIA) and Frankel scale by 4 studies where 79.3% (41.2%-100%) cases improved by at least 1 grade. Aydoğan et al. subjectively reported improvement in all patients operated in their series. Simultaneous fusion procedure was done in 9 studies. Seven studies used radiographs for assessment of fusion whereas 2 studies used CT scans to confirm fusion at operated levels. Average fusion rate was 98.4%.

Key Question 3: What were the complications described in the studies?

Complications discussed in the studies were cement (PMMA) related, associated with spinal fixation, or associated with spine surgery.

Cement leak (CL) was the most common complication observed in the studies. Most of the CL were asymptomatic or with minimal complications such as transient hypoesthesia or motor weakness.

Three studies used Yeom’s classification to define cement leak. Most common pattern of CL occurred through basivertebral veins (type B). It was noticed in 32 (57%) patients. Janssens et al. noted 66.7% asymptomatic CL and 5.5% symptomatic leak of which 1.2% required revision surgery for cement removal from epidural space. Martín-Fernández et al. in their large series of 313 patients observed 62.3% incidence of CL. Overall, 1.55% of these CL were symptomatic with radicular pain.

Overall pulmonary cement embolism (PCE) was reported in 16 cases (1.5%); highest incidence of 7.9% was described by Janssens et al. in their study (Table 4). Superficial infection was noted in 16 (1.5%) patients, which responded to antibiotics. Twenty-one (2.1%) patients developed deep surgical site infection and were treated with wound debridement and antibiotics.

Dural leak was noticed in 3 patients and Cauda equina syndrome after surgery was noticed in 1 patient. A total of 89 (1.93%) screws were found loosened, out of which 15 (0.32%) were in cemented group and 74 (1.61%) were in noncemented group.

Adjacent level compression fracture (ACF) was noticed in 30 (2.76%) patients.

Discussion

Osteoporosis affects around 200 million people around the globe. Vertebral osteoporosis with decreased bony trabeculae results in poor bone metal integration. Use of cement augmentation in known to increase the pull-out strength by 250% thus imparting immediate construct stability.

Other salvage methods include alternate methods of fixation like sublaminar wires and hooks, increasing screw dimensions, expandable screws and hydroxyapatite–coated screws. However, none of these methods provide immediate construct stability as provided by cement augmented fixation.

Most of the studies over CAPS in osteoporotic vertebra have been published lately. Five studies have been published during the period 2000-2008 whereas 12 studies were reported in the later half of study period (2009-2017).

PMMA is cement of choice for screw augmentation. Wuisman et al. used calcium apatite cement in their study. Authors have suggested that calcium apatite cement hardsens with nonexothermic reaction with lesser risk of injury to the neural tissue in case of leakage. However, it may get integrated with surrounding bone and get resorbed with time. Eventually, resorption of the cement matrix around the screws may loosen the purchase in bone and may lead to pull-out.

There was improvement in clinical and radiological outcome parameters in all studies. Only few studies have performed a comparative analysis with noncement-augmented screws. Sawakami et al. found screw back-out in 3 (14.3%) cases in the noncemented group and 1 such case required revision. Five noncemented screws required revision in study by Seo et al. Martin-Fernández et al. reported the highest number of cemented screw revisions. They revised 56 (17.9%) screws; however, their revisions were mostly to address adjacent segment–related issues, including adjacent vertebral
Table 3. Details of the Outcomes (Neurological, Clinical, and Radiological).

| Authors          | Clinical                                                                 | Radiological                                                                 | Revision |
|------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|----------|
| El Saman et al⁶  | 1. Loss of correction (Postoperative to last follow-up).                  | C: 3° ± 0.8°.                                                               |          |
|                  |                                                                           | NC: 7.2° ± 1.3°.                                                            |          |
| Sawakami et al⁷  | C: 3° ± 0.8°.                                                               | NC: 7.2° ± 1.3°.                                                            |          |
|                  | 2. Improvement in kyphosis (pre- to postoperative) (mean) 8.5°             |                                                                               |          |
|                  |                                                                           |                                                                               |          |
| Pesenti et al⁸   | 1. Length of hospital stay (mean) 6.4 days                                 | Kyphosis preoperative: 12.9° (3° - 19°, ± 5.2°)                             |          |
|                  |                                                                           | Kyphosis postoperative: 4.4° (3° - 14°, ± 4.6°)                              |          |
| Piñera et al⁹    | 1. Length of stay (mean) 8 days.                                           | I. Fusion 23 (100%) based on CT scans                                         |          |
| Amendola et al¹⁰ | 1. VAS, pre-/postoperative 8.2/1.7                                        | I. Fusion 11/11 (100%) based on radiographs and CT scan                      |          |
| Seo et al¹¹      | 1. Improvement in VAS (back): C 8.5 to 1.9; C 8.0 to 2.1                   | I. Fusion 100% based on radiographs                                          |          |
| Park et al¹²     | 1. Modified McNab’s criteria: all cases had good to excellent outcome.    |                                                                               |          |
|                  | 2. VAS, 8.5 ± 1.5 to 2.2 ± 2.0                                             |                                                                               |          |
| Authors             | Clinical                                                                 | Radiological                                                                 | Revision |
|---------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|----------|
| Wuisman et al\^13   | 1. Relief in backache 6/7                                                 | 1. Improvement in kyphosis: (pre- to postoperative): 12.3°                   | 0        |
|                     |                                                                           | 2. Improvement in AVH: 56%                                                  |          |
|                     |                                                                           | 1. Fusion based on radiographs 100%                                          |          |
| Chang et al\^14     | 1. VAS (mean) 9.2 to 1.5                                                  | Kyphosis preoperative: 23.2° (3.2°-49.1°)                                   | 0        |
|                     | 2. ODI (mean) 77.5 to 44.2.                                               | Kyphosis postoperative: 11.9° (8.8°-35.8°)                                   |          |
|                     | 3. Neurological improvement 31 (76%) patients regained physiological function (Frankel grading) | 1. Kyphosis correction (pre- to postoperative): 11.3°                        |          |
|                     |                                                                           | 2. Loss of correction (postoperative to last follow-up) (mean): 3°           |          |
|                     |                                                                           | (1.9°-12.9°)                                                                |          |
|                     |                                                                           | 3. Fusion 100% based on radiographs                                          |          |
| Cho et al\^15       | 1. VAS improvement, 8.59 ± 0.41 to 2.78 ± 0.95                           | Kyphosis preoperative: 31.95° ± 44°                                         | 0        |
|                     | 2. Neurological improvement: 22/22 patients (at least 1/2 Frankel grade) | Kyphosis postoperative: 15.24° ± 7.8°                                        |          |
|                     |                                                                           | Kyphosis last follow-up: 19.56° ± 8.6°                                      |          |
|                     |                                                                           | AVH preoperative: 13.22 ± 7.8 mm                                            |          |
|                     |                                                                           | AVH postoperative: 35.10 ± 9.6 mm                                           |          |
|                     |                                                                           | AVH last follow-up: 35.14 ± 7.0 mm                                          |          |
|                     |                                                                           | 1. Improvement in kyphosis (pre- to postoperative): 26.17°                   |          |
|                     |                                                                           | 2. Loss of correction (postoperative to last follow-up): 4.32°              |          |
|                     |                                                                           | 3. Improvement in anterior vertebral height (pre-to postoperative): 62.8%    |          |
|                     |                                                                           | 4. Fusion 100% based on radiographs                                          |          |
| Girardo et al\^16   | 1. Neurological improvement: all cases with incomplete deficit improved (n = 22) by 1 to 2 Frankel grade | 1. Loss of correction (postoperative to last follow-up) 4.6° ± 3°           | 0        |
|                     | 2. VAS improvement (Mean) 8.5 to 4.8.                                     | 2. Screw’s apex-vertebral body anterior cortex mean gap (SAAC gap): pre-/postoperative: 6.5/6.5 mm |          |
|                     | 3. ODI improvement (mean) 78% to 54%                                      | 3. Screw’s apex-vertebral body superior endplate mean gap (SASE gap): pre-/postoperative: 10.1/9.8 mm |          |
| Kim et al\^17       | 1. Improvement in VAS: 8.1 to 2.8.                                        | Kyphosis: preoperative 21.6 ± 5.8 Revision: 0                               |          |
|                     | 2. Modified MacNab’s criteria (functional outcome): Excellent 15 patients; good 4 patients; fair 1 patient | Kyphosis postoperative 8.4 ± 4.7. AVH preoperative: 0.35 ± 0.12 mm AVH postoperative: 0.70 ± 0.16 |          |
|                     |                                                                           | 1. Improvement in kyphosis (pre-to postoperative): 13.2                     |          |
|                     |                                                                           | 2. Loss of correction (postoperative to last follow-up) (mean) 2°            |          |
|                     |                                                                           | 3. Improvement in AVH: 50%                                                  |          |
|                     |                                                                           | 4. Fusion 100% based on radiographs                                          |          |
fracture, adjacent disc disease, or pseudo-arthrosis formation.

- CL is the most common complication, which may progress in pulmonary cement embolism. CL was classified according to Yeom’s classification. Type-B leakage occurred through basivertebral epidural veins, type-S occurred through segmental veins, and type-C through cortical defects. Janssen et al. and Martín-Fernández et al. in their large studies, have reported CL rates of 66.7% and 62.3%, respectively. Although, majority of CL were asymptomatic requiring no further treatment, morbidity and mortality associated with cement usage were significant. Janssen et al. noticed 30-day mortality of 1.8% in their study group and suggested against liberal use of cement augmentation. They have concluded that technical improvement in instrumentation or cementing technique has not decreased the rates of CLs and associated complications.

- Strategies have been suggested to reduce the incidence of CL. Fenestrated screws have been preferred choice for cement augmentation. A total of 8 studies used fenestrated screws and their used has been more frequent in studies reported after year 2010. Pilot hole preparation into the pedicle followed by cement injection and screw placement was done in numerous studies. Sawakami et al. performed augmentation by manually covering the screws with PMMA cement before placing it into the pedicles. Chang et al. suggested inserting the cement cannula 5 mm short of the selected screw length to avoid anterior cement breach. Wuisman et al. showed that 5 of their 7 cases had cement leak when retrograde type of cement injection was used from pressurization effect during screw insertion and advocated for direct method of cement injection.

- Additional vertebroplasty was done using PMMA cement in few studies. Aydoğan et al. performed vertebroplasty in all cases along with cement placement adjacent to the instrumented levels. Chang et al. used additional laminal hooks at levels adjacent to CAPS.

- Amount of cement per screw ranged from 1 to 3 cm³. Frequency of CL were higher in cases where multiple vertebra have been instrumented rather than the amount of the cement used. Hu et al. suggested that rate of CL was higher with lower BMD and was not dependent on amount of cement injected per vertebra. Consistency of cement at the time of injection was not widely studied; however, few studies did recommend using toothpaste like consistency to avoid extravasation.

- Fusion procedure was done in nine studies over the patients with nonmalignant affection of vertebra. Most common of procedure to be performed was posterolateral fusion. Interbody fusion was done in cases with neurological impairment and severe vertebral height loss. Cho et al. performed corpectomy with interbody fusion in all cases of Kummell’s disease. Sawakami et al. in their comparative study has found better fusion rates in cemented group as compared to the noncemented group.

- In our review, cement augmentation provided improved anchorage for the pedicle screws in the osteoporotic vertebral body. Improvement in pain parameters were maintained after surgery. Patients in CAPS group, maintained alignment better after correction of deformity with mild loss of correction. Cement augmentation provided desired resilience to the vertebra to withstand corrective forces for deformity correction and allow interbody fusion procedure.

- Perhaps, categorization of osteoporosis based on the nature of the lesion (osteolytic and nonosteolytic) would have been better, however it was beyond the scope of the present study based on the literature search. Etiologies for osteoporosis have been defined.

### Table 3. (continued)

| Authors                  | Clinical                                              | Radiological                                           | Revision                                                                 |
|--------------------------|--------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------------------------|
| Aydoğan et al.¹⁹         | Neurological improvement: all patients                 | 1. Fusion, solid 91.9% based on radiographs            | Revision: 1 screw                                                       |
| Moon et al.²⁰            | 1. Improvement in VAS: Leg 8.82 ± 0.83 to 1.42 ± 0.73. Back VAS 7.87 ± 0.95 to 2.30 ± 1.61. | 2. Prolo’s scale, pre-/postoperative: 4.22 ± 0.95 / 7.76 ± 1.74          | Revision: 0                                                              |
| Janssen et al.²¹         |                                                        |                                                        | Revision: 7 (intraspinal extravasated cement removal 1; superficial infection/CSF leak 6) |
| Martín-Fernández et al.²²|                                                        |                                                        | Revision: 56 (17.9%) (adjacent disc degeneration 20; adjacent level vertebral fracture 19; pseudoarthrosis 17) |

Abbreviations: C, cemented; NC, noncemented; AVH, anterior vertebral height; CSF, cerebrospinal fluid; CT, computed tomography; ODI, Oswestry disability index; SF-36 Short Form–36 questionnaire; VAS, visual analogue scale.
There is a paucity of literature comparing cemented versus noncemented screws in treatment of osteoporosis. We could not find any clinical trial comparing efficacy or safety of cement augmented screws.

There were 3 comparative studies demonstrating improved pain relief with maintenance of spinal alignment. However, cement-related complications cannot be overlooked. Judicious use of cement augmentation and active vigilance toward vascular complications could minimize catastrophic events.

**Table 4. Complications Reported in the Studies With the Details.**

| Authors            | Intraoperative | Clinical | Radiological |
|--------------------|----------------|----------|--------------|
| El Saman et al     | Not discussed  | —        | 1. CZ around the screws or loosening | 1. CZ around the screws or loosening, C 5 (4.3%); NC 54 (62.8%) |
| Sawakami et al     | Vascular complication/CL: 0 | Superficial infection (C) 2 | 1. CZ: C 5 (29.4%); NC 15 (71.4%). |
| Pesenti et al      | CL 1           | Pulmonary embolism (due to CL) 1 | 2. ACF: C 5 (29.4%); NC 5 (23.8%) |
| Piñera et al       | CL (Yeom’s classification) 29.3% of vertebra. Type B 8 (13.8%); type S 12 (20.7%); type C 3; foraminal 2 (due to screw malposition); 1 extra vertebral; 3 patients mild leg pain without palsy | Deep infection 3 (13%) | No screw loosening or back-out 0 |
| Amendola et al     | CL 2 (nerve root palsy 1) | 1. Superficial infection 2 | 1. CZ, screw back-out 0 0 |
| Seo et al          | CL 2 (transient hypoaesthesia 1, motor weakness 1) | Deep infection (C 1; NC 2) | 2. ACF: 0 |
| Park et al         | CL 1           | Superficial/deep infection 0 | Screw loosening: C 0; NC 5 (revised with cemented screws) |
| Wuisman et al      | CL 4/48 screws | 1. Transient nerve palsy 1 | Screw loosening: 0 |
| Chang et al        | CL (Yeom’s classification): 22 (26.2%) screws: Type S 15 (68%); type B 7 (32%) | Deep infection: 2 | 1. ACF: 1 |
| Cho et al          | CL: 0          | 1. Superficial infection: 1 | 2. Screw loosening: 0 |
| Girardo et al      | CL: 8 (Yeom’s classification). No neurodeficit. Type B 2; type S 5; type C 1 | 1. Superficial infection 1 | 1. ACF: 0 |
| Cho et al          | CL: 0          | 2. CSF leak 0 | 2. Screw loosening: 0 |
| Kim et al          | CL 0           | 3. Thrombophlebitis 3 | 1. ACF: 0 |
| Rasch et al        | CL 0           | Superficial/deep infection 0 | 2. Screw loosening 0 |
| Aydoğan et al      | CL 0           | Cement embolism | 1. ACF: 0 |
| Moon et al         | CL 2 (5.4%)    | 1. Superficial infection 4 | 1. ACF: 0 |
| Janssen et al      | CL: Asymptomatic CL 110 (66.7%); radiologically confirmed CL 13 (7.9%); clinically symptomatic CL 5 (3%); 2. Anaphylaxis, cement induced 1.2% | 1. Superficial infection + CSF leak 6 | 2. Screw loosening: 1 (2.7%) |
| Janssen et al      | CL 62.3% of vertebrae; epidural venous 36.8%; lateral venous 46%; foraminal 10%; extravertebral 4.1%; discal leakage 2.6%; canal leakage 5 (0.5%); asymptomatic | 2. Pulmonary cement embolism 13 (7.9%) |
| Martín-Fernández et al | CL: 0 | 1. Radicular pain (S1 foraminal leakage) 4 (1.5%). | 1. ACF: 19 |
|                    |                | 2. Deep infection 13 (4.1%) | 2. Pseudoarthrosis 17 |

**Abbreviations:** C, cemented; NC, noncemented; CZ, clear zone; CL, cement leak; ACF, adjacent compression fracture; CSF, cerebrospinal fluid.

- There is a paucity of literature comparing cemented versus noncemented screws in treatment of osteoporosis. We could not find any clinical trial comparing efficacy or safety of cement augmented screws. There were 3 comparative studies demonstrating improved pain relief with maintenance of spinal alignment. However, cement-related complications cannot be overlooked. Judicious use of cement augmentation and active vigilance toward vascular complications could minimize catastrophic events.

**Conclusion**

Most common indication for CAPS is osteoporotic affections of vertebra. Osteoporotic fractures were most frequently
treated condition. However, CAPS can be extended to primary as well as secondary osteoporosis (metastasis, myeloma, drug-induced). There has been no change in indications for CAPS usage between study duration. The past decade saw a greater number of published articles on cement augmentation. The majority or articles were European or Asian in origin. Fewer comparative studies prevented us from concluding significant advantage of CAPS. Nevertheless, clinical outcome was improved in the CAPS group. Radiological parameters showed maintained correction with minimal loss at the end of follow-up. CL was the most common complication reported. Most of the CL remained asymptomatic but indiscriminate use of cement augmentation was warranted. There was no consensus that technical improvement in instrumentation or cementing techniques have decreased the rates of complications.

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