

# The application of a new type of titanium mesh cage in hybrid anterior decompression and fusion technique for the treatment of continuously three-level cervical spondylotic myelopathy

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## Abstract

**Purpose** To evaluate the efficacy and safety of a new type of titanium mesh cage (NTMC) in hybrid anterior decompression and fusion method (HDF) in treating continuously three-level cervical spondylotic myelopathy (TCSM).

**Methods** Ninety-four cases who had TCSM and accepted the HDF from Jan 2007 to Jan 2010 were included. Clinical and radiological outcomes were compared between cases who had the NTMC (Group A,  $n = 45$ ) and traditional titanium mesh cage (TTMC, Group B,  $n = 49$ ) after corpectomies. Each case accepted one polyetheretherketone cage (PEEK) after discectomy.

**Results** Mean follow-up were 74.4 and 77.3 months in Group A and B, respectively ( $p > 0.05$ ). Differences in cervical lordosis (CL), segmental lordosis (SL), anterior segmental height (ASH) and posterior segmental height (PSH) between two groups were not significant preoperatively, 3-days postoperatively or at final visit. However, losses of the CL, SL, ASH and PSH were all significantly larger in Group B at the final visit, so did incidences of segmental subsidence and severe subsidence. Difference in preoperative Japanese Orthopedic Association (JOA), visual analog scale (VAS), neck disability index (NDI) or

SF-36 between two groups was not significant. At the final visit, fusion rate, JOA, and SF-36 were all comparable between two groups, but the VAS and NDI were both significantly greater in Group B.

**Conclusions** For cases with TCSM, HDF with the NTMC and TTMC can provide comparable radiological and clinical improvements. But application of the NTMC in HDF is of advantages in decreasing the subsidence incidence, losses of lordosis correction, VAS and NDI.

**Keywords** Cervical spondylotic myelopathy · Titanium mesh cage · Subsidence · Hybrid anterior decompression and fusion

## Introduction

For cases with multilevel cervical spondylotic myelopathy (CSM), anterior approach can provide direct decompression and construction, and it has been proven to be an effective and safe technique [1]. Anterior cervical corpectomy and fusion (ACCF) offers sufficient operating space and decompression extents, but increased blood loss and high rates of graft-related complications have limited its application [2, 3]. Anterior cervical discectomy and fusion (ACDF) is reported to be of less complications when compared with the ACCF, but it will be of difficulty and challenge for complete decompression through intervertebral space in some cases [4]. Taking all these into consideration, hybrid anterior decompression and fusion technique (HDF) that combined one-vertebrae corpectomy and one-level discectomy is developed. And it is especially suitable for cases who had simple disc herniation or small osteophyte at one level, and huge herniated disc, large osteophyte, or ossification of posterior longitudinal ligament (OPLL) at

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adjacent level [3, 5]. Researches of Guo et al. and Liu et al. had proven the effectiveness and safety of the HDF [6, 7]. However, improvement of cervical lordosis after the HDF is inferior to the ACDF at the final visit, and subsidence of the titanium mesh cage (TMC) may play an important role in loss of lordosis correction [6, 8]. The reported incidence of traditional TMC (TTMC) subsidence was as high as 96%, and severe subsidence was reported to be associated with neurological deterioration, neck pain and instrument failures [9–11]. To eliminate these complications of the TTMC, we designed a new type of TMC (NTMC, Fig. 1) and found that it could decrease the incidence of severe subsidence after one-level ACCF [12]. In this study, we compared clinical and radiological outcomes between cases who had continuously three-level CSM (TCSM) and underwent the HDF with the application of NTMC and TTMC, to assess the efficiency and safety of the NTMC.

## Materials and methods

### Patient population

From Jan 2007 to Jan 2010, a total of 113 cases had taken the HDF for TCSM by one senior surgeon consecutively. Nineteen cases who had injury history, previous cervical spine history, infection and tumor were excluded. Each case had either NTMC (Designed by ourselves) or TTMC (DePuy, USA) been implanted alternatively according to the sequence of admission, and had polyetheretherketone

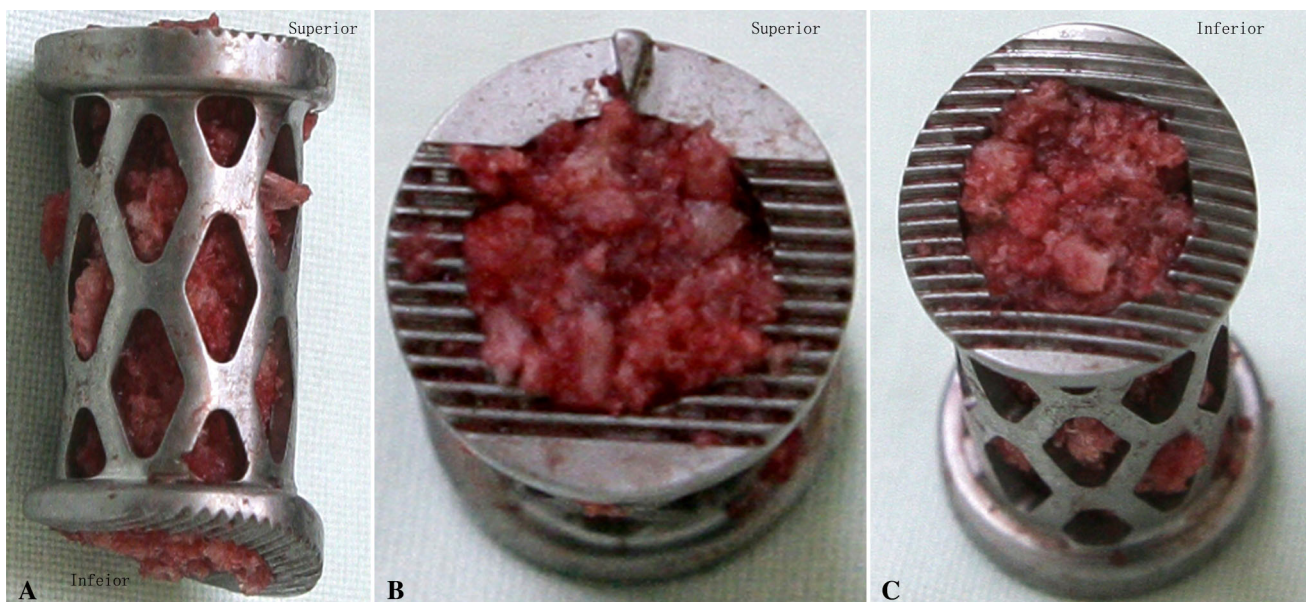
cage (PEEK, DePuy, USA) being implanted at adjacent intervertebral space. The included 94 cases were divided into Group A (NTMC/PEEK,  $n = 45$ , Fig. 2) and Group B (TTMC/PEEK,  $n = 49$ , Fig. 3) according to the TMC type.

### Surgical techniques

After general endotracheal anesthesia, a right-sided Smith-Robinson approach was carried out to expose cervical vertebral bodies and discs. Discectomy was performed first. After adequate removal of disc, posterior osteophyte and posterior longitudinal ligament, a proper-size PEEK cage packed with autogenous bone was implanted into intervertebral space. After necessary adjacent discectomies, three-fifths vertebral body was excised centrally to make a bone groove. Then the posterior longitudinal ligament was resected in each case to ensure complete decompression. For cases in Group A, the intervertebral spaces were decompressed bilaterally larger to accommodate the larger endcaps of the NTMC. After being packed with autogenous bone, the TMC was inserted into the bone groove. A semi-constrained cervical plate (Coddman or Slimlock, DePuy, USA) was used to bridge the fusion segments. All cases wear a Philadelphia neck collar for at least 2 months.

### Radiological and clinical assessments

All cases took lateral radiographs before the operation and 3 days postoperatively. Additional flexion–extension lateral radiographs were also obtained at 2, 6, 12 months and



**Fig. 1** The lateral view of the NTMC (a). The superior endcap is curved to fit the inferior endplate, and has a tuber ventrally and paralleled grooves to prevent shifting backward (b). A 10-degree

angle that tilts backward and upward and paralleled grooves are designed at the inferior endcap to fit the superior endplate (a, c)



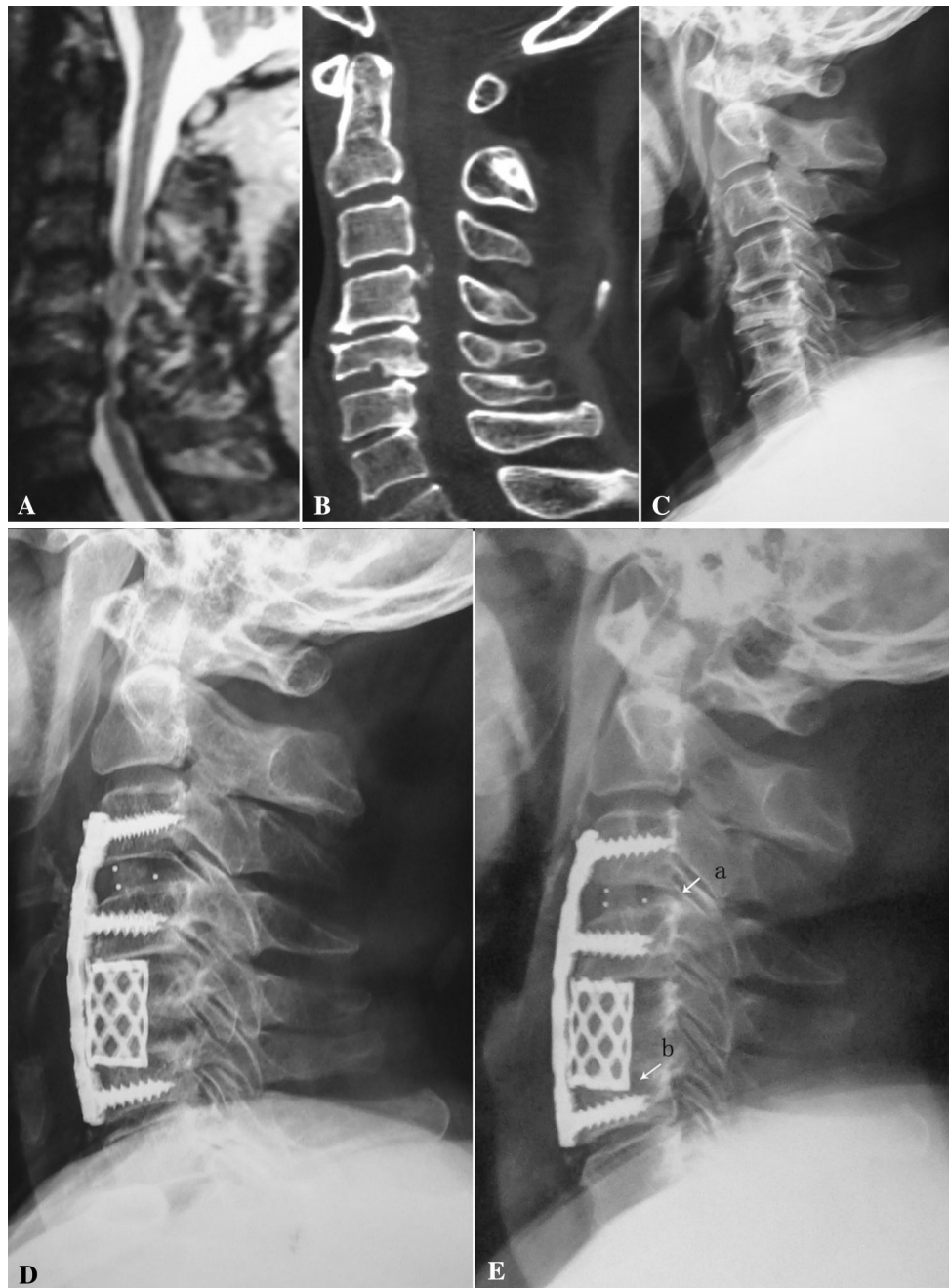
**Fig. 2** A 65-year-old female case. She complained of weakness and numbness of limbs, and chest zonesthesia for 3 months. Preoperative MRI and lateral radiograph showed huge slipped disc locating at dorsal part of C4 vertebrae body and significant disc degeneration at

C5/6 level (A–C). She accepted the HDF with NTMC/PEEK. Lateral radiograph postoperatively showed significant improvement in the CL and SL (D). The lateral radiograph 61-months postoperatively showed segmental subsidence (White arrow a, b, c and d in E)

then each year postoperatively. Bone graft fusion was defined as no motion across the fusion segment on the flexion–extension radiograph and presence of bridging bony trabeculae between endplates and grafts on the lateral radiograph. Cobb angles at C2–C3, C2–C7 and fusion segment were measured as local lordosis (LL), cervical lordosis (CL) and segmental lordosis (SL), respectively (Fig. 4). Anterior segment height (ASH) and posterior segment height (PSH) were also collected (Fig. 4). Time point of 3 days postoperatively was defined as post-operation. Loss of the CL, LL, SL, ASH or PSH was calculated

as = Final index – Postoperative index. Occurrence of segmental subsidence and severe subsidence was validated when loss value of the ASH or PSH was >0 and >3 mm, respectively.

Neurological function was evaluated by Japanese Orthopedic Association (JOA) scoring system, and neurological recovery rate (RR) was calculated as = (Final JOA – preoperative JOA)/(17–preoperative JOA) × 100%. Preoperative and final visual analog scale (VAS), neck disability index (NDI score) and 36-item short-form health survey score (SF-36) in two groups were also compared.



**Fig. 3** A 61-year-old male case. He complained of degenerative hands weakness and gait instability for 1 year. Preoperative MRI, CT and lateral radiograph showed disc degeneration and calcification at C3/4 level, intervertebral instability at C4/5 and C5/6 levels (A–C).

Lateral radiograph postoperatively showed increases in cervical lordosis and segmental lordosis after the HDF with TTMC/PEEK (D). E showed segmental subsidence 67 months postoperatively (White arrow a and b)

### Analysis methods

Statistical analyses were performed using SPSS (Version 18.0, SPSS Inc., Chicago, IL, USA). Comparisons of quantitative data were evaluated by the Independent-Samples *T* Test or Paired-Samples *T* Test, and categorical data by Pearson's Chi squared test. Difference was defined as significant when the *p* value was less than 0.05.

### Results

There weren't significant differences in demographic data between two groups (Table 1). All cases obtained bone fusion within 12 months. As shown in Table 2, differences in the ASH, PSH, LL, CL and SL weren't significant between two groups preoperatively, postoperatively and at the final visit ( $p > 0.05$ ). All the ASH, PSH, CL and SL



**Fig. 4** 1 The anterior segment height, measured as distance between anterior margins of the endplates at the fusion segment. 2 The posterior segment height, measured as distance between posterior margins of the endplates at the fusion segment. 3 Local lordosis, Cobb angle between C2 and C3. 4 Cervical lordosis, Cobb angle between C2 and C7. 5 Segmental lordosis, Cobb angle at fusion segment

increased significantly in Group A and B after the HDF, but the LL kept unchanged in both groups. Loss values of the ASH, PSH, CL and SL were all significantly larger in Group B ( $p = 0.016$  and  $0.031$ , respectively), but difference in loss of the LL between two groups was not significant ( $p > 0.05$ ). The PSH/ASH value in Group A and B was  $0.956 \pm 0.021$  and  $0.953 \pm 0.030$  postoperatively,  $0.930 \pm 0.093$  and  $0.919 \pm 0.118$  at the final visit. And

differences in the PSH/ASH value between Group A and B postoperatively and at the final visit were not significant ( $p > 0.05$ ).

Incidences of segmental subsidence and severe subsidence were 42.2 and 6.7% in Group A, 63.3 and 22.4% in Group B, and they were both significantly different between the two groups ( $p = 0.033$  and  $0.030$ , respectively). There were no breakage or extrusion of implants during follow-up periods in both groups. To exclude influences of the location of TMC and appearance of the OPLL on radiological outcomes, cases were divided into eight subgroups. Results in Table 3 showed that loss values of the ASH, PSH, CL and SL in Group A were all significantly less than that in Group B, in spite of the location of TMC or the appearance of OPLL.

As shown in Table 4, the JOA and SF-36 significantly increased, and the VAS and NDI significantly decreased in both groups at the final visit ( $p < 0.05$ ). No case in both groups experienced early or late neurological deterioration. There weren't significant differences in preoperative JOA, SF-36, VAS and NDI between two groups. At the final visit, differences in the JOA, RR and SF-36 were not significant, but the VAS and NDI were significantly larger in Group B ( $p < 0.05$ ).

## Discussion

The ACCF technique is optional for treating multilevel CSM, but high risk of hardware failure due to long lever-arm reconstruction has limited its application prospect in clinical practice, and to reduce vertebral body resection and shorten cage length seems to be the main research direction [13, 14]. Ashkenazi et al. firstly developed a hybrid decompression and fixation technique, and considered it to be a promising technique for multilevel CSM [8]. Then Xu et al. reported that the incidence of graft migration after hybrid technique with one-level ACCF and one-level cage-

**Table 1** Comparisons of general demographic data between Group A and Group B

	Group A	Group B	<i>p</i> value
Gender (male/female, <i>n</i> )	31/14	28/21	0.168
Smoke ( <i>n</i> )	19	13	0.083
Age (years)	$57.1 \pm 8.4$	$56.7 \pm 7.1$	0.831
With high signal ( <i>n</i> )	28	22	0.070
Plate type (Coddman/SlimLock, <i>n</i> )	16/29	26/23	0.088
Fusion segments ( <i>n</i> )			0.457
C3–C6	29	30	
C4–C7	16	19	
Corpectomy segment (C4/C5/C6, <i>n</i> )	9/31/5	8/33/8	0.724
Discectomy segment (C3/4/C4/5/C5/6/C6/7, <i>n</i> )	20/5/9/11	22/8/8/11	0.879
Follow-up (months)	$74.4 \pm 4.1$	$77.3 \pm 8.5$	0.311

**Table 2** Cervical lordosis, segmental lordosis and fusion segment height in two groups at different time points

	Pre.	Post.	Intra. p1	Final visit	Intra. p2	Index loss
ASH (mm)						
Group A	72.5 ± 6.7	78.7 ± 8.3	0.027 <sup>#</sup>	78.1 ± 6.4	0.033 <sup>#</sup>	0.5 ± 0.3
Group B	71.6 ± 7.2	77.5 ± 8.1	0 <sup>#</sup>	76.4 ± 6.2	0.015 <sup>#</sup>	1.1 ± 0.6*
PSH (mm)						
Group A	69.3 ± 7.3	73.8 ± 6.0	0.031 <sup>#</sup>	72.6 ± 7.8	0.045 <sup>#</sup>	1.1 ± 0.4
Group B	68.2 ± 7.7	72.4 ± 6.3	0.011 <sup>#</sup>	70.2 ± 8.0	0.042 <sup>#</sup>	2.4 ± 0.9*
LL (mm)						
Group A	3.9 ± 1.7	4.3 ± 1.5	0.466	4.1 ± 1.3	0.203	0.2 ± 0.3
Group B	4.1 ± 1.9	4.6 ± 1.9	0.652	4.0 ± 1.9	0.846	0.5 ± 0.2
CL (°)						
Group A	14.3 ± 9.3	26.4 ± 7.1	0 <sup>#</sup>	23.6 ± 8.3	0 <sup>#</sup>	2.7 ± 1.0
Group B	14.5 ± 9.0	26.8 ± 7.8	0 <sup>#</sup>	22.1 ± 7.2	0 <sup>#</sup>	4.5 ± 1.3*
SL (°)						
Group A	10.4 ± 6.9	19.6 ± 5.1	0 <sup>#</sup>	20.2 ± 5.6	0 <sup>#</sup>	-1.0 ± 0.7
Group B	10.8 ± 6.3	18.9 ± 5.6	0 <sup>#</sup>	20.7 ± 5.8	0 <sup>#</sup>	-1.9 ± 1.0*

pre. preoperatively, post. postoperatively, Intra. p1 p value of comparison between indexes preoperatively and postoperatively within the same group, Intra. p2 p value of comparison between preoperative index and final-visit index within the same group

<sup>#</sup> Intra-group *p* < 0.05

\* Inter-group *p* < 0.05 between Group A and Group B

**Table 3** Inter-group comparisons of radiological losses according to the location of TMC and appearance of the OPLL

	ASH loss (mm)	PSH loss (mm)	CL loss (°)	SL loss (°)
TMC located cephalad				
Group A (n = 20)	0.4 ± 0.3	0.7 ± 0.3	2.4 ± 0.5	-0.5 ± 0.3
Group B (n = 16)	0.8 ± 0.4	1.6 ± 0.7	3.5 ± 1.1	-1.1 ± 0.5
Inter-group <i>p</i>	0.038*	0.004*	0.017*	0.044*
TMC located caudal				
Group A (n = 25)	0.6 ± 0.2	1.3 ± 0.6	3.3 ± 1.3	-1.0 ± 0.4
Group B (n = 33)	1.5 ± 0.7	2.9 ± 1.2	5.8 ± 1.7	-2.3 ± 1.0
Inter-group <i>p</i>	0.023*	0.001*	0*	0.019*
OPLL				
Group A (n = 12)	0.3 ± 0.1	0.6 ± 0.2	1.6 ± 0.4	-0.5 ± 0.2
Group B (n = 10)	0.7 ± 0.3	1.8 ± 0.5	3.2 ± 0.9	-1.2 ± 0.6
Inter-group <i>p</i>	0.048*	0*	0*	0.002*
Non-OPLL				
Group A (n = 33)	0.8 ± 0.4	1.5 ± 0.7	3.1 ± 1.5	-1.1 ± 0.7
Group B (n = 39)	1.7 ± 0.7	2.7 ± 1.1	5.5 ± 1.2	-2.1 ± 1.1
Inter-group <i>p</i>	0*	0.016*	0*	0.032*

TMC titanium mesh cage, OPLL ossification of posterior longitudinal ligament, ASH anterior segmental height, PSH posterior segmental height, CL cervical lordosis, SL segmental cervical lordosis

\* Inter-group *p* value is less than 0.05

standalone discectomy was lower than that after standard two-level ACCF [15]. A minimum 2-year follow-up research also found that two-level ACCF and one-level stand-alone cage fixation were of advantages over three-level ACCF in greater initial stability, less postoperative incidences of reconstructive failure C5 palsy [16]. When

coming to traditional screw-plate system, three researches from our institution reported that neurological outcomes after the three-level ACDF, two-level ACCF, and the HDF with one-level ACCF and one-level ACDF were comparable, and the HDF technique provided less blood loss, operation time, non-fusion rate and complication

**Table 4** Clinical outcome comparisons between Group A and Group B

	Group A	Group B	Inter-group <i>p</i> value
JOA (scores)			
Preoperative	9.8 ± 2.8	10.2 ± 2.4	0.536
Final follow-up	13.9 ± 2.4	14.1 ± 2.1	0.683
Intra-group <i>p</i> value	0.005 <sup>#</sup>	0.028 <sup>#</sup>	
RR (%)	56.7 ± 9.8	57.9 ± 10.3	0.441
SF-36 (scores)			
Preoperative	36.3 ± 3.1	36.6 ± 3.3	0.583
Final follow-up	53.3 ± 3.6	50.7 ± 4.5	0.102
Intra-group <i>p</i> value	0 <sup>#</sup>	0 <sup>#</sup>	
VAS (scores)			
Preoperative	7.9 ± 1.5	8.1 ± 1.3	0.673
Final follow-up	2.6 ± 1.6	3.7 ± 1.7	0.024*
Intra-group <i>p</i> value	0.016 <sup>#</sup>	0.020 <sup>#</sup>	
NDI (%)			
Preoperative	35.9 ± 3.5	36.1 ± 3.7	0.662
Final follow-up	13.4 ± 2.5	17.9 ± 4.1	0.036*
Intra-group <i>p</i> value	0 <sup>#</sup>	0 <sup>#</sup>	

<sup>#</sup> Intra-group *p* is less than 0.05 when preoperative and follow-up indexes within the same group are compared

\* Inter-group *p* is less than 0.05 when indexes at the same time point are compared between two groups

incidences than two-level ACCF [6, 7, 17]. Our results also showed significant improvements in the CL, SL, JOA, SF-36, VAS and NDI at the final visit in both groups (Tables 2, 4), and no cases experienced disastrous complications. This is consistent with previous studies, and additionally proves the effectiveness and safety of the HDF for the treatment of TCSM.

Incidence of the TMC subsidence was reported to be higher than the PEEK cage, and segmental subsidence rate would grow higher after the HDF than the ACDF [11, 18]. As all cases in our study had the PEEK cage being implanted after discectomy, to decrease the TMC subsidence was of importance for preventing segmental subsidence [19–21]. Segmental lordosis reconstruction is based on the angulation of inferior and vertebral bodies at fusion segment. However, the paralleled TTMC contact faces will result in incomplete cage-endplate contacts and improper load distribution. Furthermore, as diameter of the TTMC is smaller than the vertebral sagittal diameter and most inferior cage-endplate contact area is limited at the anterior portion of the cage, posterior rim of the TTMC has to contact with the weak and cancellous endplate [22–26]. Although a new nano-hydroxyapatite/polyamide-66 cage with wider rim was reported to provide earlier fusion and less subsidence than the TTMC after single-level ACCF, contacts between the cage and endplates did not matched fully, either [27]. What's more, taking excellent biocompatibility and widely accepted safety of titanium material

into account, to improve cage-endplate contact basing on the TTMC might be an easy and safe solution. A new type of TMC which could match well with superior and inferior endplates to eliminate the cleavage and micro-motion between TMC endcaps and endplates was designed by ourselves [28]. Advantage of the NTMC in reducing severe subsidence incidence over the TTMC had been proved by Yu, et al. [12]. In this study, although the ASH and PSH in two groups postoperatively and at final visit were both comparable, losses of them were both significantly less in Group A, in spite of the location of TMC or the appearance of OPLL. Combining with less incidences of segmental subsidence and severe subsidence, results in Tables 2 and 3 suggest that the application of NTMC could provide better postoperative stability than the TTMC after the HDF.

As shown in Table 2, we found no significant differences in LL, CL or SL between two groups at the final visit. These results indicate that the application of the NTMC provide comparable capability with the TTMC in lordosis restoration. Loss of the PSH/ASH value, rather than the segmental subsidence, might mainly contribute to the improvement of the SL, but relationship hadn't been confirmed [20, 25]. In this study, comparable PSH/ASH values was accompanied by similar SL in two groups during the follow-up period. This is consistent with previous studies, but improvement of the SL and loss of the CL and in this study existed as a conflict, and development of adjacent segment degeneration should be considered [6, 17, 29, 30].

As degeneration at disc C7/T1 was not common and the fusion extent did not include the C2, small loss of the LL would result in a large change in CL [31, 32]. In this study, we found loss of the LL in Group A was less than that in Group B, although difference was not significant. And this may partly explain why loss of the CL was significantly less in Group A. To explore other risk factors which could influence lordosis changes in details, we divided cases into subgroups according to the location of TMC or the appearance of OPLL. Results in Table 3 showed that change of the CL and SL were both larger in Group B. We suppose that application of the NTMC in HDF could reduce less adjacent segment degeneration, but further study with follow-up computerized tomography (CT) and magnetic resonance image (MRI) is needed.

When it came to clinical outcomes, we found cases in two groups had comparable neurological improvement and SF-36 at the final visit, and none got neurological deterioration. This had indicated the effectiveness of the HDF with NTMC in treating cases with TCSM, and it was consistent with previous studies that used the TTMC [6, 15, 17]. Neck pain after anterior reconstruction was reported to be associated with larger incidences of segmental subsidence, especially the severe subsidence [9, 24]. The NDI is used to assess the influence of neck pain on activities of daily living, and it is associated with the VAS [33]. We found no significant differences in preoperative VAS and NDI scores between two groups, but both of them were significantly less in Group A at the final visit. Basing on these results, we suppose that application of the NTMC can provide comparable improvements in neurological function and the SF-36, and decrease negative influences of neck pain when compared with the application of the TTMC after the HDF, and these might be associated with comparable maintenance of the cervical sagittal alignment and less incidence of mesh cage subsidence after the application of the NTMC [12, 34, 35].

## Conclusions

This study indicates that the HDF with the NTMC or TTMC being implanted provides comparable improvements in cervical lordosis, JOA scores and SF-36 scores for cases with continuously TCSM. The application of NTMC could significantly reduce losses of segmental height and cervical lordosis, and decrease subsidence incidence, VAS and NDI after the HDF when compared with the TTMC.

## Compliance with ethical standards

The Institutional Review Board approval, which was consistent with the Helsinki Declaration was approved by the Ethical Committee of Changzheng Hospital. Each case signed the informed consent before

accepting the operation. No relevant financial activities outside the submitted work and no other potential conflicts.

**Conflict of interest** The authors declare that they have no conflict of interest.

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